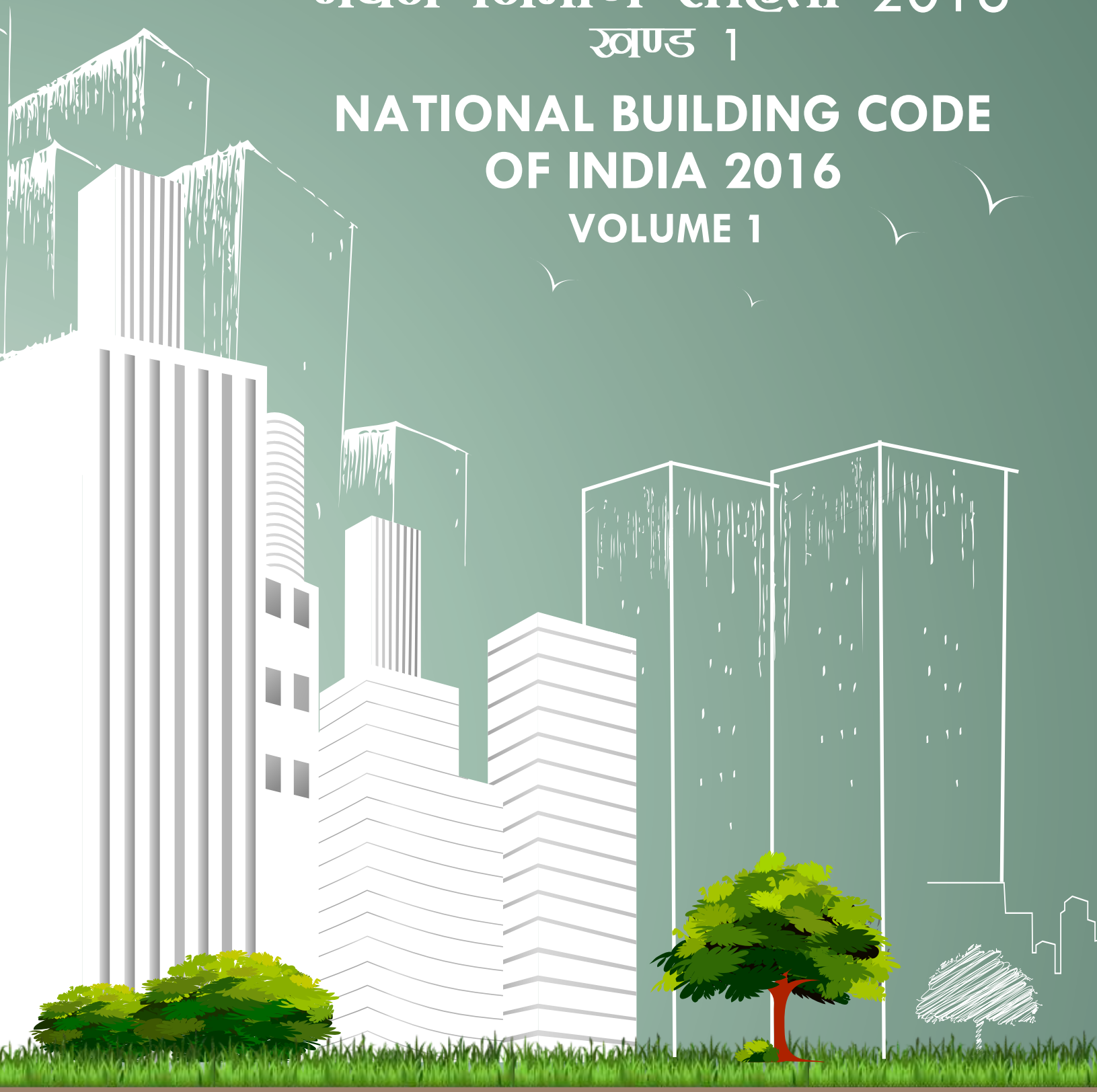
भारत की राष्ट्रीय भवन निर्माण संहिता 2016

खण्ड 1

NATIONAL BUILDING CODE OF INDIA 2016

VOLUME 1



भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

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FOREWORD

Construction programmes are interwoven in a large measure in all sectors of development, be it housing, transport, industry, irrigation, power, agriculture, education or health. Construction, both public and private, accounts for about fifty percent of the total outlay of the planned expenditure in the country. Half of the total money spent on construction activities is spent on buildings for residential, industrial, commercial, administrative, educational, medical, municipal and entertainment uses. It is estimated that about half of the total outlay on buildings is on housing. It is imperative that for such a large national investment, optimum returns are assured and wastage in construction is avoided.

Soon after the Third Five Year Plan, the Planning Commission decided that the whole gamut of operations involved in construction, such as administrative, organizational, financial and technical aspects, be studied in depth. For this study, a Panel of Experts was appointed in 1965 by the Planning Commission and its recommendations are found in the 'Report on Economies in Construction Costs', published in 1968.

One of the facets of building construction, namely, controlling and regulating buildings through municipal byelaws and departmental handbooks, received the attention of the Panel and a study of these regulatory practices revealed that some of the prevailing methods of construction were outmoded; some designs were overburdened with safety factors and there were other design criteria which, in the light of newer techniques and methodologies, could be rationalized; and building byelaws and regulations of municipal bodies which largely regulate the building activity in the country, wherever they exist, were outdated. They did not cater to the use of new building materials and the latest developments in building designs and construction techniques. It also became clear that these codes and byelaws lacked uniformity and they were more often than not 'specification oriented' and not 'performance oriented'.

These studies resulted in a recommendation that a National Building Code be prepared to unify the building regulations throughout the country for use by government departments, municipal bodies and other construction agencies. The then Indian Standards Institution (now Bureau of Indian Standards) was entrusted by the Planning Commission with the preparation of the National Building Code. For fulfilling this task, a Guiding Committee for the preparation of the Code was set up by the Civil Engineering Division Council of the Indian Standards Institution in 1967. This Committee, in turn, set up 18 specialist panels to prepare the various parts of the Code. The Guiding Committee and its panels were constituted with architects, planners, materials experts, structural, construction, electrical, illumination, air conditioning, acoustics and public health engineers and town planners. These experts were drawn from the Central and State Governments, local bodies, professional institutions and private agencies. The first version of the Code was published in 1970.

After the National Building Code of India was published in 1970, a vigorous implementation drive was launched by the Indian Standards Institution to propagate the contents and use of the Code among all concerned in the field of planning, designing and construction activities. For this, state-wise implementation conferences were organized with the participation of leading engineers, architects, town planners, administrators, building material manufacturers, building and plumbing services installation agencies, contractors, etc.

These conferences were useful in getting across the contents of the Code to the interests concerned. These conferences had also helped in the establishment of Action Committees to look into the actual implementation work carried out by the construction departments, local bodies and other agencies in different states. The main actions taken by the Action Committees were to revise and modernize their existing regulatory media, such as specifications, handbooks, manuals, etc, as well as building byelaws of local bodies like municipalities at city and town levels, *Zilla Parishads*, *Panchayats* and development authorities, so as to bring them in line with the provisions contained in the National Building Code of India. In this process, the Indian Standards Institution rendered considerable support in redrafting process.

The National Building Code of India is a single document in which, like a network, the information contained in various Indian Standards is woven into a pattern of continuity and cogency with the interdependent requirements of Parts/Sections carefully analyzed and fitted in to make the whole document a cogent continuous volume. A continuous thread of 'preplanning' is woven which, in itself, contributes considerably to the economies in construction particularly in building and plumbing services.

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The Code contains regulations which can be immediately adopted or enacted for use by various departments, municipal administrations and public bodies. It lays down a set of minimum provisions designed to protect the safety of the public with regard to structural sufficiency, fire hazards and health aspects of buildings; so long as these basic requirements are met, the choice of materials and methods of design and construction are left to the ingenuity of the building professionals. The Code also covers aspects of administrative provisions, development control rules and general building requirements; fire safety requirements; stipulations regarding materials and structural design; rules for design of electrical installations, lighting, air conditioning and heating, installation of lifts; provisions for ventilation, acoustics and plumbing services, such as water supply, drainage, sanitation and gas supply; measures to ensure safety of workers and public during construction; and rules for erection of signs and outdoor display structures. The Code today also covers provisions relating to structural use of glass; escalators and moving walks; information and communications enabled installations; solid waste management; landscape planning and design; and asset and facility management.

Some other important points covered by the Code include 'industrialized systems of building' and 'architectural control'. The increase in population in the years to come will have a serious impact on the housing problem. It has been estimated that the urban population of India will continue to increase with such pace as to maintain the pressure on demand of accommodation for them. Speed of construction is thus of utmost importance and special consideration has to be given to industrialized systems of building. With increased building activity, it is also essential that there should be some architectural control in the development of our cities and towns, if creation of ugliness and slum-like conditions in our urban areas is to be avoided.

Over a period of time, the importance of providing an environment which is conducive to younger and elder persons and the persons with disabilities, alike, has been well highlighted. The Code covers provisions on accessibility to facilitate implementation of this important aspect in all public buildings. Similarly, all building construction and built environment should take into consideration the aspects of sustainable development, which have since been duly provided in a separate chapter in the Code which should be read along with other chapters. The objective is that the building activity should be in complete harmony with the environment be it planning, design, construction or operation and maintenance. With the passage of time, more and more complex buildings including very tall buildings are being built requiring inputs and involvement of professionals from different disciplines, who should work together in harmony following an integrated multi-disciplinary approach since covered in the Code.

Above comprehensive coverage under the Code is the result of its implementation and review from time to time. Since the publication of 1970 version of the National Building Code of India, a large number of comments and useful suggestions for modifications and additions to different parts and sections of the Code were received as a result of use of the Code by all concerned, and revision work of building byelaws of some States. Based on the comments and suggestions received, the National Building Code of India 1970 was first revised in 1983 and then in 2005.

Some of the important changes in 1983 version included: addition of development control rules, requirements for greenbelts and landscaping including norms for plantation of shrubs and trees, special requirements for low income housing; fire safety regulations for high rise buildings; revision of structural design sections based on new and revised codes, such as Concrete Codes (plain and reinforced concrete and prestressed concrete), Earthquake Code, Masonry Code; addition of outside design conditions for important cities in the country, requirements relating to noise and vibration, air filter, automatic control, energy conservation for air conditioning; and guidance on the design of water supply system for multi-storeyed buildings.

Since the publication of 1983 version of National Building Code of India, the construction industry had gone through major technological advancement. In next two decades, substantial expertise had been gained in the areas of building planning, designing and construction. Also, lot of developments had taken place in the techno-legal regime and techno-financial regime, apart from the enormous experience gained in dealing with natural calamities like super cyclones and earthquakes faced by the country. Further, since the revision in 1983, based on the changes effected in the Steel Code, Masonry Code and Loading Code, as also in order to update the fire protection requirements, three amendments were brought out to the 1983 version of the Code. Considering these, it was decided to take up a comprehensive second revision of the National Building Code of India.

The major changes incorporated in the second revision of the Code in 2005 were: incorporation of a new Part 0 'Integrated approach–Prerequisite for applying provisions of the Code' emphasizing on multi-disciplinary team approach for successfully accomplishing building/development project; addition of new chapters on significant

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areas like structural design using bamboo, mixed/composite construction, and landscape planning and design; incorporation/modification of number of provisions relating to reform in administrative aspects, also detailing therein provisions to ensure structural sufficiency of buildings to facilitate implementation of the related requirements to help safely face the challenges during natural disasters like earthquake; incorporation of planning norms and requirements for hilly areas and rural habitat planning, apart from incorporation of detailed planning norms for large number of amenities; categorization of fire safety aspects distinctly into fire prevention, life safety and fire protection giving detailed treatment to each based on current information, developments and latest practices followed in the country; assigning due importance to the aspects like energy conservation and sustainable development in various parts and sections through appropriate design, usage and practices with regard to building materials, construction technologies and building and plumbing services giving due consideration to renewable resources like bamboo and practices like rain water harvesting; incorporation of the revised Earthquake Code, IS 1893 (Part 1) : 2002 'Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*fifth revision*)' for due implementation of the provisions thereof in applicable seismic zones of the country, by the Authorities.

Two amendments were thereafter issued to the Code in 2015; first to include a new chapter relating to sustainability namely, Part 11 'Approach to Sustainability', and the second to modify/include certain provisions in Part 4 'Fire and Life Safety'.

Due to large scale changes in the building construction activities, such as change in nature of occupancies with prevalence of high rises and mixed occupancies, greater dependence and complicated nature of building services, development of new/innovative construction materials and technologies, greater need for preservation of environment and recognition of need for planned management of existing buildings and built environment, there has been a paradigm shift in building construction scenario. A comprehensive revision has therefore been brought out to address all these aspects and also reflect the changes incorporated in various standards which are considerably utilized in the Code. The major changes incorporated in this third revision of the Code are as follows:

a) Provisions for association of need based professionals and agencies have been updated to ensure proper discharge of responsibilities for accomplishment of building project.
b) With a view to ensuring ease of doing business in built environment sector, a detailed provision for streamlining the approval process in respect of different agencies has been incorporated in the form of an integrated approval process through single window approach for enabling expeditious approval process, avoiding separate clearances from various authorities.
c) Further, with a view to meeting the above objective, the provision on computerization of approval process has been detailed, enabling online submission of plans, drawings and other details, and sanction thereof, aiding in speedier approval process.
d) The mechanism of ensuring certification of structural safety of buildings by the competent professional and peer review of design of buildings, have been further strengthened.
e) Requirements for accessibility in buildings and built environment for persons with disabilities and the elderly have been thoroughly revised and updated.
f) Provisions on fire and life safety have been thoroughly revised to meet the challenges of modern complex building types including the high rises.
g) Latest structural loading and design and construction codes including those relating to wind load, earthquake resistant design of buildings, steel design and foundations have been incorporated with a view to ensuring structural safety of buildings including against a disaster.
h) Provisions relating to all building and plumbing services have been updated keeping also in view the latest international practices as related to the country.
j) Provisions have been updated to ensure utilization of number of new/alternative building materials and technologies to provide for innovation in the field of building construction.
k) Construction management guidelines have been incorporated to aid in timely completion of building projects with desired quality in a safe manner within the budgeted cost.
m) Guidance has been provided for making buildings and built environment energy efficient and environmentally compatible, through the newly introduced and updated chapter on sustainability, namely Part 11 'Approach to Sustainability'.
n) New chapters have been added on structural use of glass; escalators and moving walks; information and communication enabled installations; solid waste management; and asset and facility management. The new Part on Approach to Sustainability has also been duly incorporated in the Code.

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The specific major changes incorporated in each Part/Section of the Code have been enlisted in the Foreword of the respective Part/Section.

The Code now published is the third revision or fourth version representing the present state of knowledge on various aspects of building construction. The process of preparation of the 2016 version of the Code has thrown up a number of problems; some of them were answered fully and some partially. Therefore, a continuous programme will go on by which additional knowledge that is gained through technological evolution, users' views over a period of time pinpointing areas of clarification and coverage, and results of research in the field, would be incorporated in to the Code from time-to-time to make it a living document. It is, therefore, proposed to bring out changes to the Code periodically.

The provisions of this Code are intended to serve as a model for adoption by local bodies, Public Works Departments and other government construction departments, and other construction agencies. Existing PWD codes, municipal byelaws and other regulatory media could either be replaced by the National Building Code of India or suitably modified to cater to local requirements in accordance with the provisions of the Code. Any difficulties encountered in adoption of the Code could be brought to the notice of the National Building Code Sectional Committee for corrective action.

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Central Industrial Security Force, New Delhi	Shri Rajnath Singh
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri D. K. Tulani (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Suvir Singh Shri A. A. Ansari (*Alternate*)
Delhi Fire Service, Govt of NCT of Delhi, New Delhi	Shri A. K. Sharma Dr G. C. Misra (*Alternate*)
Delhi Metro Rail Corporation, New Delhi	Shri A. K. Singh Shrimati Rashmi Bhardwaj (*Alternate*)
Directorate of Fire & Emergency Services, Govt of Goa, Goa	Shri Ashok Menon Shri Prakash M. Parab (*Alternate*)
Directorate of Maharashtra Fire Services, Mumbai	Shri M. V. Deshmukh Shri S. S. Warick (*Alternate*)
Fire & Security Association of India, Chennai	Shri Srinivas Valluri

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FM Engineering International (India) Pvt Ltd, Bengaluru	Shri Sumit Khanna Shri Manikandan Krishnamurthy (*Alternate*)
FYRPROTEK (Fire Engineers & Consultants), New Delhi	Shri Gulshan Khurana
Glazing Society of India, New Delhi	Shri R. Subramanian Shri G. N. Gohul Deepak (*Alternate*)
Indian Plumbing Association, New Delhi	Shri M. K. Gupta Shri S. K. Duggal (*Alternate*)
Institution of Fire Engineers (India), New Delhi	Shri U. S. Chhillar Shri M. S. Patyal (*Alternate*)
Insurance Regulatory and Development Authority, Hyderabad	Shri Randip Singh Jagpal Shri T. S. Naik (*Alternate*)
Kaleidoscope, Noida	Shri Amor Kool
Kone Elevator India Pvt Ltd, Chennai	Shri J. Sivaraman Shri P. M. Tipnis (*Alternate*)
Lloyd Insulations (India) Ltd, New Delhi	Shri Sanjeev Angra Shri K. K. Mitra (*Alternate*)
Maple Engineering-Design Services (India) Pvt Ltd, Bengaluru	Shri B. S. Aswathnarayan (B. S. A. Narayan) Shri H. R. Ranganath (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri S. K. Arora Col Naresh Sharma (*Alternate*)
Ministry of Home Affairs (Directorate General of Fire Services, Civil Defence & Home Guards), New Delhi	Shri D. K. Shami
Municipal Corporation of Greater Mumbai (Mumbai Fire Brigade), Mumbai	Chief Fire Officer Deputy Chief Fire Officer (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora
National Fire Service College, Nagpur	Shri Shamim
Oil Industry Safety Directorate, New Delhi	Shri A. K. Arora
Proion Consultants, New Delhi	Shri Sandeep Goel
School of Planning and Architecture, New Delhi	Dr V. K. Paul
Tamil Nadu Fire and Rescue Services Department, Chennai	Shri S. Vijayasekar
Telangana State Disaster Response and Fire Services Department, Hyderabad	Shri P. Venkateshwar Shri K. Jairam Naik (*Alternate*)
The Indian Institute of Architects, Mumbai	Shri Kapil Mehta Shri Ajay Puri (*Alternate*)
The Institution of Engineers (India), Kolkata	Dr M. P. Chowdiah Shri K. B. Rajoria (*Alternate*)
UL India Pvt Ltd, Bengaluru	Shri V. Jagdish Shri G. Karthikeyan (*Alternate*)
Uttar Pradesh Fire Service, Lucknow	Shri P. K. Rao Shri Aman Sharma (*Alternate*)
West Bengal Fire & Emergency Services, Kolkata	Shri D. P. Biswas Shri Gopal K. Bhattacharya (*Alternate*)
In personal capacity (*SJR Verity, VIVA-305, Amrita College Road, Kasavanahalli, Bengaluru 560035*)	Shri T. R. A. Krishnan
In personal capacity (*A-347, Defence colony, New Delhi 110024*)	Shri R. C. Sharma
In personal capacity (*'Isa Vasyam' TC-18/1023, B-8/2-Lakshmi Nagar, Kesavadasapuram, Thiruvananthapuram 695004*)	Shri V. Suresh

Panel for Building Materials, CED 46:P3

Organization	*Representative(s)*
In personal capacity (*8th Floor, Flat No. 2, Tower 6, ATS-One Hamlet, Sector 104, Noida 201301*)	Shri T. N. Gupta (***Convener***)
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal Shri J. K. Prasad (*Alternate*)

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Organization	*Representative(s)*
CSIR-Central Building Research Institute, Roorkee	Dr A. K. Minocha Dr S. R. Karade (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Shri Mathura Prasad (*Alternate*)
Delhi Development Authority, New Delhi	Representative
Directorate General Border Roads, New Delhi	Representative
DLF Limited, Gurugram	Representative
Housing & Urban Development Corporation Limited, New Delhi	Chairman and Managing Director Shri Akhilesh Kumar (*Alternate*)
Indian Institute of Technology Guwahati, Guwahati	Representative
Indian Institute of Technology Madras, Chennai	Dr Amlan K. Sengupta Dr Manu Santhanam (*Alternate*)
Indian Buildings Congress, New Delhi	Shri Deepak Narayan
Indian Plywood Industries Research & Training Institute, Bengaluru	Shri K. Shyama Sundar Shri M. Pavan Kumar (*Alternate*)
Inter-University Accelerator Centre, New Delhi	Shri M. K. Gupta
Larsen & Toubro Limited, Chennai	Representative
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Girish Joshi Lt Col Gaurav Kaushik (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Director General Shri V. V. Arora (*Alternate*)
The Indian Institute of Architects, Mumbai	Shri Anurag Roy Shri Atul Gupta (*Alternate*)
The Institution of Engineers (India), Kolkata	Shri Anil Gattani Shri A. V. Patil (*Alternate*)
In personal capacity (*220, Sector 21-A, Faridabad 121001*)	Shri M. M. Goyal

Panel for Loads, Forces and Effects, CED 46:P4

Organization	*Representative(s)*
In personal capacity (*c/o Academy of Scientific & Innovative Research CSIR Campus, Taramani, Chennai 600113*)	Dr Nagesh R. Iyer **(*Convener*)**
Association of Consulting Civil Engineers (India), Bengaluru	Shri Manoj Mittal
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal Shri A. K. Tiwari (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CDO) Shri Rajesh Khare (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
CSIR-Central Building Research Institute, Roorkee	Dr Achal Kumar Mittal Dr Ajay Chourasia (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr J. Rajasankar Dr G. S. Palani (*Alternate*)
Delhi Tourism and Transportation Development Corporation, New Delhi	Shri Shishir Bansal
India Meteorological Department, New Delhi	Dr Devendra Pradhan Shri K. N. Mohan (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Shri Mahesh Tandon Shri R. Gogia (*Alternate*)
Indian Institute of Technology Delhi, New Delhi	Dr Vasant Matsagar Dr Dipti Ranjan Sahoo (*Alternate*)
Indian Institute of Technology Jodhpur, Jodhpur	Dr C. V. R. Murthy
Indian Institute of Technology Roorkee, Roorkee	Dr D. K. Paul
Larsen & Toubro Limited, Chennai	Shri Surya Prakash Karri Shri Krishna Somaraju (*Alternate* 1) Shri Praveen Kumar Rai (*Alternate* 2)
Mahendra Raj Consultants Pvt Ltd, New Delhi	Shri Mahendra Raj Shri S. S. Maan (*Alternate*)

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Organization	*Representative(s)*
Mehro Consultants, New Delhi	Shri S. C. Mehrotra Shri Deepak Thakur (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri B. S. Rao (*Alternate*)
National Institute of Disaster Management, New Delhi	Representative
The Institution of Engineers (India), Kolkata	Shri U. P. Waghe Shri Anil Gattani (*Alternate*)
In personal capacity (*L-802, Design Arch, e-Homes, Sector-5, Vaishali, Ghaziabad 201010*)	Dr A. S. Arya
In personal capacity (*B-03-3, Raheja Atlantis, NH 8, Sector 31-32A, Gurugram 122001*)	Dr Prem Krishna
In personal capacity (*'Isa Vasyam' TC-18/1023, B-8/2-Lakshmi Nagar, Kesavadasapuram, Thiruvananthapuram 695004*)	Shri V. Suresh

Panel for Soils and Foundations, CED 46:P5

Organization	*Representative(s)*
In personal capacity (*188/90, Prince Anwar Shah Road, Kolkata 700045*)	Dr N. Som (***Convener***)
Afcons Infrastructure Limited, Mumbai	Shri P. S. Bansod Shri V. Ramamurty (*Alternate*)
Bharat Heavy Electricals Limited, Noida	Shri C. Pushpakaran Shri Hitesh Kumar (*Alternate*)
Cengrs Geotechnica Pvt Ltd, Noida	Shri Sanjay Gupta Shri Ravi Sundaram (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Pradeep Kumar Shri Anindya Pain (*Alternate*)
Central Public Works Department, New Delhi	Shri M. K. Sharma Shri Saurabh Gupta (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
Delhi Development Authority, New Delhi	Chief Engineer (Design) Shri Vijay Shanker (*Alternate*)
Indian Institute of Technology Delhi, New Delhi	Dr J. T. Shahu Dr R. Ayothiraman (*Alternate*)
Indian Institute of Technology Madras, Chennai	Representative
Indian Association of Structural Engineers, New Delhi	Shri Sushil K. Dhawan Dr Abhay Gupta (*Alternate*)
Indian Geotechnical Society, New Delhi	Maj Gen (Retd) S. N. Mukherjee Shri Sanjay Gupta (*Alternate*)
ITD Cementation Pvt Ltd, Mumbai	Shri Hemendra Chaudhary
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Girish Joshi Col Pradeep Tiwari (*Alternate*)
NTPC Limited, New Delhi	Dr D. N. Naresh Shri Jitendra Kumar (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri P. N. Ojha (*Alternate*)
National Institute of Disaster Management, New Delhi	Dr Chandan Ghosh Dr Amir Ali Khan (*Alternate*)
The Institution of Engineers (India), Kolkata	Prof G. B. Choudhari Dr S. S. Basarkar (*Alternate*)
In personal capacity (*C-4-B, CDS Regal Palm Garden, 383, Velachery, Chennai 600042*)	Shri A. Vijayaraman

Panel for Timber and Bamboo, CED 46:P6

Organization	*Representative(s)*
In personal capacity (*Pratap Nursery Lane, Near Gurudwara, Panditwari, Dehra Dun 248007*)	Shri K. S. Pruthi (***Convener***)

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Bamboo Society of India, Bengaluru	Dr K Sundar Naik Shri K. S. Anand (*Alternate*)
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal Shri C. N. Jha (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr B. Singh Dr B. S. Rawat (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Shri Mathura Prasad (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
Forest Research Institute (ICFRE), Dehra Dun	Shri Rajesh Bhandari Shri R. S. Topwal (*Alternate*)
Forum of Scientists, Engineers and Technologists, Kolkata	Shri Rabi Mukhopadhyay Shri Parthasarathi Mukhopadhyay (*Alternate*)
Housing & Urban Development Corporation Limited, New Delhi	Chairman and Managing Director Shri Akhilesh Kumar (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Dr Dulal Goldar Shri Hari Om Gupta (*Alternate*)
Indian Institute of Technology Delhi, New Delhi	Dr Suresh Bhalla
Indian Plywood Industries Research and Training Institute, Bengaluru	Shri Anand Nandanwar Shri Narasimhamurthy (*Alternate*)
Iyer and Mahesh Architects, Thiruvanthapuram	Shri N. Mahesh Shri K. Gangadharan (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shrimati Upinder Kaur Shrimati Rachna (*Alternate*)
North East Centre for Technology Application and Reach, Shillong	Shri Ajay Kumar Shri Krishna Kumar (*Alternate*)
The Institution of Engineers (India), Kolkata	Shri Krishna Kumar
Wonder Grass Initiative Pvt Ltd, Nagpur	Shri Vaibhav Kaley
In personal capacity (*103/II, Vasant Vihar, P.O. New Forest, Dehra Dun 248006*)	Shri S. S. Rajput

Panel for Masonry, CED 46:P7

Organization	*Representative(s)*
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora (***Convener***)
Adlakha Associates Pvt Ltd, New Delhi	Shri P. K. Adlakha Shri V. K. Sethi (*Alternate*)
Association of Consulting Civil Engineers (India), Bengaluru	Shri Umesh B. Rao Dr Raghunath S. (*Alternate*)
Bhabha Atomic Reaseach Centre, Trombay	Shri K. Srinivas Shri H. E. Iyer (*Alternate*)
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal Shri Pankaj Gupta (*Alternate*)
Central Public Works Department, New Delhi	Shri A. K. Jha Shri Rajesh Khare (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Achal Kumar Mittal Dr Ajay Chourasia (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr A. Ramachandra Murthy Ms Smitha Gopinath (*Alternate*)
Delhi Development Authority, New Delhi	Chief Engineer (Design) Shri Vijay Shanker (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Shri R. Gogia Ms Sangeeta Wij (*Alternate*)
Indian Institute of Science, Bengaluru	Dr B. V. Venkatarama Reddy Dr K. S. Nanjunda Rao (*Alternate*)

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Organization	*Representative(s)*
Indian Institute of Technology Delhi, New Delhi	Representative
Indian Institute of Technology Kanpur, Kanpur	Dr Durgesh C. Rai
Indian Institute of Technology Madras, Chennai	Dr Arun Menon
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Rajiv Sahani Shri Jai Prakash (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri Satish Sharma
The Institution of Engineers (India), Kolkata	Shri P. T. Tawase Shri Azad Jain (*Alternate*)

Panel for Plain, Reinforced and Prestressed Concrete, CED 46:P8

Organization	*Representative(s)*
In personal capacity (*7A, Autumn Hue, Seasons PPD Apartments, Kuravankonam, Kowdiar, Thiruvananthapuram 695003*)	Shri Jose Kurian (***Convener***)
Association of Consulting Civil Engineers (India), Bengaluru	Shri M. S. Sudharshan
BBR (India) Pvt Ltd, Bengaluru	Shri P. Jayachandran Shri Bharat Bhushan (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CDO) Shri Rajesh Khare (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
CSIR-Central Building Research Institute, Roorkee	Shri S. K. Singh Shri S. C. Bose Gurram (*Alternate*)
CSIR-Central Road Research Institute, New Delhi	Shri J. B. Sengupta Shri Binod Kumar (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr K. Ramanjaneyulu Dr B. H. Bharathkumar (*Alternate*)
Delhi Development Authority, New Delhi	Shri Vijay Shanker
Gammon India Limited, Mumbai	Shri Sarada Prasana Mohanty
Hindustan Prefab Limited, New Delhi	Shri Rajesh Goel Shri S. K. Jain (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Shri S. C. Mehrotra Dr Rajeev Goel (*Alternate*)
Indian Concrete Institute, Chennai	Shri A. K. Jain Shri K. P. Abraham (*Alternate*)
Indian Institute of Science, Bengaluru	Representative
Indian Institute of Technology Madras, Chennai	Dr Amlan K. Sengupta
Larsen & Toubro Limited, Chennai	Shri K. Senthilnathan Shri Sthaladipti Saha (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Representative
Ministry of Road Transport and Highways, New Delhi	Chief Engineer, Standard & Research (Bridges)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri Satish Sharma (*Alternate*)
Research, Designs and Standards Organization (Ministry of Railways), Lucknow	Shri H. L. Suthar Shri Praveen Khorana (*Alternate*)
STUP Consultants Pvt Ltd, Mumbai	Shri S. G. Joglekar Dr N. Bandyopadhyay (*Alternate*)
Tandon Consultants, New Delhi	Shri Mahesh Tandon
The Institution of Engineers (India), Kolkata	Shri S. S. Chakraborty Dr M. A. Chakrabarti (*Alternate*)
In personal capacity (*A-4/110, Konark Apartments, Kalkaji, New Delhi 110019*)	Dr A. K. Mullick
In personal capacity (*M1F1, VGN Minerva Apartments, Guruswamy Road, Nolambur, Chennai 600095*)	Dr C. Rajkumar

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In personal capacity (*E-1, 402, White House Apartments, 15th Cross, 6th Main, R.T. Nagar, Bengaluru 560032*)	Shri S. A. Reddi
In personal capacity (*7046, Sector B, Pocket 10, Vasant Kunj, New Delhi 110070*)	Shri T. Viswanathan
In personal capacity (*EA-92, Maya Enclave, Hari Nagar, New Delhi 110064*)	Shri R. C. Wason

Panel for Steel, CED 46:P9

Organization	*Representative(s)*
In personal capacity (*II-2A, Rani Meyyammai Towers, Chennai 600036*)	Dr V. Kalyanaraman (***Convener***)
Association of Consulting Civil Engineers (India), Bengaluru	Shri S. C. Mehrotra
Central Public Works Department, New Delhi	Chief Engineer (CDO) Shri A. K. Gupta (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
CSIR-Structural Engineering Research Centre, Chennai	Dr G. S. Palani Dr G. Raghava (*Alternate*)
Engineers India Ltd, New Delhi	Shri Anurag Sinha Shri Vikram K. Gupta (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Dr K. Srinivasa Rao Dr Abhay Gupta (*Alternate*)
Indian Institute of Technology Madras, Chennai	Dr S. Arul Jayachandran
Institute for Steel Development and Growth, Kolkata	Shri Pydi Lakshmana Rao Shri Arijit Guha (*Alternate*)
Interarch Building Products Pvt Ltd, Noida	Shri Gautam Suri Shri Sunil Pulikkal (*Alternate*)
Jindal Steel and Power Limited, New Delhi	Shri Ashwani Kumar Ms Neha Sharma (*Alternate*)
Kalpataru Power Transmission Ltd, Gandhinagar	Shri B. B. Shah Shri Sujal B. Shah (*Alternate*)
Larsen & Toubro Limited, Chennai	Shri T. Venkatesh Rao
M. N. Dastur & Co (P) Ltd, Kolkata	Shri Satyaki Sen Shri Tapan Kumar Bhaumik (*Alternate*)
MECON Limited, Ranchi	Shri A. Krishna Rao Shri C. Krishnam Raju (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Girish Joshi Lt Col Sandeep Khokher (*Alternate*)
PEB Manufacturers' Association, Navi Mumbai	Shri Gautam Suri Shri Manish Garg (*Alternate*)
Research, Designs and Standards Organization (Ministry of Railways), Lucknow	Shri A. K. Dadria Shri Srijan Tripathi (*Alternate*)
Steel Authority of India Ltd (Centre for Engineering & Technology), Ranchi	Shri R. M. Chattopadhyay Shri G. K. Mitra (*Alternate*)
Tata Consulting Engineers Limited, Mumbai	Shri Pratip Bhattacharya
Tata Steel Ltd, Jamshedpur	Shri Hariharaputhiran H.
The Institution of Engineers (India), Kolkata	Shri R. P. Gupta

Panel for Prefabrication and Systems Buildings, CED 46:P10

Organization	*Representative(s)*
L&T Metro Rail (Hyderabad) Limited, Hyderabad	Shri M. P. Naidu (***Convener***)
Adlakha Associates Pvt Ltd, New Delhi	Shri P. K. Adlakha
B. G. Shirke Construction Technology Pvt Ltd, Pune	Shri Yogesh P. Kajale Shri Sanjay M. Adsar (*Alternate*)

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Building Materials & Technology Promotion Council, New Delhi	Shri J. K. Prasad
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Shri Mathura Prasad (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep
CSIR-Central Building Research Institute, Roorkee	Dr Ajay Chourasia Shri Narender Kumar (*Alternate*)
CSIR-Structural Engineering Research Centre, Chennai	Dr J. Prabakar Dr Jolly Annie Peter (*Alternate*)
Delhi Development Authority, New Delhi	Chief Engineer (Design) Shri Vijay Shanker (*Alternate*)
Hindustan Prefab Limited, New Delhi	Shri Rajesh Goel Shri Satish Kumar Jain (*Alternate*)
Indian Institute of Technology Madras, Chennai	Representative
Indian Association of Structural Engineers, New Delhi	Shri Mahesh Tandon Shri N. Jain (*Alternate*)
Indian Concrete Institute, Chennai	Shri Rajkumar Pillai
Institute for Steel Development and Growth, Kolkata	Shri Arijit Guha
Kirby Building Systems India Ltd, Hyderabad	Representative
Larsen & Toubro Limited, Chennai	Shri S. Veeramani Shri C. K. Somaraju (*Alternate*)
Lloyd Insulations (India) Ltd, New Delhi	Shri Ajay Singh Shri Jitendra Kumar Jain (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Girish Joshi Lt Col Gaurav Kaushik (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri B. S. Rao (*Alternate*)
PEB Manufacturers' Association, Navi Mumbai	Shri Gautam Suri
Pranav Construction Systems Pvt Ltd, Navi Mumbai	Representative
Shirish Patel and Associates Consultants Pvt Ltd, Mumbai	Shri Shirish B. Patel Shri P. H. Srinivasachar (*Alternate*)
Systems Building Technologists, New Delhi	Shri G. B. Singh
Tata Bluescope Steel Ltd, Pune	Shri Krishnakant Rane
The Indian Institute of Architects, Mumbai	Shri S. R. Sikka
The Institution of Engineers (India), Kolkata	Dr R. K. Bhandari Shri Hemant S. Vadalkar (*Alternate*)

Panel for Constructional Practices and Safety, CED 46:P11

Organization	*Representative*(*s*)
In personal capacity (*102, Shraddha Temple Tree, Rustam Bagh, Bengaluru 560017*)	Shri P. Krishnan (***Convener***)
Adlakha Associates Pvt Ltd, Delhi	Shri P. K. Adlakha
Builders Association of India, Mumbai	Shri S. Senthil Kumar Shri Neerav Parmar (*Alternate*)
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Shri Mathura Prasad (*Alternate*)
Construction Industries Development Council, New Delhi	Shri P. R. Swarup Shri Sunil Mahajan (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Shri S. K. Negi Shri S. K. Singh (*Alternate*)
Director General of Factory Advice Service and Labour Institute, Mumbai	Shri S. N. Borkar Shri B. N. Jha (*Alternate*)
Engineers India Ltd, New Delhi	Shri A. K. Mishra Shri D. Jana (*Alternate*)

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Gammon India Limited, Mumbai	Shri Prakash Tikare Shri Sylvester F. Pereira (*Alternate*)
Hindustan Prefab Limited, New Delhi	Shri Rajesh Goel Shri S. K. Jain (*Alternate*)
Indian Association of Structural Engineers, New Delhi	Shri Manoj Mittal Shri R. Gogia (*Alternate*)
Indian Buildings Congress, New Delhi	Shri Deepak Narayan
Indian Plywood Industries Research & Training Institute, Bengaluru	Shri Jagadish Vengala Shri Anand Nandanwar (*Alternate*)
L&T Metro Rail (Hyderabad) Limited, Hyderabad	Shri M. P. Naidu
Larsen & Toubro Limited, Chennai	Shri S. Selvaganpathy Shri N. Ramachandran (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Brig Dinesh Kumar Gupta Shri B. Varshney (*Alternate*)
NBCC (India) Limited, New Delhi	Shri H. S. Yadav Shri S. C. Jain (*Alternate*)
School of Planning and Architecture, New Delhi	Dr V. K. Paul
The Indian Institute of Architects, Mumbai	Shri Kailash Chandra Jatia Shri C. M. Sapra (*Alternate*)
The Institution of Engineers (India), Kolkata	Shri D. S. Sachdev Dr H. M. Raje (*Alternate*)
In personal capacity (*7A, Autumn Hue, Seasons PPD Apartments, Kuravankonam, Kowdiar, Thiruvananthapuram 695003*)	Shri Jose Kurian
In personal capacity (*Pratap Nursery Lane, Near Gurudwara, Panditwari, Dehra Dun 248007*)	Shri K. S. Pruthi
In personal capacity (*'Isa Vasyam' TC-18/1023, B-8/2-Lakshmi Nagar, Kesavadasapuram, Thiruvananthapuram 695004*)	Shri V. Suresh
In personal capacity (*220, Ankur Apartment, Mother Dairy Road, Patparganj, New Delhi 110092*)	Dr V. Thiruvengadam
In personal capacity (*K-11, Kailash Colony, New Delhi 110048*)	Shri Balbir Verma

Panel for Lighting and Ventilation, CED 46:P12

Organization	*Representative(s)*
In personal capacity (*435/6, New Adarsh Nagar, Roorkee 247667*)	Dr Ishwar Chand (***Convener***)
Ab Initio, Thane	Shri Shirish Deshpande
Bureau of Energy Efficiency, New Delhi	Shri Saurabh Diddi Shri Ashish Saraswat (*Alternate*)
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri D. K. Tulani (*Alternate*)
CEPT University, Ahmedabad	Shri Rajan Rawal Shri Yash Shukla (*Alternate*)
Chandigarh College of Architecture, Chandigarh	Dr Pradeep Bhagat
CSIR-Central Building Research Institute, Roorkee	Shri N. Babu Balam Shri Ibrahim Sohel (*Alternate*)
CSIR-National Physical Laboratory, New Delhi	Dr Parag Sharma Shri V. K. Jaiswal (*Alternate*)
Director General Factory Advice Service and Labour Institute, Mumbai	Shri S. N. Borkar Shri B. N. Jha (*Alternate*)
Indian Institute of Technology Delhi (Centre for Energy Studies), New Delhi	Representative
Indian Society for Lighting Engineers, New Delhi	Shri Gulshan Aghi Shri Gaurav Arora (*Alternate*)
Kaleidoscope, Noida	Shri Amor Kool
Larsen & Toubro Limited (Sustainability Group), Chennai	Shri R. Balakrishnan

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Organization	*Representative(s)*
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Shri Jaya Prakash (*Alternate*)
Ministry of New and Renewable Energy, New Delhi	Dr A. K. Tripathi Shri H. C. Borah (*Alternate*)
Municipal Corporation of Greater Mumbai, Mumbai	Executive Engineer Shri R. K. Rahate (*Alternate*)
Philips India Limited, Kolkata	Shrimati Sudeshna Mukhopadhyay Shri Ashish Bahal (*Alternate*)
School of Planning and Architecture, New Delhi	Dr V. K. Paul Dr Anil Dewan (*Alternate*)
Siddhirja Environment Technologies Pvt Ltd, Noida	Shri Ankur Khandelwal
Space Design Consultants, New Delhi	Prof Vinod Kumar Gupta
The Indian Institute of Architects, Mumbai	Prof Ashok B. Lall
The Institution of Engineers (India), Kolkata	Shri R. N. Rajpoot
In personal capacity (*262, Solanipuram, Roorkee 247667*)	Dr P. K. Bhargava
In personal capacity (*Shree Bhavan, Moh. Neelkhudana, Sikhola Chowk, Jwalapur, Haridwar 249407*)	Shri Shree Kumar

Panel for Electrical Installations, CED 46:P13

Organization	*Representative(s)*
In personal capacity (*Pine 002, SJR Park Vista Apartments, Haralur Road, Bengaluru 560012*)	Shri J. N. Bhavani Prasad (***Convener***)
AECOM India Private Limited, Noida	Shri Kishor Kumar
Aeon Integrated Building Design Consultants, New Delhi	Shri Puneet Gupta
Bureau of Energy Efficiency, New Delhi	Shri Saurabh Diddi Shri Ashish Saraswat (*Alternate*)
C&S Electric Limited, New Delhi	Shri P. S. Teji Shri Yashwant Sarathe (*Alternate*)
Central Electricity Authority, New Delhi	Shri R. K. Verma Shri A. K. Rajput (*Alternate*)
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri D. K. Tulani (*Alternate*)
Chief Electrical Inspectorate, Govt of Tamil Nadu, Chennai	Chief Electrical Inspector Senior Electrical Inspector (Hqrs) (*Alternate*)
DEHN India Pvt Ltd, Gurugram	Shri Vikas Almadi Shri Brijesh Malik (*Alternate*)
Delhi Metro Rail Corporation, New Delhi	Shri Sanjeev Kumar Shri Ashok Tewari (*Alternate*)
Engineers India Ltd, New Delhi	Shri B. R. Bhogal Shri Harish Kumar (*Alternate*)
ITC Ltd, Gurugram	Shri I. K. Suresh
Larsen & Toubro Limited, Chennai	Shri D. Maheswaran Shri K. K. Jembu Kailas (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Shri Sunil Agarwal (*Alternate*)
Ministry of New and Renewable Energy, New Delhi	Representative
OBO Bettermann (I) Pvt Ltd, Chennai	Shri S. Gopakumar
Proion Consultants, New Delhi	Shrimati Shruti Goel
Public Works Department (Electrical Division), Govt of Maharashtra, Mumbai	Shri Sandeep A. Patil Shri Hemant Sali (*Alternate*)
Schneider Electric India Pvt Ltd, Gurugram	Shri Amitabha Sarkar Shri Rajkumar Singh (*Alternate*)
Siemens Limited, Chennai	Shri Kishor Yadao
Solar Energy Corporation of India, New Delhi	Shri C. K. Singh

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Organization	*Representative(s)*
The Institution of Engineers (India), Kolkata	Prof Samiran Choudhuri Lt Gen (Retd) S. K. Jain (*Alternate*)
In personal capacity (*C-20, Sector 47, Noida 201301)*	Shri N. Nagarajan

Panel for Air Conditioning and Heating, CED 46:P14

Organization	*Representative(s)*
AECOM India Private Limited, Noida	Dr Prem C. Jain (***Convener***)
Aeon Integrated Building Design Consultants, New Delhi	Shri Ashish Rakheja
ASHRAE India Chapter, New Delhi	Shri Sunil Kher
Blowtech Air Devices Pvt Ltd, Noida	Shri Sushil K. Choudhury
Blue Star Limited, Chennai	Shri B. Thiagarajan Shri M. Srinivas Reddy (*Alternate*)
Bureau of Energy Efficiency, New Delhi	Shri Sanjay Seth Shri Saurabh Diddi (*Alternate*)
Caire Consult, Greater Noida	Shri Ankit Jain
Carrier Airconditioning & Refrigeration Ltd, Gurugram	Shri Arun Bhatia Shri Bimal Tandon (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr B. M. Suman Dr Shorab Jain (*Alternate*)
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri D. K. Tulani (*Alternate*)
CEPT University, Ahmedabad	Shri Rajan Rawal Shri Yash Shukla (*Alternate*)
Climaveneta Climate Technologies (P) Ltd, Bengaluru	Shri Anil Dev Shri Anil Sharma (*Alternate*)
Comfort Care System Pvt Ltd, New Delhi	Shri Yogesh Malhotra
Daikin Airconditioning India Pvt Ltd, Gurugram	Shri Kanwaljeet Jawa Shri Sanjay Goyal (*Alternate*)
Delhi Fire Service, Govt of NCT of Delhi, New Delhi	Shri A. K. Sharma Dr G. C. Misra (*Alternate*)
Delhi Metro Rail Corporation, New Delhi	Shri A. K. Gupta Shri A. K. Singh (*Alternate*)
Eskayem Consultants Pvt Ltd, Mumbai	Shri K. Ramachandran
IBM India Pvt Ltd, Mumbai	Shri Sudipta Sanyal
Indian Green Building Council, Hyderabad	Shri S. Srinivas Shri Praveen Kumar Soma (*Alternate*)
Indian Institute of Technology Delhi, New Delhi	Dr Sanjeev Jain
Indian Society for Heating, Refrigeration and Air Conditioning Engineers, Delhi	Shri D. Nirmal Ram Shri Ashwini Mehra (*Alternate*)
International Ground Source Heat Pump Association, India Chapter, New Delhi	Shri Richie Mittal
Kanwal Industries Corporation, Noida	Shri Pawandeep Singh
Kirloskar Chillers Private Limited, Pune	Shri Avinash Manjul Shri Gaurang Dabholkar (*Alternate*)
Malaviya National Institute of Technology, Jaipur	Dr Jyotirmay Mathur
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Shri R. N. Sinha (*Alternate*)
Schneider Electric India Pvt Ltd, Gurugram	Dr Satish Kumar
Sterling India Consulting Engineers, New Delhi	Shri G. C. Modgil Ms Khushboo Modgil (*Alternate*)
Suvidha Engineers India Ltd, Noida	Shri Ashok K. Virmani Shri Sanjay Mookerjee (*Alternate*)

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Organization	*Representative(s)*
The Institution of Engineers (India), Kolkata	Shri Pradeep Chaturvedi
UL India Pvt Ltd, Bengaluru	Shri V. Manjunath
Voltas Limited, New Delhi	Shri Ashwani Sharma Shri Pankaj Goel (*Alternate*)
In personal capacity (*C-9, 9511, Vasant Kunj, New Delhi 110070*)	Dr R. S. Agarwal
In personal capacity (*262, Solanipuram, Roorkee 247667*)	Dr P. K. Bhargava
In personal capacity (*435/6, New Adarsh Nagar, Roorkee 247667*)	Dr Ishwar Chand
In personal capacity, (*E 203, Belaire, Golf Course Road, Gurugram 122022*)	Shri Prabhat Goel

Panel for Acoustics, Sound Insulation and Noise Control, CED 46:P15

Organization	*Representative(s)*
Suri and Suri Consulting Acoustical Engineers, Noida	Shri Gautam Suri (***Convener***)
All India Radio, New Delhi	Shri Animesh Chakraborty Shri Jitender Pruthi (*Alternate*)
Central Public Works Department, New Delhi	Shri Rajesh Kumar Dhiman Shri Arun Kumar Tyagi (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr S. K. Panigrahi Dr B. M. Suman (*Alternate*)
CSIR-National Physical Laboratory, New Delhi	Dr Mahavir Singh Dr Naveen Garg (*Alternate*)
Indian Institute of Science, Bengaluru	Prof M. L. Munjal
Indian Institute of Technology Kharagpur, Kharagpur	Dr A. R. Mohanty
Indian Institute of Technology Madras, Chennai	Prof S. Narayanan Prof P. Chandramouli (*Alternate*)
Indian Institute of Technology Roorkee, Roorkee	Dr E. Rajasekar
Lloyd Insulations (India) Ltd, New Delhi	Shri N. Srinivas Shri Umesh Khanna (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri A. K. Arora Shrimati Upinder Kaur (*Alternate*)
P. S. Subramanian Associates, Chennai	Dr S. Kandaswamy Dr P. Senthil Kumar (*Alternate*)
School of Planning and Architecture, New Delhi	Dr Shuvojit Sarkar
The Indian Institute of Architects, Mumbai	Shri Indra Nath Basu
The Institution of Engineers (India), Kolkata	Shri K. V. Chaubal Shri P. K. Adlakha (*Alternate*)
In personal capacity (*608/L-1, Solani Enclave, New Adarsh Nagar, Roorkee 247667*)	Shri R. K. Srivastava

Panel for Installation of Lifts and Escalators, CED 46:P16

Organization	*Representative(s)*
TAK Consulting Pvt Ltd, Mumbai	Shri T. A. K. Mathews (***Convener***)
Builders Association of India, Mumbai	Representative
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri Sham Sunder Garg (*Alternate*)
Electrical Inspectorate, Govt of NCT of Delhi, New Delhi	Shri Mukesh Kumar Sharma Shri Jogender Singh (*Alternate*)
Chief Electrical Inspectorate, Govt of Tamil Nadu, Chennai	Shri V. Jayavel Shri P. Manohar (*Alternate*)
Delhi Development Authority, New Delhi	Shri Sandeep Mehta Shri Navneet Kumar Mittal (*Alternate*)
Delhi Fire Service, Govt of NCT of Delhi, New Delhi	Shri A. K. Sharma Dr G. C. Misra (*Alternate*)

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Organization	*Representative(s)*
Directorate of Maharashtra Fire Services, Mumbai	Shri M. V. Deshmukh Shri Santosh Warick (*Alternate*)
ECE Industries Limited, Ghaziabad	Shri M. Balasubramanian Shri K. Mohan (*Alternate*)
Fujitec India Pvt Ltd, Chennai	Shri S. P. Rao Shri R. Rajesh (*Alternate*)
Inspectorate of Lifts, Directorate of Electricity, Kolkata	Representative
Johnson Lifts Pvt Ltd, Chennai	Shri T. Subramanian Shri V. Karthikeyan (*Alternate*)
Kone Elevator India Pvt Ltd, Chennai	Shri P. M. Tipnis Shri P. Gurumoorthy (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Shri Sunil Agarwal (*Alternate*)
Otis Elevator Company (India) Limited, New Delhi	Shri Abhijit Dandekar Shri H. N. Prashanth (*Alternate*)
Public Works Department, Govt of Maharashtra, Mumbai	Shri Sandeep A. Patil Shri Sanjay Bhasme (*Alternate*)
Schindler India Pvt Limited, Mumbai	Shri Nimish Deshpande Shri Ronnie Dante (*Alternate*)
TAK Consulting Pvt Ltd, Mumbai	Ms Anandi Khandekar
The Indian Institute of Architects, Mumbai	Shri J. B. Karamchandani Shri Vijay Garg (*Alternate*)
The Institution of Engineer (India), Kolkata	Dr R. K. Dave
In personal capacity (*K-33A, First Floor, Green Park, New Delhi 110016*)	Shri S. K. Dheri
In personal capacity [*4, Vidharbha Samrat Co-op. Housing Society, 93 C, V. P. Road, Vile Parle (W) Mumbai 400056*]	Shri A. S. Herwadkar

Panel for Plumbing Services, CED 46:P17

Organization	*Representative(s)*
Indian Plumbing Association, New Delhi	Shri B. S. Aswathnarayan (B. S. A. Narayan) (***Convener***)
AECOM India Private Limited, Noida	Shri B. V. Shiva Kumar
Brihan Mumbai Licensed Plumbers' Association, Mumbai	Shri D. K. Daiya Shri B. M. Shah (*Alternate*)
Central Ground Water Board, Faridabad	Member (SML) Regional Director (*Alternate*)
Central Pollution Control Board, New Delhi	Dr A. B. Akolkar Dr Sanjeev Agrawal (*Alternate*)
Central Public Health and Environmental Engineering Organization, New Delhi	Representative
Central Public Works Department, New Delhi	Chief Engineer (CSQ) Shri Rabindra Kumar (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Ajay Chourasia Shri Ibrahim Sohel (*Alternate*)
CSIR-National Environmental Engineering Research Institute, Nagpur	Shri A. S. Dubey Shri M. Karthik (*Alternate*)
Delhi Development Authority, New Delhi	Shri D. P. Singh Shri Anil Kumar Tyagi (*Alternate*)
Delhi Jal Board, New Delhi	Chief Engineer (Central & North)
East Delhi Municipal Corporation, Delhi	Shri Vijay Prakash Shri Ajay Kumar Mittal (*Alternate*)
Indian Plumbing Association, New Delhi	Shri M. K. Gupta Shri H. R. Ranganath (*Alternate*)

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Organization	*Representative(s)*
Indraprastha Gas Limited, New Delhi	Shri Pankaj Sharma Shri Avijit Narayan (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Shri Jaya Prakash (*Alternate*)
Municipal Corporation of Greater Mumbai, Mumbai	Deputy Hydraulic Engineer (Planning & Control) Executive Engineer (Planning & Research) (*Alternate*)
Nous Hospital Consultants Pvt Ltd, New Delhi	Dr K. B. Sood
Proion Consultants, New Delhi	Shri Sandeep Goel
Tata Consulting Engineers Limited, Mumbai	Shri Dheeraj Kaushik
The Indian Institute of Architects, Mumbai	Shri Uday Pande
The Institution of Engineers (India), Kolkata	Shri P. C. Tyagi
In personal capacity (*B/58A, Gangotri Enclave, Alaknanda, New Delhi 110019*)	Shri J. D'Cruz
In personal capacity (*610, Technology Apartments, 24 Patparganj, New Delhi 110092*)	Shri Subir Paul

Panel for Landscaping, Signs and Outdoor Display Structures, CED 46:P18

Organization	*Representative(s)*
In personal capacity (*167/8, Sarai Julena, Okhla Road, New Delhi 110025*)	Prof M. Shaheer (***Former Convener***)
Integral Designs International Studio Pvt Ltd, New Delhi	Shri Samir Mathur (***Convener***)
Central Public Works Department, New Delhi	Shri Rajesh Kumar Dhiman Shri Arun Kumar Tyagi (*Alternate*)
Delhi Development Authority, New Delhi	Representative
Delhi Urban Arts Commission, New Delhi	Shri Samir Mathur Shrimati Sonali Bhagwati (*Alternate*)
Housing & Urban Development Corporation Limited, New Delhi	Shrimati Usha Prasad Mahavir Shrimati Varsha Punhani (*Alternate*)
Indian Society of Landscape Architects, Ahmedabad	Shri Sachin Jain Ms Savita Punde (*Alternate*)
Institute of Town Planners, India, New Delhi	Dr S. K. Kulshrestha
M. S. Y. K. Design, New Delhi	Shri Yogesh Kapoor
Municipal Corporation of Greater Mumbai, Mumbai	Shrimati Minakshi Mane Shrimati Ashlesha Modak (*Alternate*)
National Institute of Design, Ahmedabad	Shri Anil Sinha Shri Immanuel Suresh (*Alternate*)
New Delhi Municipal Council, New Delhi	Shri Rakesh Goel
School of Planning and Architecture, New Delhi	Prof Rommel Mehta
South Delhi Municipal Corporation, New Delhi	Representative
The Indian Institute of Architects, Mumbai	Shri Mahesh Paliwal
The Institution of Engineers (India), Kolkata	Prof Jitendra Singh
The Maharaja Sayajirao University of Baroda, Vadodara	Prof S. R. Raval
Town and Country Planning Organization, Ministry of Urban Development, New Delhi	Shrimati Jasmin Bimra Mallik
In personal capacity (*D-198, Defence Colony, New Delhi 110024*)	Shri Ravindra Bhan
In personal capacity (*874/4, Near Pundalik Temple, Alto Porvorim, Goa 403521*)	Shrimati Vinita Vijayan Pugal

Panel for Sustainability, CED 46:P19

Organization	*Representative(s)*
AECOM India Private Limited, Noida	Dr Prem C. Jain (***Convener***)
AECOM India Private Limited, Noida	Ms Sanyukta Pande
Ankoor Sanghvi Architects, Rajkot	Shri Ankoor Sanghvi

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Organization	*Representative(s)*
Building Materials & Technology Promotion Council, New Delhi	Dr Shailesh Kumar Agrawal Shri J. K. Prasad (*Alternate*)
Bureau of Energy Efficiency, New Delhi	Shri Sanjay Seth
Central Public Works Department, New Delhi	Shri Mathura Prasad Shri Rajesh Khare (*Alternate*)
CEPT University, Ahmedabad	Shri Rajan Rawal
Confederation of Real Estate Developers' Association of India, New Delhi	Shri G. Yoganand Shri Hemant Dattaji Naiknavare (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Shri Yadvendra Pandey Dr Ashok Kumar (*Alternate*)
Delhi Development Authority, New Delhi	Engineer Member Shri Ashok Ghodeshwar (*Alternate*)
Design and Development, New Delhi	Shrimati Sheetal Rakheja
Indian Association of Structural Engineers, New Delhi	Dr Ravande Kishore Shri Manoj Mittal (*Alternate*)
Indian Buildings Congress, New Delhi	Shri P. Krishnan Shri P. S. Chadha (*Alternate*)
Indian Green Building Council, Hyderabad	Shri M. Anand Shri Punit Agarwal (*Alternate*)
Indian Institute of Science (Center for Sustainable Technologies), Bengaluru	Dr Monto Mani
Institute of Town Planners, India, New Delhi	Dr S. K. Kulshrestha
International Institute of Information Technology, Hyderabad	Dr Vishal Garg Dr Pradeep Kumar Ramancharla (*Alternate*)
Kaleidoscope, Noida	Shri Amor Kool
Karan Grover and Associates, Vadodara	Shri Karan Grover
Kone Elevator India Pvt Ltd, Chennai	Shri P. M. Tipnis Shri J. Sivaraman (*Alternate*)
Larsen & Toubro Limited, ECC Division, Chennai	Shri Rajan Venkateswaran Shri Sthaladipti Saha (*Alternate*)
Malaviya National Institute of Technology, Jaipur	Dr Jyotirmay Mathur Dr Sanjay Mathur (*Alternate*)
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shrimati Upinder Kaur Shri Mahesh Arjun Ruperee (*Alternate*)
Ministry of New and Renewable Energy, New Delhi	Dr A. K. Tripathi
Panika, Ahmedabad	Shri Nimish Patel Shrimati Parul Zaveri (*Alternate*)
Proion Consultants, New Delhi	Shri Sandeep Goel
School of Planning and Architecture, New Delhi	Dr V. K. Paul
Surat Municipal Corporation, Surat	Shri J. M. Patel Shri J. S. Shah (*Alternate*)
Sustainable Urbanism International, Bengaluru	Dr Jyoti Hosagrahar
The Energy and Resources Institute, New Delhi	Ms Mili Majumdar
The Indian Institute of Architects, Mumbai	Shri Prafulla Karkhanis Shri Abhijit Ray (*Alternate*)
The Institution of Engineers (India), Kolkata	Shri G. Prabhakar Shri B. Anantaramloo (*Alternate*)
Town and Country Planning Organization, Ministry of Urban Development, New Delhi	Shri Paresh Duria Dr Pawan Kumar (*Alternate*)
UL India Pvt Ltd, Bengaluru	Shri V. Manjunath Shri Puneet Randeo (*Alternate*)
In personal capacity [*Archana 105-B, Ambika Nagar, M. G. Road, Dombivali (W), Mumbai 421202*]	Shri Santosh Deodhar

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In personal capacity (*8th Floor, Flat No. 2, Tower 6, ATS-One Hamlet, Sector 104, Noida 201301*)	Shri T. N. Gupta
In personal capacity (*L/109, Sarita Vihar, New Delhi 110076*)	Shri Ashok Khurana
In personal capacity (*102, Shraddha Temple Tree, Rustam Bagh, Bengaluru 560017*)	Shri P. Krishnan
In personal capacity (*7A, Autumn Hue, Seasons PPD Apartments, Kuravankonam, Kowdiar, Thiruvananthapuram 695003*)	Shri Jose Kurian
In personal capacity (*167/8, Sarai Julena, Okhla Road, New Delhi 110025*)	Prof M. Shaheer
In personal capacity (*'Isa Vasyam' TC-18/1023, B-8/2-Lakshmi Nagar, Kesavadasapuram, Thiruvananthapuram 695004*)	Shri V. Suresh

Panel for Glass and Glazing, CED 46:P20

Organization	*Representative*(*s*)
In personal capacity (*A2/16, Sri Agrasen Society, Plot No. 10, Sector 7, Dwarka, New Delhi 110075*)	Shri R. N. Dandekar (***Convener***)
AECOM India Private Limited, Noida	Shri Vijay K. Mattoo Shri Sunil Shahani (*Alternate*)
Ahluwalia Contracts India Limited, New Delhi	Shri Pradeep Kumar Shri Jaspal Singh Rawat (*Alternate*)
All India Glass Manufacturers' Federation, New Delhi	Shri Somasundaram Senthil Shri Rupinder Shelly (*Alternate*)
Bureau of Energy Efficiency, New Delhi	Representative
Central Public Works Department, New Delhi	Shri Mathura Prasad
Confederation of Construction Products and Services, New Delhi	Shri Shashi Kant Shri Deepak Gahlowt (*Alternate*)
Creative Design Consultants & Engineers Pvt Ltd, Ghaziabad	Shri Aman Deep Shri Barjinder Singh Ghai (*Alternate*)
CSIR-Central Building Research Institute, Roorkee	Dr Ashok Kumar Shri S. K. Negi (*Alternate*)
Delhi Development Authority, New Delhi	Chief Engineer (Design) Shri Vijay Shanker (*Alternate*)
Facade India Testing Inc, Thane	Shri V. S. Ravi Shri Pravin Gaikwad (*Alternate*)
Glazing Society of India, Chennai	Shri R. Subramanian Shri G. N. Gohul Deepak (*Alternate*)
GSC Glass Ltd, Greater Noida	Shri C. J. Singh
Indian Association of Structural Engineers, New Delhi	Shri S. C. Mehrotra Shri Mahesh Tandon (*Alternate*)
Indian Institute of Technology Madras, Chennai	Dr S. Arul Jayachandran
Indian Institute of Technology Roorkee, Roorkee	Dr Avlokita Agrawal Dr E. Rajasekar (*Alternate*)
Larsen & Toubro Limited, Chennai	Shri Sthaladipti Saha
Meinhardt Facade Technology India Pvt Ltd, Chennai	Shri Mahesh Arumugam
Municipal Corporation of Greater Mumbai (Mumbai Fire Brigade), Mumbai	Chief Fire Officer Deputy Chief Fire Officer (*Alternate*)
NBCC (India) Limited, New Delhi	Shri Hem Raj Shri H. S. Yadav (*Alternate*)
Saint-Gobain Glass India, Chennai	Shri Manish Srivastava Shri N. Murali (*Alternate*)
Schueco India Private Limited, Bengaluru	Shri Antony John Shri Piyush Kumar Srivastava (*Alternate*)
The Indian Institute of Architects, Mumbai	Shri Vijay Garg Shri Ashutosh Agarwal (*Alternate*)

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Organization	*Representative(s)*
The Institution of Engineers (India), Kolkata	Shri P. K. Adlakha
Winwall Technology India Pvt Ltd, Chennai	Shri P. Jothi Ramalingam
In personal capacity (*K-33A, First Floor, Green Park, New Delhi 110016*)	Shri S. K. Dheri

Panel for Information and Communication Enabled Installations, CED 46:P21

Organization	*Representative(s)*
In personal capacity (*C-501, Shivam Apartments, Plot No. 14, Sector-12, Dwarka, New Delhi 110078*)	Shri A. K. Mittal (***Convener***)
Airports Authority of India, New Delhi	Shri D. K. Kamra Shri Vivek Chourey (*Alternate*)
Association of Unified Telecom Service Providers of India, New Delhi	Representative
Building Industry Consulting Service International - India District, Mumbai	Shri Ninad Mohan Desai
Cellular Operators Association of India, New Delhi	Shri Vikram Tiwathia Shrimati Vertika Misra (*Alternate*)
Central Industrial Security Force, New Delhi	Shri Naresh Kumar
Central Public Works Department, New Delhi	Shri Chaitanya Kumar Varma Shri D. K. Tulani (*Alternate*)
CMAI Association of India, New Delhi	Prof N. K. Goyal
Department of Telecommunication, Ministry of Communications, New Delhi	Shri V. K. Hirna Shri Arvind Chawla (*Alternate* 1) Shri Saurabh Chaturvedi (*Alternate* 2)
Gujarat International Finance Tec-City Company Limited, Gandhinagar	Shri Ramakant Jha Shri Nilesh Purey (*Alternate*)
Indian Buildings Congress, New Delhi	Shri Bhishma Kumar Chugh Shri P. S. Chadha (*Alternate*)
Internet Service Providers Association of India, New Delhi	Shri Brajesh Chandra Jain
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Col R. Baijal
Ministry of Electronics & Information Technology, New Delhi	Dr Anil Kumar Kaushik Shri Prakash Kumar (*Alternate*)
Ministry of Railways, New Delhi	Shrimati Vinita Narera
Proion Consultants, New Delhi	Shrimati Shruti Goel
Roads and Buildings Department, Govt of Telangana, Hyderabad	Shri G. Ramakrishna Kumar Deputy Chief Engineer (*Alternate*)
Sterlite Technologies, Pune	Shri S. N. Gupta Shri Priyadarshi Sidhartha (*Alternate*)
Telecom System Design & Manufacturers Association, New Delhi	Shri Bhupesh Yadav Shri Rahul Dubey (*Alternate*)
The Indian Institute of Architects, Mumbai	Representative
The Institution of Engineers (India), Kolkata	Representative
Town and Country Planning Organization, Ministry of Urban Development, New Delhi	Shri K. K. Joadder Shri R. Srinivas (*Alternate*)
UBICO Networks Pvt Ltd, Gurugram	Shri Nitin Kohli
In personal capacity (*Pine 002, SJR Park Vista Apartments, Haralur Road, Bengaluru 560012*)	Shri J. N. Bhavani Prasad

Panel for Asset and Facility Management, CED 46:P22

Organization	*Representative(s)*
In personal capacity (*411, Sector A, Pocket C, Vasant Kunj, New Delhi 110070*)	Shri Krishna Kant (***Convener***)
Airports Authority of India, New Delhi	Shri D. K. Kamra Shri Vivek Chourey (*Alternate*)

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Organization	*Representative(s)*
C. B. Richard Ellis, Gurugram	Shri Aneesh Kadyan
Central Industrial Security Force, New Delhi	Dr K. C. Wadhwa Shrimati Harpreet Kaur (*Alternate*)
Central Public Works Department, New Delhi	Shri Prabhakar Singh Shri Pramod Kumar Singh (*Alternate*)
Climaveneta Climate Technologies (P) Ltd, Bengaluru	Shri Anil Dev Shri Nitin Joshi (*Alternate*)
Cushman and Wakefield India Pvt Ltd, Gurugram	Shri Dinesh Wadehra Shri Sajit Sankar (*Alternate*)
DLF Home Developers Limited, Gurugram	Shri Gautam Dey
Honeywell International India Pvt Ltd, Gurugram	Shri Varun Jain
Indian Buildings Congress, New Delhi	Shri Deepak Narayan
Jones Lang Lasalle Meghraj Building Operations Pvt Ltd, Gurugram	Shri Sumit Rakshit
Medanta Medicity, Gurugram	Shri Sanjay Batra
Military Engineer Services, Engineer-in-Chief's Branch, Army HQ, New Delhi	Shri D. K. Tyagi Lt Col Gaurav Kaushik (*Alternate*)
National Council for Cement and Building Materials, Ballabgarh	Shri V. V. Arora Shri Brijesh Singh (*Alternate*)
Realty Automation and Security Systems Pvt Ltd, Pune	Shri Nitin Joshi
Security and Intelligence Services (India) Ltd, New Delhi	Shri Ritu Raj Sinha Brig (Retd) U. K. Dhar (*Alternate*)
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Important Explanatory Note for Users of the Code

In any Part/Section of this Code, where reference is made to 'good practice' in relation to design, constructional procedures or other related information, and where reference is made to 'accepted standard' in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [3(2)] refers to the Indian Standard given at serial number (2) of the list of standards given at the end of Part 3, that is, IS 4878:1986 'Byelaws for construction of cinema buildings (*first revision*)'.

b) Good practice [4(6)] refers to the Indian Standard given at serial number (6) of the list of standards given at the end of Part 4, that is, IS 1646:2015 'Code of practice for fire safety of buildings (General):Electrical installations (*third revision*)'.

c) Good practice [6-1(5)] refers to the Indian Standard given at serial number (5) of the list of standards given at the end of Section 1 of Part 6, that is, IS 15498:2004 'Guidelines for improving the cyclonic resistance of low rise houses and other buildings/structures'.

d) Accepted standard [6-2(6)] refers to the Indian Standard given at serial number (6) of the list of standards given at the end of Section 2 of Part 6, that is, IS 1498:1970 'Classification and identification of soils for general engineering purposes (*first revision*)'.

e) Accepted standards [6-5A(18)] refers to the Indian Standards given at serial number (18) of the list of standards given at the end of Subsection 5A of Part 6, that is, IS 516:1959 'Method of test for strength of concrete' and IS 5816:1999 'Method of test for splitting tensile strength of concrete (*first revision*)'.

f) Accepted standard [6-5B(20)] refers to the Indian Standard given at serial number (20) of the list of standards given at the end of Subsection 5B of Part 6, that is, IS 9103:1999 'Specification for admixtures for concrete (*first revision*)'.

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INFORMATION FOR THE USERS ABOUT AVAILABILITY OF THE CODE IN GROUPS

For the convenience of the users, the National Building Code of India 2016 is available as a comprehensive volume as well as in the following five groups, each incorporating the related Parts/Sections dealing with particular area of building activity:

Group 1	**For Development/ Building Planning and Related Aspects**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 1	Definitions
		Part 2	Administration
		Part 3	Development Control Rules and General Building Requirements
		Part 4	Fire and Life Safety
		Part 5	Building Materials
		Part 10	Landscape Development, Signs And Outdoor Display Structures
			Section 1 Landscape Planning, Design and Development
			Section 2 Signs and Outdoor Display Structures
		Part 11	Approach to Sustainability
Group 2	**For Structural Design and Related Aspects**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 6	Structural Design
			Section 1 Loads, Forces and Effects
			Section 2 Soils and Foundations
			Section 3 Timber and Bamboo
			3A Timber
			3B Bamboo
			Section 4 Masonry
			Section 5 Concrete
			5A Plain and Reinforced Concrete
			5B Prestressed Concrete
			Section 6 Steel
			Section 7 Prefabrication, Systems Building and Mixed/ Composite Construction
			7A Prefabricated Concrete
			7B Systems Building and Mixed/ Composite Construction
			Section 8 Glass and Glazing
		Part 11	Approach to Sustainability
Group 3	**For Aspects Relating to Construction, and Asset/ Facility Management**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 7	Construction Management, Practices and Safety
		Part 11	Approach to Sustainability
		Part 12	Asset and Facility Management
Group 4	**For Aspects Relating to Building Services**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 8	Building Services
			Section 1 Lighting and Natural Ventilation
			Section 2 Electrical and Allied Installations
			Section 3 Air Conditioning, Heating and Mechanical Ventilation
			Section 4 Acoustics, Sound Insulation and Noise Control
			Section 5 Installation of Lifts, Escalators and Moving Walks
			5A Lifts
			5B Escalators and Moving Walks
			Section 6 Information and Communication Enabled Installations
		Part 11	Approach to Sustainability
Group 5	**For Aspects Relating to Plumbing Services and Solid Waste Management**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 9	Plumbing Services (including Solid Waste Management)
			Section 1 Water Supply
			Section 2 Drainage and Sanitation
			Section 3 Solid Waste Management
			Section 4 Gas Supply
		Part 11	Approach to Sustainability

The information contained in different groups will serve the concerned professionals dealing with the respective areas. However, it is advisable that professionals essentially dealing with any of the above groups should also refer the other groups.

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NATIONAL BUILDING CODE OF INDIA

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 0) covers guidelines to be followed for judicious implementation of the provisions of various Parts/Sections of the National Building Code of India following an integrated approach.

In order to provide safe, healthy and sustainable habitat, careful consideration needs to be paid to the building construction activity. Building planning, designing and construction activities have developed over the centuries. Large number of ancient monuments and historical buildings all over the world bear testimony to the growth of civilization from the prehistoric era with the extensive use of manual labour and simple systems as appropriate to those ages to the present day mechanized and electronically controlled operations for designing and constructing buildings and for operating and maintaining systems and services. In those days, buildings were conceptualized and built by master builders with high levels of artisan skills. Technological and socio-economic developments in recent times have led to remarkable increase in demand for more and more sophistication in buildings resulting in ever increasing complexities. These perforce demand high levels of inputs from professionals of different disciplines such as architecture, civil engineering, structural engineering, functional and life safety services including special aspects relating to utilities, landscaping, etc, in conceptualization, spatial planning, design and construction of buildings of various material and technology streams, various services including operation, maintenance, repairs and rehabilitation aspects throughout the service life of the building.

This Code, besides prescribing various provisions, also allows freedom of action to adopt appropriate practices and provides for building planning, designing and construction for absorbing traditional practices as well as latest developments in knowledge in the various disciplines as relevant to a building including computer aided and/or other modern sensors aided activities in the various stages of conceptualization, planning, designing, constructing, maintaining and repairing the buildings. India being a large country with substantial variations from region to region, this Code has endeavoured to meet the requirements of different regions of the country, both urban and rural, by taking into consideration factors such as climatic and environmental conditions, geographical terrain, vulnerability to natural disasters, ecologically appropriate practices, use of eco-friendly materials, use of appropriate conventional and alternative technologies, reduction of pollution, protection and improvement of local environment and also socio-economic considerations, towards the creation of sustainable human settlements.

This Part of the Code dealing with ‘integrated approach’ gives an overall direction for practical applications of the provisions of different specialized aspects of spatial planning, designing and construction of buildings, creation of services, and proposes an integrated approach for utilizing appropriate knowledge and experience of qualified professionals, right from the conceptualization through construction and completion stages of a building project and indeed during the entire life cycle. The ‘integrated approach’ should not only take care of functional, aesthetic and safety aspects, but also the operational and maintenance requirements. Also, cost optimization has to be achieved through proper selection of materials, techniques, equipment installations, etc. Further, value engineering and appropriate management techniques should be applied to achieve the aim set forth for the purpose of construction of a building fully meeting the specified and implied needs of spatial functions, user requirements, safety and durability aspects, life and health safety, comfort, services, etc, in the building. Integration among various professionals/services may be facilitated by use of appropriate software, systems, tools, simulations, etc.

The aim of the ‘integrated approach’ is to get the maximum benefit from the building and its services in terms of objectives such as quality, timeliness and cost-effectiveness. In the team approach which is an essential pre-requisite for integrated approach, the aim clearly is to maximize the efficiency of the total system through appropriate optimization of each of its sub-systems, and ensuring coordination among various disciplines and agencies that are involved during planning, design, construction, operation and maintenance of buildings and the associated infrastructure. In other words, in the team, the timely inputs from each of the professional disciplines have to be so optimized that the total system’s efficiency becomes the maximum. It may be emphasized that maximizing the efficiencies of each sub-system may not necessarily assure the maximization of the efficiency of the total system. It needs hardly to be stated that specified or implied safety will always get precedence over functional efficiency

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and economy. Further, progressive approach such as that relating to the concept of intelligent buildings would be best taken care of by the 'integrated approach' as laid down in this Part.

The continued effort towards development may progressively be aimed at leading us to achieve better and smarter solutions, such as through development of smart cities encompassing sustainability apart from utilizing optimum resources and delivering through intelligent ways, the various facilities and amenities. The integrated approach enshrined in this Part is of immense help in achieving the objective of such smart buildings and cities. It goes without saying that the objective of sustainable development as professed in Part 11 'Approach to Sustainability' of the Code can be best achieved through such an integrated approach.

Proper construction management and certification covering the various dimensions brought out above may go a long way in achieving the above goal of real integrated approach.

This Part was first introduced in 2005 as an adjunct to various other Parts/Sections of the Code. Based on the experience gained in the use of this Part, this revision has been brought out. The significant modifications incorporated in this revision include the following:

a) List of professionals who may be part of multi-disciplinary teams has been updated.
b) Considering the latest provisions relating to construction project management now included in the Part 7 'Construction Management, Practices and Safety' of the Code, the provisions in this Part relevant to construction project management functions have been accordingly updated.
c) Various considerations to be taken care of by the design teams, project/construction management team, and operation and maintenance team have been further reinforced considering the present day requirements and expectations from buildings and built environment.
d) Provisions relating to operation and maintenance have been further extended to include decommissioning and deconstruction (including demolition) to give importance to planned decommissioning and deconstruction after the useful service life of the built facility is over.
e) With the introduction of the new Part 11 'Approach to Sustainability' of the Code, appropriate references to sustainability wherever relevant to the integrated approach, have been taken care of.
f) Accessibility and universal design for ensuring barrier free environment for persons with disabilities has been emphasized by further reinforcing the provisions to this effect appropriately.
g) Annex A giving brief details of the coverage of various provisions under different Parts/Sections of the Code, has been updated, considering modification in the scopes of existing Parts/Sections and inclusion of new Parts/Sections.

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NATIONAL BUILDING CODE OF INDIA

PART 0 INTEGRATED APPROACH — PREREQUISITE FOR APPLYING PROVISIONS OF THE CODE

1 SCOPE

This Code (Part 0) covers guidelines to be followed for judicious implementation of the provisions of various Parts/Sections of the National Building Code of India following an integrated approach.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

2.1 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.2 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *Shamianahs*/*Pandals*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions shall not be considered as building.

2.3 Owner — A person, a group of persons or a body having a legal interest in land and/or building thereon. This includes freeholders, leaseholders or those holding a sublease, who will have legal right to occupation and have liabilities in respect of safety or building condition.

In the case of lease or sublease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/lessee till the allotment/lease subsists.

NOTE — For the purpose of the Code, the word 'owner' will also cover the generally understood terms like 'client', 'user', etc.

3 GENERAL

3.1 Buildings shall be classified as Residential, Educational, Institutional, Assembly, Business, Mercantile, Industrial, Storage and Hazardous in groups and sub-divisions as classified in Part 4 'Fire and Life Safety' of the Code.

For various related provisions of buildings with respect to administration; development control rules and general building requirements; building materials; fire and life safety; structural design; construction management, practices and safety; building and plumbing services; landscape development, signs and outdoor display structures; sustainability; asset and facility management, and other Parts/Sections of the Code may be referred to. For provisions on sustainability of buildings and built environment, reference to the concerned Part may be made, which while also referring to the other Parts/Sections as may be required, gives a comprehensive approach to sustainability.

3.2 The brief coverage in various Parts/Sections of the Code which cover detailed provisions on different aspects of development of land/building construction activity, are given in Annex A, with a view to providing an overview for the users of the Code.

4 TEAM APPROACH

4.1 A land development/building project and the built facility during its service life comprises the following major stages:

a) Location/siting,
b) Conceptualization and planning,
c) Designing and detailing,
d) Construction/execution,
e) Operation and maintenance, and
f) Decommissioning and deconstruction.

Each stage necessarily requires professionals of many disciplines who should work together as a well coordinated team to achieve the desired product delivery with quality and safety and other objectives, in an effective manner.

Appropriate multi-disciplinary teams (*see* **4.1.1** to **4.1.3**) need to be constituted to successfully meet the requirements of different stages. Each team may comprise need based professionals out of the following depending upon the nature, magnitude and complexity of the project:

1) Architect;
2) Civil engineer;
3) Structural engineer;
4) Geotechnical engineer;
5) Electrical engineer;
6) Plumbing engineer;

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7) Fire protection engineer;
8) Heating, ventilation and air conditioning engineer;
9) Lift, escalator and moving walk specialist;
10) Acoustics specialist;
11) Information/communication technology engineer;
12) Health, safety and environment specialist;
13) Environment/sustainability specialist;
14) Town planner;
15) Urban designer;
16) Landscape architect;
17) Security system specialist;
18) Interior designer;
19) Quantity surveyor;
20) Project/construction manager;
21) Accessibility and universal design specialist;
22) Asset/facility manager; and
23) Other subject specialist(s).

It is important that leaders and members of design team, project management/construction management team, and operation and maintenance team, depending on the size and complexity of the project, are carefully selected considering their qualification, experience and expertise in these fields.

4.1.1 *Design Team*

In building projects, various aspects like form; space planning; aesthetics; fire and life safety; structural adequacy; plumbing services; lighting and natural ventilation; electrical and allied installations; air conditioning, heating and mechanical ventilation; acoustics, sound insulation and noise control; installation of lifts and escalators; building automation; data and voice communication; other utility services installations; landscape planning, design and development; urban planning; etc need to be kept in view right at the concept stage. The project requiring such multi-disciplinary inputs need a coordinated approach among the professionals for proper integration of various design inputs. For this, and to take care of the complexities of multi-disciplinary requirements, a design team of professionals from the required disciplines shall be constituted at the appropriate stage. Here, it is desirable that the multi-disciplinary integration is initiated right from the concept stage. The team shall finalize the plan. The composition of the team shall depend on the nature, magnitude and complexities of the project. Design is an evolutionary and participatory process, where participation of the owner constitutes a very important input at all stages, and the same shall be ensured by the design team.

To ensure proper implementation of the design, the design team, may be associated during the construction/ execution stage.

4.1.2 *Project Management and Construction Management Teams*

The objective of project management or construction management is primarily to achieve accomplishment of a project in accordance with the designs and specifications in a stipulated time and cost framework, etc, with a degree of assurance prior to commencement and satisfaction on completion and commissioning.

For large projects, separate teams of experienced professionals from the required disciplines may be constituted for project management (including planning and scheduling) and for construction management depending upon the complexities of the project. However, for smaller projects these teams may be combined. The teams shall be responsible for day-to-day execution, supervision, quality control, etc, and shall ensure inter-disciplinary coordination during the construction stage. The team shall be responsible to achieve satisfactory completion of the project in respect of all relevant project management functions like cost, time, quality, safety, etc. Some members of the design team may also be included in the project management team and/or associated actively during the project execution stage.

4.1.3 *Operation and Maintenance Team*

Operation, maintenance and repairs also require a multi-disciplinary approach to ensure that all the requirements of the users are satisfactorily met. During maintenance and repairs, the jobs requiring inter-disciplinary coordination have to be executed in such a manner as not only to cause least inconvenience to the user but also to ensure that there is no mismatch or damage to the structure, finishing, fittings and fixtures, and to preserve the integrity of other services. For carrying out routine maintenance/repair jobs, utilization of the services of trained technicians preferably having multi-disciplinary skills should be encouraged.

Special repairs, rehabilitation and retrofitting are specialized jobs which demand knowledge of the existing structure/installations. Association of concerned specialists may be helpful for these works.

The operation and maintenance team may also be known as asset and facility management or estate management team.

5 PLANNING, DESIGNING AND DEVELOPMENT

5.1 The main functions of design team (*see* **4.1.1**) constituted for the planning, designing and development, are as under:

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a) Formalization of design brief in consultation with the owner.
b) Site survey and soil investigation.
c) Preparation of alternative concept designs, highlighting both their positive and negative aspects.
d) Selection of a concept in consultation with and with the consent of the owner.
e) Sizing the system.
f) Development of design, involving:
    1) Integration of architecture, structure and services,
    2) Synthesis of requirements of each discipline, and
    3) Interaction with each other within the design team and with the owner.
g) Preparation of preliminary designs and drawings and obtaining the owners' approval.
h) Preparation of preliminary cost estimates for approval of owner.
j) Preparation of work-breakdown structure and programme for pre-construction activities.
k) Assisting client to obtain approvals of the Authority/authorities.
m) Preparation of detailed specifications and construction working drawings with integration of engineering inputs of all concerned disciplines.
n) Preparation of detailed design of each discipline for various services.
p) Peer review/proof checking of the drawings/ designs in case of major/important projects, depending upon their complexity and sensitivity.
q) Preparation of detailed cost estimate.
r) Obtaining final approval of the client.
s) Preparation of bill of quantities, specifications and tender documents.

5.2 The following considerations, as may be applicable to the project, may be considered during planning, notwithstanding the other relevant aspects specifically prescribed in concerned Parts/Sections of this Code; these considerations in general are with the objective of addressing important issues like environmental protection, energy conservation, cultural issues, creating barrier free built-environment, safety aspects, etc, all of these leading towards sustainable development, and have to be applied with due regard to the specific requirements of size and type of project:

1) Geoclimatic, geological and topographical features.
2) Geotechnical considerations with respect to soil/rock, water table, etc.
3) Varied sociological pattern of living in the country.
4) Effective land use to cater to the needs of the society in a most convenient manner.
5) Modular planning and standardization to take care of future planning giving due consideration to the specified planning controls.
6) Emphasis on daylight utilization, natural ventilation, shielding, and window area and disposition; daylighting to be supplemented with an integrated design of artificial lighting.
7) Optimum utilization of renewable energy sources duly integrated in the overall energy system design; with consideration of active and passive aspects in building design including thermal performance of building envelope.
8) Rain water harvesting, integrated water management including recycle and reuse, etc.
9) Use of appropriate building materials considering aspects like energy consumption in production, transportation and utilization, recyclability, etc, and for deconstruction, for promoting sustainable development.
10) Requisite mandatory provisions for persons with disabilities.
11) Acoustical controls for buildings and the surroundings.
12) Promotion of artwork in buildings, especially, major/important buildings.
13) Due cognizance of recommendations of the Archaeological Survey of India with regard to national monuments and construction in archaeologically important sites.
14) Due cognizance of relevant provisions applicable to coastal regulation zone.
15) Conservation of heritage structures and areas, with due consideration to the concerns of the archaeological departments.
16) Environmental and social impact analysis.
17) Design of services with emphasis on aspects of energy efficiency, environment friendliness and maintainability.
18) Integrated waste management.
19) Voice and data communication, automation of building services, and intelligent building; use of security and surveillance system in important and sensitive buildings, such as access control for the people as well as for vehicle.
20) Interlinking of fire alarm system, fire protection system, security system, ventilation, electrical systems, etc.

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21) Analysis of emergency power, standby power requirement and captive power systems.
22) Cost optimization through techniques like value engineering.
23) Adoption of innovative technologies giving due consideration to constructability and quality aspects.
24) Instrumentation of building, monitoring and use of information so generated to effect improvements in planning and design of future building projects, and use of such instrumentation to monitor any adverse effect on the building as well as neighbouring buildings.

6 CONSTRUCTION/EXECUTION (ACTUALIZATION)

6.1 The main functions of the teams (*see* **4.1.2**) constituted for Project Management/Construction Management may be to,

a) specify criteria for selection of constructors;
b) specify quality control, quality audit system and safety system;
c) short-list constructors;
d) have pre-bid meetings with the intending constructors;
e) receive and evaluate tenders;
f) select constructors;
g) execution and supervision;
h) monitor for quality, time and cost control and for other project management functions;
j) prepare/certify the completion (as-built) drawings;
k) assist in getting statutory approvals at various stages; and
m) ensure availability of operation manuals for field use.

6.2 Apart from the specific provisions laid down in the concerned Parts/Sections of the Code, the following considerations, as may be applicable to the project concerned, shall be given due attention:

a) Adopting scientific principles of construction project management, including quality, cost, time, and safety management.
b) Engagement of executing and supervising agencies, which meet the specified norms of skills, specialization, experience, resourcefulness, etc, for the work.
c) Ensuring inter-disciplinary coordination during construction.
d) Contract management and techno-legal aspects.
e) Completion, commissioning and trial run of installations/equipment and their operation and maintenance through the suppliers/other teams, where necessary.
f) Make available shop drawings as well as as-built drawings for the building and services.
g) Arrange all maintenance and operation manual from the concerned suppliers/manufacturers.

6.3 The team of professionals (*see* **4.1.2**) shall work and monitor the project activities for successful construction/execution of the project with regard to various construction project management functions, particularly, time, cost, quality and safety.

7 OPERATION, MAINTENANCE, DECOMMISSIONING AND DECONSTRUCTION

7.1 The team of professionals (*see* **4.1.3**) shall set up a system of periodic maintenance and upkeep of constructed buildings.

7.2 The operation and maintenance team shall be responsible for preparation/application of operation and maintenance manual, and draw maintenance schedule/ frequencies and guidelines for maintenance personnel. Apart from the specific provisions laid down in concerned Parts/Sections of the Code, the following, as may be applicable to the project concerned, shall additionally be taken into account:

a) Periodic validation of buildings by competent professionals through inspection of the buildings in respect of structural safety and safety of electrical and other installations and ensuring that all fire safety equipment/systems are in proper working condition.
b) Periodic accessibility audits to ensure that the buildings remain universally accessible and barrier free for persons with disabilities.
c) Preparation of predictive/preventive maintenance schedules for all installations in the building and strictly following the same; the record of the preventive maintenance to be properly kept.
d) Ensuring inter-disciplinary coordination during operation and maintenance, and repairs; deployment of trained personnel with multi-disciplinary skills to be encouraged.
e) Condition survey of structures and installations, identification of distress of various elements and initiating plans for rehabilitation/ retrofitting well in time. Post-disaster investigations by competent engineer/specialist.

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7.3 The proposals for rehabilitation/retrofitting should be prepared after detailed investigations through visual inspection, maintenance records and testing as required and got executed through specialized agencies under the guidance and supervision of competent professionals. For further details and good practices regarding the same, reference shall be made to Part 7 'Construction Management, Practices and Safety' of the Code.

7.4 After the useful service life of a building is over, or for other reasons such as redevelopment and proposed change in use of the land and built facility, it may be required to deconstruct a building. Such a deconstruction is preceded by an organized decommissioning. The decommissioning and deconstruction needs to be well planned and coordinated among concerned building professionals so as to ensure safety during such operations, as also retrieval of appropriate products, components and systems, for their possible reuse or recycling, or disposal as may be appropriate. This may in turn require a comprehensive decommissioning and deconstruction (including demolition) plan, which may be prepared during the initial stages of the project and kept available for use at the end of life cycle of the same.

ANNEX A

(*Clause* 3.2)

BRIEF DETAILS OF THE COVERAGE OF VARIOUS PROVISIONS UNDER DIFFERENT PARTS/SECTIONS OF THE CODE

A-1 PART 1 DEFINITIONS

It lists the terms appearing in all the Parts/Sections of the National Building Code of India. However, some common definitions are reproduced in this Part also.

A-2 PART 2 ADMINISTRATION

It covers the administrative aspects of the Code, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner and all professionals involved in the planning, design and construction of the building.

A-3 PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

It covers the development control rules and general building requirements for proper planning and design at the layout and building level to ensure health safety, public safety and desired quality of life. It also covers requirements for accessibility in buildings and built environment for elders and persons with disabilities.

A-4 PART 4 FIRE AND LIFE SAFETY

It covers the requirements for fire prevention, life safety in relation to fire, and fire protection of buildings. It also specifies occupancy-wise classification, constructional aspects, egress requirements and protection features that are necessary to minimise danger to life and property from fire.

A-5 PART 5 BUILDING MATERIALS

It covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

A-6 PART 6 STRUCTURAL DESIGN

This Part through its eight Sections provides for structural adequacy of buildings to deal with both internal and external environment, and provides guidance to engineers/structural engineers for varied usage of material/technology types for building design.

A-6.1 Section 1 Loads, Forces and Effects

It covers basic design loads to be assumed in the design of buildings. The imposed loads, wind loads, seismic forces, snow loads and other loads, which are specified therein, are minimum working loads which should be taken into consideration for purposes of design.

A-6.2 Section 2 Soils and Foundations

It covers geotechnical design (principles) of building foundations, such as shallow foundations, like, continuous strip footings, combined footings, raft foundations, deep foundations like pile foundations and other foundation systems to ensure safety and serviceability without exceeding the permissible stresses of the materials of foundations and the bearing capacity of the supporting soil/rock. It also covers provisions relating to preliminary work required for

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construction of foundations and protection of excavation.

A-6.3 Section 3 Timber and Bamboo

A-6.3.1 *Section 3A Timber*

It covers the general principles involved in the design of structural timber in buildings, including elements of structures connected together by fasteners/fastening techniques.

A-6.3.2 *Section 3B Bamboo*

It covers the general principles involved in the design of structural bamboo in buildings with regard to mechanical resistance and durability of structures. It also covers design of both bamboo (round bamboo, split bamboo, glued laminated bamboo) and bamboo-based panels joined together with adhesives or mechanical fasteners. It also covers minimum strength data, dimensional stability, grading requirements and traditional bamboo joints for quality assurance. Constructional aspects using bamboo, such as, work on site, fabrication of components off-site and their erection on site are also covered to the extent necessary to indicate and ensure the quality of material and standard of workmanship to comply with the assumptions of the design rules and the limitations.

A-6.4 Section 4 Masonry

It covers the structural design aspects of unreinforced load bearing and non-load bearing walls, constructed with masonry units permitted therein. It also deals with the selection of materials, special features of design and construction for masonry construction using rectangular masonry units and covers guidelines regarding earthquake resistant buildings constructed using masonry of low strength. It also covers provisions for design of reinforced brick and reinforced brick concrete floors and roofs. It also gives the recommendations for structural design aspects of reinforced load bearing and non-load bearing walls, constructed with different types of bricks and blocks.

A-6.5 Section 5 Concrete

A-6.5.1 *Section 5A Plain and Reinforced Concrete*

It covers the general structural use of plain and reinforced concrete.

A-6.5.2 *Section 5B Prestressed Concrete*

It covers the general structural use of prestressed concrete. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

A-6.6 Section 6 Steel

It covers the structural design aspects of steel structures in buildings. It applies to general construction using hot rolled steel sections and steel tubes, joined using riveting, bolting and welding.

A-6.7 Section 7 Prefabrication, Systems Building and Mixed/Composite Construction

A-6.7.1 *Section 7A Prefabricated Concrete*

It covers recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete

A-6.7.2 *Section 7B Systems Building and Mixed/Composite Construction*

It covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for systems building and mixed/composite construction.

A-6.8 Section 8 Glass and Glazing

It covers the following:

a) Selection and application of glass in buildings, different types of glass, their requirements and associated glazing materials.
b) Guiding provision for glazing in buildings with respect to their effect on energy, visual (light) and solar environments in the building.
c) Selection of glass in buildings, subject to wind loading, seismic loading and special considerations for fire rated glass and related materials.
d) Provisions for the selection of and manifestation on glass used in buildings, subject to safety with respect to human impact on the occupants.
e) Provisions relating to glazing systems such as selection, design, fabrication, installation, testing and maintenance.

A-7 PART 7 CONSTRUCTION MANAGEMENT, PRACTICES AND SAFETY

It covers construction project management; construction planning, site management and building construction practices; storage, stacking and handling of materials; and safety of personnel during construction operations for all elements of a building and demolition of buildings; and habitat and welfare

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requirements for workers. It also covers guidelines relating to repairs, retrofitting and strengthening of buildings.

A-8 PART 8 BUILDING SERVICES

This Part through its six elaborate Sections on utilities provides detailed guidance to concerned professionals/ utility engineers for meeting necessary functional requirements in buildings.

A-8.1 Section 1 Lighting and Natural Ventilation

It covers requirements and methods for lighting and natural ventilation of buildings.

A-8.2 Section 2 Electrical and Allied Installations

It covers the essential requirements for electrical installations in buildings to ensure efficient use of electricity including safety from fire and shock. It also includes general requirements relating to lightning protection of buildings and brief provisions on certain allied installations.

A-8.3 Section 3 Air Conditioning, Heating and Mechanical Ventilation

It covers the planning, design considerations, installation, testing, commissioning and handing over and also operation and maintenance of air conditioning, heating and mechanical ventilation systems for buildings. It also covers refrigeration for cold storages.

A-8.4 Section 4 Acoustics, Sound Insulation and Noise Control

It covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

A-8.5 Section 5 Installation of Lifts, Escalators and Moving Walks

A-8.5.1 *Section 5A Lifts*

It covers the requirements for planning, design, installation, operation, maintenance and inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) so as to ensure safe movement of people with satisfactory performance.

It also gives information that should be exchanged among the architect/engineer, the consulting engineer and the lift manufacturer from the stage of planning to installation including maintenance.

A-8.5.2 *Section 5B Escalators and Moving Walks*

It covers the essential requirements for planning, installation, operation, maintenance and inspection of escalators and moving walks so as to ensure safe movement of people with satisfactory performance, while using these.

It also gives information that should be exchanged among the architect/engineer, the consulting engineer and the escalator/moving walk manufacturer from the stage of planning to installation including maintenance.

A-8.6 Section 6 Information and Communication Enabled Installations

It covers the essential requirements for information and communication enabled installations, technology systems and related cabling installations in a building. It also covers the basic design and integration requirements for telecommunication spaces within the building/buildings along with their cabling infrastructure, their pathway components and passive connectivity hardware.

It also includes general requirements relating to installation of different communication equipment, cable terminations, power connections and general guidelines required for planning and providing information and communication technology (ICT) services in the building at the planning and execution stages. The provisions given herein are basic requirements applicable to all residential and other buildings.

A-9 PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

This Part through its four Sections gives detailed guidance to concerned professionals/plumbing engineers with regard to plumbing and other related requirements in buildings including solid waste management.

A-9.1 Section 1 Water Supply

It covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. It also deals with general requirements of plumbing connected to public water supply and design of water supply systems along with general guidelines about expansion in piping systems, and swimming pools.

A-9.2 Section 2 Drainage and Sanitation

It covers the design, layout, construction and maintenance of drains for foul water, surface water, subsoil water and sewage; together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cesspool, soakaway or to other approved point of disposal/ treatment work.

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A-9.3 Section 3 Solid Waste Management

It covers the provisions relating to solid waste management systems, assessment of per capita solid waste quantities and treatment of solid waste quantities and treatment of solid waste within the building, building complexes and their built environment.

A-9.4 Section 4 Gas Supply

It covers the requirements regarding the safety of persons and property for all piping uses and for all types of gases for purposes like fuel, lighting and medical in buildings.

A-10 PART 10 LANDSCAPE DEVELOPMENT, SIGNS AND OUTDOOR DISPLAY STRUCTURES

A-10.1 Section 1 Landscape Planning, Design and Development

It covers requirements of landscape planning, design and development with the view to promoting quality of outdoor built and natural environments and the protection of land and its resources.

A-10.2 Section 2 Signs and Outdoor Display Structures

It covers the requirements with regard to public safety, structural safety and fire safety of all signs and outdoor display structures.

A-11 PART 11 APPROACH TO SUSTAINABILITY

It covers the parameters required to be considered for planning, design, construction, operation and maintenance of buildings and those relating to land development, from sustainability point of view. It is a supplement to all other Parts/Sections of the Code and shall be read along with them.

A-12 PART 12 ASSET AND FACILITY MANAGEMENT

It covers provisions relating to management of building assets and associated facilities and includes various aspects relating to maintenance of all types of facilities and fixed assets, such as buildings and building services. It does not cover assets other than physical assets.

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NATIONAL BUILDING CODE OF INDIA

PART 1 DEFINITIONS

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

Each Part or Section of the National Building Code of India gives the definitions of the special terms used in it. These definitions may be found in the clause 'Terminology' normally placed immediately after the 'Scope' in each Part/Section. However, users may find this Part very convenient for reference as it gives the alphabetically arranged list of terms defined in all the Parts/Sections, along with the location of the definition. It may also be noted that in some cases like in Part 3 'Development Control Rules and General Building Requirements' and Part 7 'Construction Management, Practices and Safety' of the Code, these have been placed in other appropriate clauses rather than after 'Scope' considering the suitability and convenience afforded therefrom.

In this revision, this Part has been updated to cover the various terms actually covered in different Parts/Sections in this revision of the Code.

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NATIONAL BUILDING CODE OF INDIA

PART 1 DEFINITIONS

1 SCOPE

This Part lists the terms which are appearing in all the Parts/Sections of the National Building Code of India, along with their definitions. The terms have been arranged in their alphabetical order. The Part(s)/ Section(s) in which these terms are appearing, have been indicated against the terms.

However, some common definitions are reproduced in this Part also, the definitions being placed immediately below the term concerned.

A

*A*95 — Part 8/Section 5A

Abandoned Sign — Part 10/Section 2

Ability — Part 3

Acceleration — Part 8/Section 5A, Part 8/Section 5B

**Acces*s — Part 3, Part 12

Access Aisle — Part 3

Access Panel — Part 9/Section 1

Access Point — Part 8/Section 6

Accessible Site, Building, Facility or Portions — Part 3

Accessible Route — Part 3

Accessible Toilet — Part 3

Accessory — Part 8/Section 2

Accessory Use — Part 2, Part 3

Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

Accidental Loads — Part 6/Section 6

*Accompanying Lo*ad — Part 6/Section 6

Action — Part 6/Section 6

Action Effect or Load Effect — Part 6/Section 6

Actual Length — Part 6/Section 6

Adaptive Thermal Comfort — Part 11

Advertising Sign — Part 10/Section 2

**Ageing* — Part 3, Part 12

Air Admittance Valve — Part 9/Section 2

*Air Brea*k — Part 9/Section 2

Air Change per Hour — Part 8/Section 1

Air Circuit Breaker (*ACB*) — Part 8/Section 2

Air Conditioning — Part 8/Section 3

Air Gap, Drainage — Part 9/Section 2

Air Gap, Water Distribution — Part 9/Section 1

Air System Balancing — Part 8/Section 3

Air Valve — Part 9/Section 1

Allowable Load — Part 6/Section 2

Alteration — Part 2, Part 3

A change from one type of occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

Alternating Current Variable Voltage (ACVV) Control — Part 8/Section 5A

Alternating Current Variable Voltage Variable Frequency (ACVVVF) Control — Part 8/Section 5A

Altitude — Part 8/Section 1

Ambient Noise — Part 8/Section 4

*Anaerobic Diges*tion — Part 9/Section 3

Anchor Pile — Part 6/Section 2

Anchorage Device — Part 6/Section 5B

Angle of Attack — Part 6/Section 1

Angle of Inclination — Part 8/Section 5B

Animated Sign — Part 10/Section 2

Annealed Fire Resistant Glass — Part 6/Section 8

Annealed Glass (see Glass) — Part 6/Section 8

Antenna — Part 8/Section 6

Anti-siphon — Part 9/Section 1

Apparatus — Part 8/Section 2

Appliance — Part 8/Section 2

Appliance Valve — Part 9/Section 4

Approved — Part 2, Part 3, Part 10/Section 2

Approved by the Authority having jurisdiction.

Approved Agency — Part 9/Section 4

Appurtenance — Part 9/Section 1

Area of Rescue Assistance — Part 3

Area of Special Control — Part 10/Section 2

As-built Information — Part 12

As-cut Finished Sizes — Part 6/Section 8

Aspect Ratio — Part 6/Section 8

Assembly Buildings — Part 6/Section 1

* Definitions are different.

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Asset — Part 12
Asset Life — Part 12
Asset Register — Part 12
Asset Type — Part 12
Asset/Facility Management — Part 12
Assisted Evacuation — Part 3, Part 4
Assistive Product/Device — Part 3
Atmospheric Pressure — Part 8/Section 3
Atrium — Part 4
Attenuation — Part 8/Section 6
Audible Frequency Range — Part 8/Section 4
Authorities Concerned — Part 4

An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving or accepting equipment, materials, an installation, or a procedure.

Authority Having Jurisdiction — Part 0, Part 2, Part 3, Part 6/Section 7A, Part 6/Section 7B, Part 7, Part 9/Section 1, Part 9/Section 4, Part 10/Section 2, Part 11

The authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

Authorization — Part 9/Section 3
Automatic Door — Part 3
Automatic Fire Detection and Alarm System — Part 4
Automatic Operation — Part 8/Section 5A
Automatic Rescue Device — Part 8/Section 5A
Automatic Sprinkler System — Part 4
Automatic Water Spray Systems — Part 4
Auxiliary Brake — Part 8/Section 5B
Available Head — Part 9/Section 1
Avenue — Part 10/Section 1
A-Weighted Sound Pressure — Part 8/Section 4
A-Weighted Sound Pressure Level — Part 8/Section 4
Axial Flow Fan — Part 8/Section 1
Axis of Measurement — Part 8/Section 5A
Azimuth — Part 8/Section 1

B

Backbone — Part 8/Section 6
Backbone Cabling Media Distribution and Building Pathway — Part 8/Section 6
Back Fill — Part 6/Section 2
Back Pressure Backflow — Part 9/Section 1
Back Siphonage — Part 9/Section 1
Back to Back Cluster — Part 3
Back Up — Part 9/Section 2
Back-up Protection — Part 8/Section 2
Back Water Valve — Part 9/Section 2
Backflow — Part 9/Section 1
Backflow Prevention Device — Part 9/Section 1
Background noise — Part 8/Section 4
Background Noise Correction — Part 8/Section 5B
Balcony — Part 3
Balustrade — Part 6/Section 8, Part 8/Section 5B
Balustrade Decking — Part 8/Section 5B
Bamboo — Part 6/Section 3B
Bamboo Clump — Part 6/Section 3B
Bamboo Culm — Part 6/Section 3B
Bamboo Mat Board — Part 6/Section 3B
Bamboo Mat Corrugated Sheet — Part 6/Section 3B
*Bamboo Mat Veneer Composi*te — Part 6/Section 3B
Band — Part 6/Section 4
Banner — Part 10/Section 2
Banner Sign– Part 10/Section 2
Barrel — Part 9/Section 1
Barrier — Part 8/Section 2
Base — Part 9/Section 1
Basement or Cellar — Part 3
Basic Protection — Part 8/Section 2
Basic Module — Part 6/Section 7A, Part 6/Section 7B
Bath Room Group — Part 9/Section 1, Part 9/Section 2
Bather Load — Part 9/Section 1
Batter Pile (Raker Pile) — Part 6/Section 2
Battery of Fixtures — Part 9/Section 2
Beads or Glazing Beads — Part 6/Section 8
Beam — Part 6/Section 3B, Part 6/Section 6
Beam, Built-Up-Laminated — Part 6/Section 3A
Beam, Glued-Laminated — Part 6/Section 3A
Bearing Capacity, Safe — Part 6/Section 2
Bearing Capacity, Ultimate — Part 6/Section 2
Bearing Pressure, Allowable (Gross or Net) — Part 6/Section 2
Bearing Type Connection — Part 6/Section 6
Bed Block — Part 6/Section 4
Bed Pan Washer — Part 9/Section 2
Bedding — Part 9/Section 1
Benching — Part 9/Section 2
Benchmarking — Part 12
*Biodegradable Wa*ste — Part 12
Biodiversity — Part 11
Bite — Part 6/Section 8
Biodegradable Substance — Part 9/Section 3

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Biomethanation — Part 9/Section 3
Block (Setting Block) — Part 6/Section 8
Bond — Part 6/Section 4
Bonded Member — Part 6/Section 5B
Bonded Post-tensioning — Part 6/Section 5B
Bonding Conductor — Part 8/Section 2
Bonding Ring Conductor (*BRC*) — Part 8/Section 2
Bored Cast In-situ Pile — Part 6/Section 2
Bored Compaction Pile — Part 6/Section 2
Bored Pile — Part 6/Section 2
Bottom Car Clearance — Part 8/Section 5A
Bottom Car Run-by — Part 8/Section 5A
Bottom Counterweight Run-by — Part 8/Section 5A
Box System — Part 6/Section 4
Braced Member — Part 6/Section 6
Brake Load — Part 8/Section 5B
Branch — Part 9/Section 2
Branch Soil Pipe (BSP) — Part 9/Section 2
Branch Soil Waste Pipe (BSWP) — Part 9/Section 2
Branch Vent Pipe (BVP) — Part 9/Section 2
Branch Waste Pipe (BWP) — Part 9/Section 2
Breadth — Part 6/Section 1
Break-In — Part 8/Section 4
Break-Out — Part 8/Section 4
Breaking Strength — Part 6/Section 3B
Bresummer — Part 6/Section 3A
Briefing — Part 12
Brightness Ratio or Contrast — Part 8/Section 1
Brittle Cladding — Part 6/Section 6
Broad Band Noise — Part 8/Section 4
Buckling Load — Part 6/Section 6
*Buckling Strength or Resist*ance — Part 6/Section 6
**Buffer* — Part 8/Section 5A, Part 10/Section 1
Buffer Zone — Part 12
Building — Part 0, Part 2, Part 3, Part 4

Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *Shamianahs*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

* Definitions are different.

Building, Height of — Part 2, Part 3, Part 4

The vertical distance measured, in the case of flat roofs from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and in the case of gables facing the road, the midpoint between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

Building Drain-Combined — Part 9/Section 2
Building Drain-Sanitary — Part 9/Section 2
Building Drain-Storm — Part 9/Section 2
Building Sewer — Part 9/Section 2
Building Sub-Drain — Part 9/Section 2
Building Trap — Part 9/Section 2
Building Energy Simulation (*BES*) — Part 8/Section 3
Building Environment — Part 11
Building Fabric — Part 12
Building Information Model (*BIM*) — Part 12
Building Integrated Renewable Energy — Part 8/ Section 3
Building Line — Part 2, Part 3, Part 10/Section 2

The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time to time as decided by the Authority.

Building Maintenance — Part 12
Building Management System (BMS) — Part 8/ Section 3, Part 8/Section 6, Part 12
Building Performance — Part 11
Buildings Related Illnesses (*BRI*) — Part 8/Section 3
Built-up Section — Part 6/Section 6
Built Environment — Part 11
Bunched — Part 8/Section 2
Bundle-Column — Part 6/Section 3B
Buried Direct — Part 8/Section 2
Bus Bar — Part 8/Section 6
Busbar Trunking System — Part 8/Section 2
Business Buildings — Part 6/Section 1
Business Continuity Management (*BCM*) — Part 12
Buttress — Part 6/Section 4
Bypass Equipotential Bonding Conductor — Part 8/ Section 2

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C

Cabin — Part 3
Cable — Part 6/Section 5B, Part 8/Section 2
Cable, Circuit Integrity — Part 8/Section 2
Cable, Flame Retardant (FR) — Part 8/Section 2
Cable, Flame Retardant Low Smoke Halogen Free (FR-LSH) — Part 8/Section 2
Cable, Flexible — Part 8/Section 2
Cable, Metal-Sheathed — Part 8/Section 2
Cable, PVC Sheathed-Insulated — Part 8/Section 2
Cable, Weatherproof — Part 8/Section 2
Cable, XLPE — Part 8/Section 2
Cable Armoured — Part 8/Section 2
Cable Bracket — Part 8/Section 2
Cable Channel — Part 8/Section 2
Cable Cleat — Part 8/Section 2
Cable Coupler — Part 8/Section 2
Cable Ducting — Part 8/Section 2
Cable Ladder — Part 8/Section 2
Cable Raceways — Part 8/Section 2
Cable Tray — Part 8/Section 2
Cable Trunking — Part 8/Section 2
Cable Tunnel — Part 8/Section 2
Call Indicator — Part 8/Section 5A
Camber — Part 6/Section 6
Candela (cd) — Part 8/Section 1
Canopy — Part 3
Canopy/Tree Canopy — Part 10/Section 1
Canopy Sign — Part 10/Section 2
Car Bodywork — Part 8/Section 5A
Car Door Electric Contact — Part 8/Section 5A
Car Frame — Part 8/Section 5A
Car Platform — Part 8/Section 5A
Car Switch Operation — Part 8/Section 5A
Carbon Emissions — Part 12
Carbon Footprint — Part 12
Cartridge Fuse Link — Part 8/Section 2
Carpet Area — Part 3
Ceiling Rose — Part 8/Section 2
Cell — Part 6/Section 3B
Cellular Concrete — Part 6/Section 7A, Part 6/Section 7B
Cellulose — Part 6/Section 3B
Central Field — Part 8/Section 1
Centre Internode — Part 6/Section 3B
Centre of Rigidity — Part 6/Section 4
Centrifugal Fan — Part 8/Section 1
Cesspool — Part 9/Section 2
Chair — Part 9/Section 1
Chair Rail — Part 6/Section 8
Channel — Part 9/Section 1
Characteristic Load — Part 6/Section 3B, Part 6/Section 5B, Part 6/Section 6
Characteristic Strength — Part 6/Section 3B, Part 6/Section 5B
Characteristic Yield/Ultimate Stress — Part 6/Section 6
Check — Part 6/Section 3A
Chhajja — Part 3
Chimney — Part 3
Chowk or Courtyard — Part 3
Chowk, Inner — Part 3
Chowk, Outer — Part 3
Circuit — Part 8/Section 2
Circuit, Final Sub — Part 8/Section 2
Circuit Breaker — Part 8/Section 2
Circuit Breaker, Linked — Part 8/Section 2
Circuit Integrity Cable Support and Fixing Materials — Part 8/Section 2
Circulation Path — Part 3
Circulation Space — Part 3
Clay — Part 6/Section 2
Clay, Firm — Part 6/Section 2
Clay, Soft — Part 6/Section 2
Clay, Stiff — Part 6/Section 2
Cleaning — Part 12
Cleaning Eye — Part 9/Section 2
Cleaning Services — Part 12
Clear — Part 3
Clear Design Sky — Part 8/Section 1
Clear Glass — Part 6/Section 8
Clear Waste Water– Part 9/Section 2
Clearance– Part 8/Section 5A
Cleat — Part 8/Section 2
Cleavability — Part 6/Section 3B
Climber (Creeper/Vine) — Part 10/Section 1
Closed Clusters — Part 3
Closed Sign — Part 10/Section 2
Closely-Spaced Modules — Part 6/Section 1
Cluster — Part 3
Cluster Court Town House — Part 3
Cluster Plot — Part 3
Coaxial Cable — Part 8/Section 6
Coincidence Factor — Part 8/Section 2
Collapse — Part 6/Section 3B
Collection — Part 9/Section 3
Collection Chamber — Part 9/Section 2

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Colour Contrast — Part 3
Colour Rendering Index (CRI) — Part 8/Section 1
**Column* — Part 6/Section 3B, Part 6/Section 6
Column or Strut — Part 6/Section 5B
Column — Part 6/Section 4
Columnar — Part 10/Section 1
Coefficient of Linear Expansion — Part 6/Section 8
Coefficient of Performance, Compressor, Heat Pump — Part 8/Section 3
Coefficient of Performance, Compressor, Refrigerating — Part 8/Section 3
Coefficient of Performance (*Heat Pump*) — Part 8/Section 3
Coefficient of Performance (*Refrigerating*) — Part 8/Section 3
Comb — Part 8/Section 5B
Comb Lighting — Part 8/Section 5B
Comb Plate — Part 8/Section 5B
Comb Plate Switch — Part 8/Section 5B
Comb Teeth — Part 8/Section 5B
Combination Sign– Part 10/Section 2
Combustible Material — Part 4, Part 6/Section 8, Part 10/Section 2

A material that, in the form in which it is used and under the conditions anticipated, will ignite and burn; a material that does not meet the definition of noncombustible or limited combustible.

Common Path of Travel — Part 4
Common Rafter — Part 6/Section 3B
Communication Pipe — Part 9/Section 1
Compact Section — Part 6/Section 6
Compact Substation or Prefabricated Substation — Part 8/Section 2
Competent Authority — Part 9/Section 4
Competent Maintenance Person — Part 8/Section 5A
Competent Person — Part 12
Component — Part 6/Section 7A, Part 6/Section 7B
Composite Members — Part 6/Section 7A, Part 6/Section 7B
Composite Station — Part 4
Composting — Part 9/Section 3
Compression Wood — Part 6/Section 3A
Computer Aided Facilities Management (CAFM) — Part 12
Computer Aided Maintenance Management System (CMMS) — Part 12
Concrete Grades — Part 6/Section 4

* Definitions are different.

Concourse — Part 4
Condition Monitoring — Part 12
Conductor of a Cable or Core — Part 8/Section 2
Conductor, Aerial — Part 8/Section 2
Conductor, Bare — Part 8/Section 2
Conductor, Earthed — Part 8/Section 2
Conductor, Insulated — Part 8/Section 2
Conduit — Part 8/Section 2
Confined Space — Part 12
Connection — Part 9/Section 2
Connector — Part 8/Section 2
Connector Box or Joint Box — Part 8/Section 2
Connector for Portable Appliances — Part 8/Section 2
Consolidation Point (CP) — Part 8/Section 6
Constant Stress Range — Part 6/Section 6
Construction and Demolition Waste — Part 9/Section 3
Construction Equipment — Part 7
**Consumer* — Part 9/Section 1, Part 9/Section 2
Consumer's Pipe– Part 9/Section 1
Consumer's Terminals — Part 8/Section 2
Contaminants — Part 8/Section 1
Continuous Operating Voltage (U_c) — Part 8/Section 2
Contour — Part 10/Section 1
Contour Interval — Part 10/Section 1
Control — Part 8/Section 5A
Conversion — Part 2
Cooking Alcove — Part 3
Cooling Load — Part 8/Section 3
Cooling Tower — Part 8/Section 3
Cord, Flexible — Part 8/Section 2
Core of a Cable — Part 8/Section 2
Corrective Maintenance — Part 12
Correlated Colour Temperature (CCT) — Part 8/Section 1
Corridor — Part 6/Section 8
Corrosion — Part 6/Section 6
Counterweight — Part 8/Section 5A
Cover — Part 9/Section 1
Covered Area — Part 3, Part 4

Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area (*see* Table 2 of Part 4 'Fire and Life Safety' of the Code):

a) Garden, rockery, well and well structures, plant nursery, waterpool, swimming pool (if uncovered), platform round a tree, tank,

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fountain, bench, *Chabutara* with open top and unenclosed on sides by walls and the like;

b) Drainage culvert, conduit, catch–pit, gully pit, chamber, gutter and the like;

c) Compound wall, gate, unstoreyed porch and portico, slide, swing, uncovered staircases, ramp areas covered by *Chhajja* and the like; and

d) Watchman's booth, pumphouse, garbage shaft, electric cabin or sub-stations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this part, covered area equals the plot area minus the area due for open spaces in the plot.

Coupled Glazing (*Secondary Glazing*) — Part 6/Section 8

Crane Load — Part 6/Section 6

Creep — Part 6/Section 5B

Creep Coefficient — Part 6/Section 5B

Crime Prevention through Environmental Design (CPTED) — Part 12

Critical Activities — Part 12

Critical Asset — Part 12

Critical Damping — Part 6/Section 1

Crookedness — Part 6/Section 3B

Cross Wall — Part 6/Section 3B

Cross-Connect — Part 8/Section 6

Cross-Connection — Part 9/Section 1

Cross-Sectional Area of Masonry Unit — Part 6/Section 4

Cross-Talk — Part 8/Section 4

Crown of Trap — Part 9/Section 2

Crumple Section — Part 6/Section 4

Crush Train Load — Part 4

'Cul-de-Sac' Cluster — Part 3

Cumulative Figure — Part 6/Section 6

Current Carrying Capacity of a Conductor — Part 8/Section 2

Current Using Equipment — Part 8/Section 2

Curtain Wall — Part 6/Section 4, Part 6/Section 8

Curvature — Part 6/Section 3B

Customer's/Consumer's Connection — Part 9/Section 4

Cut-Out — Part 8/Section 2

Cut-Off Level — Part 6/Section 2

Cut-Off Limit — Part 6/Section 6

D

Damp Situation — Part 8/Section 2

Damping — Part 6/Section 1

Danger — Part 8/Section 2

Daylight Area — Part 8/Section 1

Daylight Factor — Part 8/Section 1

Daylight Penetration — Part 8/Section 1

Deconstruction — Part 12

De-Structured Bamboo — Part 6/Section 3B

Dead — Part 8/Section 2

Dead Knot — Part 6/Section 3A

Dead Loads — Part 6/Section 6

Decay or Rot — Part 6/Section 3A

Decayed Knot — Part 6/Section 3A

Decibel — Part 8/Section 4

Deciduous Tree — Part 10/Section 1

Dedicated Outdoor Air System (*DOAS*) — Part 8/Section 3

Deep Area — Part 9/Section 1

Deep Manhole — Part 9/Section 2

Deflection — Part 6/Section 6

Deflector Sheave– Part 8/Section 5A

Delamination — Part 6/Section 3B

Deliverable — Part 12

Demand Based Ventilation — Part 8/Section 3

Density — Part 3

Depth — Part 6/Section 1

Depth of Manhole — Part 9/Section 2

Design Acceleration — Part 8/Section 5A

Design Acceleration Spectrum — Part 6/Section 1

Design Current (of a Circuit) — Part 8/Section 2

Design Development — Part 12

Design Horizontal Seismic Coefficient — Part 6/Section 4

**Design Life* — Part 6/Section 6, Part 12

Design Load/Factored Load — Part 6/Section 6

Design Pressure Difference — Part 8/Section 3

Design Spectrum — Part 6/Section 6

Design Horizontal Acceleration Coefficient — Part 6/Section 1

Design Horizontal Force — Part 6/Section 1

Detached Building — Part 3

Detail Category — Part 6/Section 6

Developed Height — Part 6/Section 1

Developed Length — Part 9/Section 2

Development — Part 2, Part 3

'Development' with grammatical variations means the carrying out of building, engineering, mining or other

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operations in, or over, or under land or water, or in the use of any building or land, and includes redevelopment and layout and subdivision of any land; and `to develop' shall be construed accordingly.

Dew Point Temperature — Part 8/Section 3
Diameter — Part 9/Section 2

The nominal internal diameter of pipes and fittings.

Diameter of Knot — Part 6/Section 3A
Diaphragm — Part 6/Section 7A
Diaphragm, Structural — Part 6/Section 3A
Dilution Ventilation — Part 8/Section 1
Direct Contact — Part 8/Section 2
Direct to Home (DTH) — Part 8/Section 6
Direct Earthing System — Part 8/Section 2
Direct Solar Illuminance — Part 8/Section 1
Direct Tap — Part 9/Section 1
Direction Sign — Part 10/Section 2
Disability — Part 3
Disaster — Part 11
Discolouration — Part 6/Section 3A, Part 6/Section 3B
Disconnector — Part 8/Section 2
Discontinuity — Part 6/Section 6
Discrimination (Over-Current Discrimination) — Part 8/Section 2
Disposal — Part 9/Section 3
Distance Piece — Part 6/Section 8
Distance Area or Resistance Area (for an Earth Electrode only) — Part 8/Section 2
Distribution/Distributing Company — Part 9/Section 4
Diversity Factor — Part 8/Section 2
Diving Pool — Part 9/Section 1
Documented Information — Part 12
Domestic Hazardous Waste — Part 12
Door — Part 8/Section 5A
Door-to-Door Time — Part 8/Section 5A
Door and Shutter Assembly Door-Set — Part 6/Section 8
Door Closer — Part 8/Section 5A
Door Closing Time — Part 8/Section 5A
Door Opening Time — Part 8/Section 5A
Door Operator — Part 8/Section 5A
Door, Centre Opening Sliding — Part 8/Section 5A
Door, Mid-Bar Collapsible — Part 8/Section 5A
Door, Multi-Panel — Part 8/Section 5A
Door, Single Slide — Part 8/Section 5A
Door, Swing — Part 8/Section 5A
Door, Two Speed Siding — Part 8/Section 5A
Door, Vertical Bi-parting — Part 8/Section 5A
Door, Vertical Lifting — Part 8/Section 5A
Double Button (Continuous Pressure) Operation — Part 8/Section 5A
Double Glazed Fire Resistant Glass — Part 6/Section 8
Double Glazing — Part 6/Section 8
Down-Comer — Part 4
Down Take Tap — Part 9/Section 1
Drain — Part 2, Part 3, Part 9/Section 2

A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

Drain Vent Pipe (DVP) — Part 9/Section 2
**Drainage* — Part 2, Part 3, Part 9/Section 2, Part 10/Section 1
Drainage Fixture Unit (DFU) — Part 9/Section 2
Drainage Work — Part 9/Section 2
Driven Cast In-situ Pile — Part 6/Section 2
Drop Connection — Part 9/Section 2
Drop Manhole — Part 9/Section 2
Dry Riser — Part 4
Dry Waste — Part 12
Dry Bulb Temperature — Part 8/Section 1, Part 8/Section 3
Duct — Part 8/Section 2
Ducting — Part 8/Section 2
Duct System — Part 8/Section 3
Ductility — Part 6/Section 1, Part 6/Section 6
Dumb Waiter — Part 8/Section 5A
Dump Sites — Part 12
**Durability* — Part 6/Section 6, Part 12
Duration of Load — Part 6/Section 3A
Duress Alarms — Part 12
Dwelling Unit/Tenement — Part 3
Dwellings — Part 6/Section 1

E

Earth — Part 8/Section 2
Earth Continuity Conductor — Part 8/Section 2
Earthed Concentric Wiring — Part 8/Section 2
Earth Electrode — Part 8/Section 2
Earth Electrode Network — Part 8/Section 2
Earth Electrode Resistance — Part 8/Section 2
Earth Fault — Part 8/Section 2
Earth Fault Current — Part 8/Section 2

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Earth Leakage Current — Part 8/Section 2
Earthing — Part 8/Section 2
Earthing Conductor — Part 8/Section 2
Earthing Lead — Part 8/Section 2
Earthing Resistance, Total — Part 8/Section 2
Earthquake Loads — Part 6/Section 6
Ecological Footprint — Part 11
Ecosystem — Part 11
Economizer, Air — Part 8/Section 3
Economizer, Water — Part 8/Section 3
**Edge Distance* — Part 6/Section 3A, Part 6/Section 6
Edge Deterioration — Part 6/Section 8
Edge Faults — Part 6/Section 8
Edge Polished — Part 6/Section 8
Edging — Part 6/Section 8
Educational Buildings — Part 6/Section 1
Effective Frontal Area — Part 6/Section 1
Effective Height — Part 6/Section 4
Effective Lateral Restraint — Part 6/Section 6
**Effective Length* — Part 6/Section 4, Part 6/Section 6
Effective Opening — Part 9/Section 1
Effective Perceived Noise Level in Decibel (EPN dB) — Part 8/Section 4
**Effective Temperature (ET)* — Part 8/Section 1, Part 8/Section 3
Effective Thickness — Part 6/Section 4
Efficiency of a Pile Group — Part 6/Section 2
Egress — Part 10/Section 1
Elastic Cladding — Part 6/Section 6
Elastic Critical Moment — Part 6/Section 6
Elastic Design — Part 6/Section 6
Elastic Limit — Part 6/Section 6
Electric Shock — Part 8/Section 2
Electric Sign — Part 10/Section 2
Electrical and Mechanical Interlock — Part 8/Section 5A
Electrical Equipment (abb: Equipment) — Part 8/Section 2
Electrically Independent Earth Electrode — Part 8/Section 2
Electrical Supply System for Life and Safety Services — Part 8/Section 2
Electro-Mechanical Lock — Part 8/Section 5A
Electronic Devices — Part 8/Section 5A
Element of Surface Area — Part 6/Section 1
Elevation — Part 10/Section 1
Embodied Energy — Part 11
Emergency Brake — Part 8/Section 5B
Emergency Lighting — Part 4
Emergency Lighting System — Part 4
Emergency Stop Switch — Part 8/Section 5B
Emergency Switching — Part 8/Section 2
Emission Sound Pressure Level (L_{pA}) — Part 8/Section 5B
Emissivity (E) — Part 11
Emulative Detailing System — Part 6/Section 7A
Enclosed Station — Part 4
Enclosed Distribution Board — Part 8/Section 2
Enclosure — Part 8/Section 2
*End Dist*ance — Part 6/Section 3A, Part 6/Section 3B, Part 6/Section 6
End Splitting — Part 6/Section 3B
End-User — Part 12
Endemic Plant — Part 10/Section 1
Energy Efficiency Ratio (*EER*) — Part 8/Section 3
Energy Recovery Unit — Part 8/Section 3
Entraining Load — Part 4
Environmental Impact — Part 11
Environmental Indicator (K_{2A}) — Part 8/Section 5B
Epicenter — Part 6/Section 1
Equipotential Bonding — Part 8/Section 2
Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq.T}$ — Part 8/Section 4
Equivalent Sound Absorption Area of a Room, A — Part 8/Section 4
Equivalent Sound Pressure Level (L_{Aeq}) — Part 8/Section 5A, Part 8/Section 5B
Erection Loads — Part 6/Section 6
Erection Tolerance — Part 6/Section 6
Erosion — Part 10/Section 1
Escalator — Part 3, Part 8/Section 5B
Escape Lighting — Part 4
Estimated Service Life (ESL) — Part 12
Evacuation Lift — Part 4
Evaporative Cooling — Part 8/Section 3
Evergreen Tree — Part 10/Section 1
Exhaust of Air — Part 8/Section 1
Exit — Part 3, Part 4
Exit Access — Part 4
Exit Access Corridor — Part 4
Exit Discharge — Part 4
Exotic — Part 10/Section 1
Exposed Conductive Part — Part 8/Section 2

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Exposed Edge — Part 6/Section 8
Exposed Metal — Part 8/Section 2
Exposed Surface Area to Mass Ratio — Part 6/Section 6
Exterior Panel — Part 8/Section 5B
Exterior Property — Part 12
Exterior Sign — Part 10/Section 2
External Envelope — Part 12
External Faces of Cluster — Part 3
External Influence — Part 8/Section 2
External Lightning Protection System — Part 8/Section 2
External Reflected Component (ERC) — Part 8/Section 1
Extraneous Conductive Part — Part 8/Section 2

F

Fabrication Tolerance — Part 6/Section 6
Facade — Part 6/Section 8
Facade Level — Part 8/Section 4
Faced Wall — Part 6/Section 4
Faceted Glazing — Part 6/Section 8
Factor of Safety — Part 6/Section 6
Factor of Safety (with Respect to Bearing Capacity) — Part 6/Section 2
*Facilities Maintena*nce — Part 12
Facility — Part 12
Facility Asset Maintenance — Part 12
Fatigue — Part 6/Section 6
Fatigue Loading — Part 6/Section 6
Fatigue Strength — Part 6/Section 6
Fault — Part 8/Section 2
Fault Current — Part 8/Section 2
Fault Protection — Part 8/Section 2
Feed Cistern — Part 9/Section 1
Fence — Part 10/Section 1
Fenestration — Part 6/Section 8
Fetch Length — Part 6/Section 1
Fin — Part 6/Section 8
Final Circuit — Part 8/Section 2
Final Prestress — Part 6/Section 5B
Final Tension — Part 6/Section 5B
Finger Joint — Part 6/Section 3A
Finger Jointed Timber — Part 6/Section 3A
Fire Barrier (or Fire Resisting Barrier) — Part 4
Fire Compartment — Part 4
Fire Damper — Part 8/Section 3
Fire Door and Fire Door Assembly — Part 4
Fire Exit — Part 4
Fire Exit Hardware — Part 4
Fire Exposure Condition — Part 6/Section 6
Fireman's Lift — Part 4
Fire Load — Part 4
Fire Load Density — Part 4
Fire Protection System — Part 6/Section 6
**Fire Resistance* — Part 4; Part 6/Section 6
Fire Resistance Level — Part 6/Section 6
Fire Resistance Rating — Part 4
Fire Resistant Wall — Part 4
Fire Separation — Part 3, Part 4, Part 6/Section 8

The distance, in metre, measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of a street or other public space for the purpose of preventing the spread of fire.

Fire Stop — Part 4
Fire Suppression Systems — Part 4
Fire Survival Distribution Board — Part 8/Section 2
Fire Wall or Fire Separating Wall — Part 4
Firefighting Shaft (Fire Tower) — Part 4
Fitting, Lighting — Part 8/Section 2
Fittings — Part 9/Section 1, Part 9/Section 2

The appurtenances such as coupling, flange, branch, bend, tees, elbows, unions, waste (with or without plug), P or S trap (with or without vent), stop ferrule, bib tap, pillar tap, bath faucet, water meter, garden hydrant, valves and any other article used in connection with water supply, drainage and sanitation.

Fixed Equipment — Part 8/Section 2
Fixture Unit — Part 9/Section 1, Part 9/Section 2
Flameproof Enclosure– Part 8/Section 2
Flattened Bamboo — Part 6/Section 3B
Flexural Stiffness — Part 6/Section 6
Float Glass — Part 6/Section 8
Float Operated Valve — Part 9/Section 1
Floor — Part 3

The lower surface in a storey on which one normally walks in a building. The general term 'floor' unless specifically mentioned otherwise shall not refer to a 'mezzanine floor'.

Floor Area (Gross) — Part 4
Floor Area Ratio (FAR) — Part 3, Part 4

The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot.

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Floor Hole — Part 7
Floor Opening — Part 7
Floor Response Spectrum — Part 6/Section 1
Floor Selector — Part 8/Section 5A
Floor Stopping Switch — Part 8/Section 5A
Flush Over Panel — Part 6/Section 8
Flushing Cistern — Part 9/Section 1
Flushometer Tank — Part 9/Section 1
Foam Protection System — Part 4
Foliage — Part 10/Section 1
Footing — Part 6/Section 2
Force Coefficient — Part 6/Section 1
Formation — Part 9/Section 1, Part 9/Section 2
Foundation — Part 6/Section 2
Foundation, Raft — Part 6/Section 2
Frame — Part 6/Section 8
Frameless Glazing — Part 6/Section 8
Free-Field Level — Part 8/Section 4
Freestanding Sign– Part 10/Section 2
French Drain or Rubble Drain — Part 9/Section 2
**Frequency* — Part 8/Section 4, Part 8/Section 6
Fresh Air or Outside Air — Part 8/Section 1
Friction Type Connection — Part 6/Section 6
Front Putty — Part 6/Section 8
Frost Line — Part 9/Section 1, Part 9/Section 2
Full Culm — Part 6/Section 3B
Fully Framed Glazing — Part 6/Section 8
Functional Earthing — Part 8/Section 2
Fundamental or Ultimate Stress — Part 6/Section 3A, Part 6/Section 3B
Fuse — Part 8/Section 2
Fuse Carrier — Part 8/Section 2
Fuse Element — Part 8/Section 2
Fuse Link — Part 8/Section 2

G

Gallery — Part 3
Gap — Part 6/Section 8
Garage, Private — Part 3
Garage, Public — Part 3
Gas Fitter — Part 9/Section 4
Gauge — Part 6/Section 6
Geared Machine — Part 8/Section 5A
Gearless Machine — Part 8/Section 5A
General Ventilation — Part 8/Section 1
General Washing Place — Part 9/Section 1
Generator of Wastes — Part 9/Section 3
Geogrid — Part 10/Section 1
Geo-textile — Part 10/Section 1
Geothermal Heat Pump — Part 8/Section 3
Geyser — Part 9/Section 1
Girth of Tree — Part 10/Section 1
Glare — Part 8/Section 1
Glass — Part 6/Section 8
Glazing-Bite — Part 6/Section 8
Global Warming Potential (GWP) — Part 8/Section 3
Globe Temperature — Part 8/Section 1
Glue — Part 6/Section 3A
Glued Laminated (Glulam) — Part 6/Section 3A
Glued Laminated, horizontally — Part 6/Section 3A
Glued Laminated, vertically — Part 6/Section 3A
Goods Lift — Part 8/Section 5A
Grab Bars — Part 3
Grade — Part 10/Section 1
Gradient Height — Part 6/Section 1
Gradient — Part 10/Section 1
Grading — Part 10/Section 1
Grass Paver — Part 10/Section 1
Grasses — Part 10/Section 1
Gravel — Part 6/Section 2
Gravity Load — Part 6/Section 6
Grease Interceptor (*or Grease Trap*) — Part 9/Section 2
Green Roof — Part 10/Section 1
Green Roof System — Part 11
Green Walls — Part 10/Section 1
Ground Improvement — Part 6/Section 2
Ground Roughness — Part 6/Section 1
Ground Sign — Part 10/Section 2
Ground-Borne Noise — Part 8/Section 4
Groundcover — Part 10/Section 1
Group Automatic Operation — Part 8/Section 5A
Group Housing — Part 3
Group Open Space– Part 3
Grout — Part 6/Section 4
Grouted Cavity Reinforced Masonry — Part 6/Section 4
Grouted Hollow-Unit Masonry — Part 6/Section 4
Grouted Masonry — Part 6/Section 4
Grouted Multi-Wythe Masonry — Part 6/Section 4
Guard Railing — Part 7
Guard Rail — Part 6/Section 8
Guide Rails — Part 8/Section 5A
Guide Rails Fixing– Part 8/Section 5A
Guide Shoe — Part 8/Section 5A
Gully Chamber– Part 9/Section 2

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Gully Trap– Part 9/Section 2
Gusset Plate — Part 6/Section 6
Gust — Part 6/Section 1

H

Habitable Room — Part 3
Hairline Scratch — Part 6/Section 8
Halo — Part 6/Section 8
Hand-Held Equipment — Part 8/Section 2
Handling Capacity (HC) — Part 8/Section 5A
* *Handrail* — Part 3, Part 8/Section 5B
Hard Landscape — Part 10/Section 1
Hardy Plant — Part 10/Section 1
Harmonics (Current and Voltage) — Part 8/Section 2
Haunching — Part 9/Section 1
Hazardous Live-Part — Part 8/Section 2
Hazardous Waste — Part 12
Headway — Part 4
Heat Island Effect — Part 10/Section 1, Part 11
Heat Pump — Part 8/Section 3
Heat Recovery — Part 8/Section 3
Heat Soaking — Part 6/Section 8
Heat Strengthened Glass — Part 6/Section 8
Heating Load — Part 8/Section 3
Hedge — Part 10/Section 1
Heel Rest Bend or Duck-Foot Bend — Part 9/Section 1
Hemi Cellulose — Part 6/Section 3B
Herb — Part 10/Section 1
Hermetic Seal — Part 6/Section 8
High Activity Area — Part 6/Section 8
High Altitudes — Part 9/Section 1, Part 9/Section 2
High Rise Building — Part 4
High Risk Area — Part 6/Section 8
High Shear — Part 6/Section 6
Highway Authority — Part 9/Section 1, Part 9/Section 2
Hoisting Beam — Part 8/Section 5A
Hollow Unit — Part 6/Section 4
Horizontal Cabling — Part 8/Section 6
Horizontal Cabling Media Distribution and Building Pathway — Part 8/Section 6
Horizontal Cross-Connect (HC) — Part 8/Section 6
Horizontal Exit — Part 4
Horizontal Pipe — Part 9/Section 1, Part 9/Section 2
Horizontal Sun Angle (HSA) — Part 11
Hospital Lift — Part 8/Section 5A
Hot Water Tank — Part 9/Section 1
House Keeping — Part 12

* Definitions are different.

Hue — Part 3
Humidification — Part 8/Section 1
Humidity, Absolute — Part 8/Section 1
Humidity, Relative — Part 8/Section 1
Hybrid Building — Part 8/Section 3
Hydrant System — Part 4
Hydro-pneumatic Systems — Part 9/Section 1
Hydronic Systems — Part 8/Section 3
Hydronic System Balancing — Part 8/Section 3

I

Identification Sign — Part 10/Section 2
Illuminance — Part 8/Section 1
Illuminated Sign — Part 10/Section 2
Impact Sound Pressure Level, L_i — Part 8/Section 4
Impairment — Part 3
Importance Factor — Part 6/Section 1
**Imposed Load (Live Load)* — Part 6/Section 1, Part 6/Section 6
Impulse Current — Part 8/Section 2
Impulse Withstood Voltage — Part 8/Section 2
Increments — Part 6/Section 7A, Part 6/Section 7B
Independent Cluster– Part 3
Indirect Contact — Part 8/Section 2
Indirect-Direct Cooling — Part 8/Section 3
Indirect Waste Pipe — Part 9/Section 2
Indoor Air Quality (IAQ) — Part 8/Section 3, Part 11
Indoor Ambient Noise — Part 8/Section 4
Indoor Environment Quality (IEQ) — Part 11
Industrial Buildings — Part 6/Section 1
Industrial Plugs and Sockets — Part 8/Section 2
Infill Balustrades — Part 6/Section 8
Infiltration/Exfiltration — Part 8/Section 3
Inflammable Material — Part 8/Section 2
Information Management — Part 12
Informational Sign — Part 10/Section 2
Ingress — Part 10/Section 1
Initial Load Test — Part 6/Section 5B
Initial Prestress — Part 6/Section 5B
Initial Tension — Part 6/Section 5B
Injection — Part 6/Section 2
Inlet — Part 9/Section 1
Inlet Fittings — Part 9/Section 2
Inlet Hopper — Part 9/Section 2
Inner Diameter — Part 6/Section 3B
Insanitary — Part 9/Section 2
Insertion Loss — Part 8/Section 4

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Inside Location — Part 6/Section 3A, Part 6/Section 3B
Inside Plant (ISP) — Part 8/Section 6
Inspection Chamber — Part 9/Section 2
Inspection Door — Part 8/Section 5B
Instability — Part 6/Section 6
**Installation* — Part 8/Section 5A, Part 9/Section 4
Installation (Electrical) — Part 8/Section 2
Installer — Part 8/Section 5A
Institutional Buildings — Part 6/Section 1
Insulated — Part 8/Section 2
Insulating Glass Unit (IGU) — Part 6/Section 8
Insulation — Part 8/Section 2
Insulation, Basic — Part 8/Section 2
Insulation, Double — Part 8/Section 2
Insulation, Reinforced — Part 8/Section 2
Insulation, Supplementary — Part 8/Section 2
Intensity of Earthquake — Part 6/Section 1
Interceptor — Part 9/Section 2
Interceptor Manhole or Interceptor Chamber — Part 9/Section 2
Interior Panel — Part 8/Section 5B
Interlayer — Part 6/Section 8
Interlocking Cluster — Part 3
Intermediate Cross-Connect — Part 8/Section 6
Internal Faces of Cluster– Part 3
Internal Lightning Protection System — Part 8/ Section 2
Internal Partition — Part 6/Section 8
Internal Reflected Component (IRC) — Part 8/ Section 1
International Symbol of Accessibility — Part 3, Part 10/ Section 2
Interval — Part 8/Section 5A
Intrusion Detection Systems — Part 12
Invasive Plant — Part 10/Section 1
Invert — Part 9/Section 2, Part 10/Section 1
Internet of Things — Part 8/Section 6
Irrigation — Part 10/Section 1
Isolation — Part 8/Section 2
Isolator — Part 8/Section 2
Isoptera — Part 6/Section 3A

J

Jerk — Part 8/Section 5A
Joint — Part 6/Section 3B, Part 6/Section 4
Joist — Part 6/Section 3B
Jointed Detailing System — Part 6/Section 7A
Joint Reinforcement — Part 6/Section 4
Junction Box — Part 8/Section 2
Junction Pipe — Part 9/Section 1, Part 9/Section 2

K

* *Kerb* — Part 3, Part 10/Section 1
Kerb Ramp — Part 3
Knot — Part 6/Section 3A
Knot Hole– Part 6/Section 3A
Knurled Surface — Part 3

L

Lagging — Part 9/Section 1, Part 9/Section 2
Lamella Roof — Part 6/Section 3A
Laminated Safety Glass — Part 6/Section 8
*Laminated Veneer Lumbe*r — Part 6/Section 3A
Laminations — Part 6/Section 3A
Landfilling — Part 9/Section 3
Landing — Part 3
Landing Call Push — Part 8/Section 5A
Landing Door — Part 8/Section 5A
Landing Zone — Part 8/Section 5A
Large Lobby — Part 8
Latent Heat — Part 8/Section 3
Latent Heat Load — Part 8/Section 3
Lateral Restraint for a Beam — Part 6/Section 6
Lateral Support — Part 6/Section 4
Latewood — Part 6/Section 3A
Leachate — Part 9/Section 3
Leading Imposed Load — Part 6/Section 6
Leaf — Part 6/Section 4
Leakage Current — Part 8/Section 2
Ledge or Tand — Part 3
Length of Internode — Part 6/Section 3B
Levelling Device, Lift Car — Part 8/Section 5A
Levelling Device, One Way Automatic — Part 8/ Section 5A
Levelling Device, Two-Way Automatic Maintaining — Part 8/Section 5A
Levelling Devices — Part 8/Section 5A
Levelling Zone — Part 8/Section 5A
LEMP Protection Measures (SPM) — Part 8/Section 2
Licensed (or Registered) Plumber — Part 9/Section 1, Part 9/Section 2
Life Cycle — Part 12
Life Cycle Assessment (LCA) — Part 11
Lift — Part 3, Part 8/Section 5A

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An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform. The word 'elevator' is also synonymously used for 'lift'.

Lift Car — Part 8/Section 5A
Lift Landing — Part 8/Section 5A
Lift Lobby — Part 4
Lift Machine — Part 8/Section 5A
Lift Pit — Part 8/Section 5A
Lift Ride Quality — Part 8/Section 5A
Lift Well — Part 8/Section 5A
Lift Well Enclosure — Part 8/Section 5A
Light Output Ratio (LOR) or Efficiency — Part 8/Section 1
Light Pipe — Part 8/Section 1
Light Reflectance Value (LRV) — Part 3
Light Shelf — Part 8/Section 1/, Part 11
Light Transmission — Part 6/Section 8
Light Transmittance — Part 6/Section 8
Light-Weight Concrete — Part 6/Section 7A
Lighting — Part 8/Section 1
Lightning Electromagnetic Impulse — Part 8/Section 2
Lightning Protection — Part 8/Section 2
Lightning Protection Level (LPL) — Part 8/Section 2
Lightning Protection System (LPS) — Part 8/Section 2
Lightning Protection Zone — Part 8/Section 2
Lignin — Part 6/Section 3B
Line Conductor — Part 8/Section 2
Linear Defects — Part 6/Section 8
Limit State — Part 6/Section 6
Liquefaction — Part 6/Section 1
Lithological Features — Part 6/Section 1
Live Knot — Part 6/Section 3A
Live or Alive — Part 8/Section 2
Live Load — Part 6/Section 6
Live Part — Part 8/Section 2
Load — Part 6/Section 6
Load Bearing Wall — Part 6/Section 4
Load Carrying Unit — Part 8/Section 5B
Loaded Edge Distance — Part 6/Section 3A
Loaded End or Compression End Distance — Part 6/Section 3B
Local Area Network (LAN) — Part 8/Section 6
Local Exhaust Ventilation– Part 8/Section 1
Local Multipoint Distribution System (LMDS) — Part 8/Section 6
Location — Part 6/Section 3A
Locations, Industrial– Part 8/Section 2
Locations, Non-Industrial — Part 8/Section 2
Loft — Part 3
Loose Grain (Loosened Grain) — Part 6/Section 3A
Loose Knot — Part 6/Section 3A
Lower Inner Decking — Part 8/Section 5B
Lower Outer Decking — Part 8/Section 5B
Low Rise Building — Part 6/Section 1
Low-Voltage Switchgear and Controlgear Assembly — Part 8/Section 2
Lumen — Part 8/Section 1
Luminaire — Part 8/Section 2
Luminance (at a Point of a Surface in a Given Direction) (Brightness) — Part 8/Section 1
Luminous Flux — Part 8/Section 1

M

M2M — Part 8/Section 6
Machete — Part 6/Section 3B
Machinery — Part 8/Section 5B
Machinery Spaces — Part 8/Section 5B
Maximum Capacity — Part 8/Section 5B
Made-Up Ground — Part 6/Section 2
Main Cross-connect — Part 8/Section 6
Main Distribution Frame (MDF) — Part 8/Section 6
Main Drain — Part 9/Section 1
Main Earthing Terminal — Part 8/Section 2
Main Member — Part 6/Section 6
Main Soil Pipe (MSP) — Part 9/Section 2
Main Soil and Waste Pipe (MSWP) — Part 9/Section 2
Main Vent Pipe (MVP) — Part 9/Section 2
Main Waste Pipe (MWP) — Part 9/Section 2
Maintenance — Part 12
Maintenance Factor — Part 8/Section 1
Maintenance Management — Part 12
Maintenance Manual — Part 12
Maintenance Organization — Part 8/Section 5A
Maintenance Plan — Part 12
Maintenance Policy — Part 12
Maintenance Programme — Part 12
Maintenance Strategy — Part 12
Make-Up Air — Part 8/Section 1
Make-Up Water — Part 9/Section 1
Management System — Part 12
Manhole — Part 9/Section 2
Manhole Chamber — Part 9/Section 2
Manifestation — Part 6/Section 8
Manifold — Part 9/Section 4
Manoeuvring Zone — Part 3
Mansard — Part 10/Section 2

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Mantrap — Part 12
Marquee Sign– Part 10/Section 2
Masonry — Part 6/Section 4
Masonry Unit — Part 6/Section 4
Mass Rapid Transit — Part 4
Master Plan — Part 3
Mat — Part 6/Section 3B
Material Handling Hoists — Part 7
Maximum Thickness — Part 6/Section 8
Mean Ground Level — Part 6/Section 1
Mean Outer Diameter — Part 6/Section 3B
Mean Radiant Temperature — Part 8/Section 3
Mean Wall Thickness — Part 6/Section 3B
Means of Egress — Part 4
Means of Escape — Part 4
Measured Speed — Part 8/Section 5B
Mechanical Ventilation — Part 8/Section 1
Mechanically Laminated — Part 6/Section 3A
Mercantile Buildings — Part 6/Section 1
Meridian — Part 8/Section 1
Meshed Bonding Network (MESH-BN) — Part 8/Section 2
Metropolitan Area Network (MAN) — Part 8/Section 6
Mezzanine Floor — Part 3
Metro-station — Part 4
Microclimate — Part 10/Section 1
Mill Tolerance — Part 6/Section 6
Miniature Circuit Breaker (MCB) — Part 8/Section 2
Minimum Thickness — Part 6/Section 8
Mixed Mode Building — Part 8/Section 3
Mixed Occupancy — Part 4
Mobile Equipment — Part 8/Section 2
Modal Mass in Mode of a Structure — Part 6/Section 1
Modal Participation Factor — Part 6/Section 1
Modes of Oscillation — Part 6/Section 1
Modular Co-ordination — Part 6/Section 7A, Part 6/Section 7B
Modular Grid — Part 6/Section 7A, Part 6/Section 7B
Module — Part 6/Section 7A, Part 6/Section 7B
Modulus of Elasticity (Young's Modulus) — Part 6/Section 8
Moment Resistant Frame — Part 6/Section 4
Moment Resistant Frame with Shear Walls — Part 6/Section 4
Monitoring — Part 8/Section 2
Monolithic Glass — Part 6/Section 8
Mortise and Tenon — Part 6/Section 3B
Mould — Part 6/Section 3A
Moulded Case Circuit Breaker (MCCB) — Part 8/Section 2
Mound — Part 10/Section 1
Moving Walk — Part 8/Section 5B
Mulching — Part 10/Section 1
Mullion — Part 6/Section 8
Multichannel Multipoint Distribution System (MMDS) — Part 8/Section 6
Multimodule — Part 6/Section 7A, Part 6/Section 7B
Multiple Earthed Neutral System — Part 8/Section 2
*Multiple Occupa*ncy — Part 4
Multi-User Telecommunications Outlet Assembly (MUTOA) — Part 8/Section 6
Municipal Authority — Part 9/Section 3
Municipal Solid Waste — Part 9/Section 3

N

Native Plant — Part 10/Section 1
Natural Period in Mode of Oscillation — Part 6/Section 1
Natural Ventilation — Part 8/Section 1
Naturalised Plant — Part 10/Section 1
Naturally Conditioned Building — Part 8/Section 3
Negative Skin Friction — Part 6/Section 2
Net Section — Part 6/Section 3B
Neutral Conductor — Part 8/Section 2
Newel — Part 8/Section 5B
Node — Part 6/Section 3B
Noise — Part 8/Section 4
Noise Exposure Forecast (NEF) — Part 8/Section 4
Noise Criteria — Part 8/Section 4
Noise Rating (NR) — Part 8/Section 4
Noise Reduction Co-efficient (NRC) — Part 8/Section 4
Nominal/Rated Speed — Part 8/Section 5B
Nominal Thickness — Part 6/Section 8
Nominal Travel Time — Part 8/Section 5A
Non-Combustible Material — Part 6/Section 8
Non-Renewable Resource — Part 11
Non-Selective Collective Automatic Operation — Part 8/Section 5A
Non-transit Occupancy — Part 4
Normal Mode of Oscillation — Part 6/Section 1
Normal Operation — Part 8/Section 5A
Normal Stress — Part 6/Section 6
Normalized Impact Sound Pressure Level — Part 8/Section 4
North and South Points — Part 8/Section 1

O

Occupancy or Use Group — Part 2, Part 3, Part 4

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The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy, an occupancy shall be deemed to include the subsidiary occupancies which are contingent upon it.

Occupant Load — Part 4
Occupants — Part 12
Occupier — Part 2
Octave Band — Part 8/Section 4
Office Buildings — Part 6/Section 1

**Offset* — Part 6/Section 2, Part 9/Section 1, Part 9/Section 2
Oil Buffer — Part 8/Section 5A
Oil Buffer Stroke — Part 8/Section 5A
Open Clusters — Part 3
Open Sign — Part 10/Section 2
Open Space — Part 3
Open Space, Front — Part 3
Open Space, Rear — Part 3
Open Space, Side — Part 3
Open Station — Part 4
Operable Parts — Part 3
Operating Device — Part 8/Section 5A
Operation — Part 8/Section 5A
Operational Construction/Installation — Part 2
Operational Plan — Part 12
Operational Strategy — Part 12
Operative Temperature — Part 8/Section 3
Operator of a Facility — Part 9/Section 3
Optical Distribution Frame — Part 8/Section 6
Optical Fibre — Part 8/Section 6
Orientation of Buildings — Part 8/Section 1
Organic Coated Glass — Part 6/Section 8
Origin of an Electrical Installation — Part 8/Section 2
Outer Diameter — Part 6/Section 3B
Outside Location — Part 6/Section 3A, Part 6/Section 3B
Outside Plant (OSP) — Part 8/Section 6
Overcurrent — Part 8/Section 2
Overload Current (of a Circuit) — Part 8/Section 2
Over Speed Governor — Part 8/Section 5A
Overhead Beams — Part 8/Section 5A
Owner — Part 0, Part 2, Part 3, Part 10/Section 2

A person, a group of persons or a body having a legal interest in land and/or building thereon. This includes freeholders, leaseholders or those holding a sub-lease who will have legal right to occupation and have liabilities in respect of safety or building condition.

In case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/lessee till the allotment/lease subsists.

Ozone Depletion Potential (ODP) — Part 8/Section 3

P

Pane — Part 6/Section 8
Panel — Part 6/Section 8
Panel Wall — Part 6/Section 4
Parapet — Part 3, Part 10/Section 2
Parking Space — Part 3
Partial Safety Factor — Part 6/Section 6
Partition — Part 3, Part 6/Section 8
Partition Wall — Part 6/Section 4
Partly Framed or Unframed Glazing — Part 6/Section 8
Passenger Arrival Rate — Part 8/Section 5A
Passenger Average Transfer — Part 8/Section 5A
Passenger Average Waiting Time (AWT) — Part 8/Section 5A
Passenger Lift — Part 8/Section 5A
Passive Cooling — Part 8/Section 3
Passive Heating — Part 8/Section 3
Passive Solar Gain — Part 6/Section 8
Patterned Glass — Part 6/Section 8
Peak Ground Acceleration — Part 6/Section 1
Peak Gust — Part 6/Section 1
Peak to Peak Vibration Levels — Part 8/Section 5A
Peat — Part 6/Section 2
Pelletization — Part 9/Section 3
Percentile Level — Part 8/Section 4
Perimeter Intrusion Detection and Assessment System (PIDAS) — Part 12
Perimeter Security — Part 12
Period of Structural Adequacy under Fire — Part 6/Section 6
Period of Supply — Part 9/Section 1
Peripheral Field — Part 8/Section 1
Permanent Load — Part 6/Section 2
Permeable Paving– Part 10/Section 1
Permissible Stress — Part 6/Section 3A, Part 6/Section 3B, Part 6/Section 6
Permit — Part 2

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Persons with Disabilities — Part 3
PEN Conductor — Part 8/Section 2
Phase Conductor — Part 8/Section 2
Physical Asset — Part 12
Pier — Part 6/Section 4
Pile Foundation — Part 6/Section 2
Pile Rig — Part 7
Pile Spacing — Part 6/Section 2
Pilot — Part 9/Section 4
Pink Noise — Part 8/Section 4
Pipe System — Part 9/Section 2
Pipe Work — Part 9/Section 1
Pit — Part 8/Section 5B
Pitch — Part 6/Section 6
Pitch Pocket — Part 6/Section 3A
Place of Comparative Safety — Part 4
Planned Preventive Maintenance — Part 12
Platform — Part 7
Plastic Collapse — Part 6/Section 6
Plastic Design — Part 6/Section 6
Plastic Hinge — Part 6/Section 6
Plastic Moment — Part 6/Section 6
Plastic Section — Part 6/Section 6
Plenum — Part 8/Section 3
Plinth — Part 3

The portion of a structure between the surface of the surrounding ground and surface of the floor, immediately above the ground.

Plinth Area — Part 3

The built up covered area measured at the floor level of the basement or of any storey.

Plug — Part 8/Section 2
Plumbing — Part 9/Section 1, Part 9/Section 2
Plumbing System — Part 9/Section 1, Part 9/Section 2
Pocket Type Reinforced Masonry — Part 6/Section 4
Point of Safety — Part 4
Point (in Wiring) — Part 8/Section 2
Poisson's Ratio — Part 6/Section 6
Pool — Part 9/Section 1
Pool Depth — Part 9/Section 1
Porch — Part 3
Portable Equipment — Part 8/Section 2
*Portable S*ign– Part 10/Section 2
Position and/or Direction Indicator — Part 8/Section 5A
Positive Ventilation — Part 8/Section 1, Part 8/Section 3
Post-Tensioning — Part 6/Section 5B
Potable Water — Part 9/Section 1
Pre-tensioning — Part 6/Section 5B
Precast Concrete Piles in Prebored Holes — Part 6/Section 2
Precast Driven Pile — Part 6/Section 2
Predictive Action — Part 12
Predicted Service Life — Part 12
Prefabricate — Part 6/Section 7A, Part 6/Section 7B
Prefabricated Building — Part 6/Section 7A, Part 6/Section 7B
Preloading — Part 6/Section 2
Premises — Part 9/Section 1, Part 9/Section 2
Pressure Coefficient — Part 6/Section 1
Pressure Balancing Valve — Part 9/Section 1
Pressure Regulator — Part 9/Section 4
Pressurization — Part 4
Pressurization Level — Part 4
Prestressed Concrete — Part 6/Section 5B
Preventive Action — Part 12
Preventive Maintenance — Part 12
Primary Collection — Part 12
Principal Rafter — Part 6/Section 3B
Prism — Part 6/Section 4
Processing — Part 9/Section 3
Projecting Sign — Part 10/Section 2
Proof Stress — Part 6/Section 6
Proof Testing — Part 6/Section 6
Propagation Delay — Part 8/Section 6
Propeller Fan — Part 8/Section 1
Prospective Fault Current (I_{pf}) — Part 8/Section 2
Protection, Ingress — Part 8/Section 2
Protection, Mechanical Impact — Part 8/Section 2
Protective Coating(s) Faults — Part 6/Section 8
Protective Conductor — Part 8/Section 2
Protective Conductor Current — Part 8/Section 2
Protective Earthing — Part 8/Section 2
Protective Separation — Part 8/Section 2
Prototype Testing — Part 6/Section 6
Prying Force — Part 6/Section 6
Psychrometric Chart — Part 8/Section 3
Public Mobile Network — Part 8/Section 6
Public Way — Part 4
Puff Ventilation — Part 9/Section 2
Pure Tone — Part 8/Section 4
Purge — Part 9/Section 4
Purlins — Part 6/Section 3B

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Q

Qualified Installing Agency — Part 9/Section 4
Quetta Bond Reinforced Masonry — Part 6/Section 4

R

Radio Frequency — Part 8/Section 6
Ramp — Part 3, Part 4
RASCI Chart — Part 12
Rated Current — Part 8/Section 2
Rated Impulse Withstand Voltage Level — Part 8/Section 2
Rated Load (Lift) — Part 8/Section 5A
Rated Load — Part 8/Section 5B
Rated Speed (Lift) — Part 8/Section 5A
Rating Level — Part 8/Section 4
Rebate — Part 6/Section 8
Recirculated Air — Part 8/Section 3
Recycling — Part 9/Section 3, Part 11
Reflected Glare — Part 8/Section 1
Reflection Factor (Reflectance) — Part 8/Section 1
Reflective Coated Glass — Part 6/Section 8
Reflective Silver Coating Faults — Part 6/Section 8
Refrigerant — Part 8/Section 3
Refuge Area — Part 4
Registered Architect, Engineer, Structural Engineer, Geotechnical Engineer, Supervisor, Town Planner, Landscape Architect, Urban Designer — Part 2
Regulatory Sign — Part 10/Section 2
Reinforced Brick Slab (RB Slab) — Part 6/Section 4
Reinforced Brick Concrete Slab (RBC Slab) — Part 6/Section 4
Reinforced Masonry — Part 6/Section 4
Relative Humidity — Part 8/Section 3
Relaxation — Part 6/Section 5B
Reliability Centered Maintenance (RCM) — Part 12
Renewable Resource — Part 11
Repair, Renovate, Refurbish — Part 12
Retaining Device — Part 8/Section 5A
Residential Buildings — Part 6/Section 1
Residual Current — Part 8/Section 2
Residual Current Device — Part 8/Section 2
Residual Current Operated Circuit Breaker — Part 8/Section 2
Residual Current Operated Circuit Breaker with Integral Overcurrent Protection (RCBO) — Part 8/Section 2
Residual Current Operated Circuit Breaker without Integral Overcurrent Protection (RCCB) — Part 8/Section 2
Residual Head — Part 9/Section 1
Residual Operating Current — Part 8/Section 2
Residual Pressure — Part 9/Section 1
Residual Protection — Part 6/Section 8
Residual Waste — Part 12
Response Acceleration Coefficient of a Structure — Part 6/Section 1
Response Reduction Factor — Part 6/Section 1
Response Spectrum — Part 6/Section 1
Retiring Cam — Part 8/Section 5A
Return Period — Part 6/Section 1
Return Air — Part 8/Section 3
Reuse — Part 11
Reveal — Part 8/Section 1
Reverberation Time — Part 8/Section 4
Rheostatic Control — Part 8/Section 5A
Ride Quality — Part 8/Section 5B
Rise (Travel) — Part 8/Section 5B
Riser — Part 9/Section 4
Road — Part 2, Part 3
Road Line — Part 2, Part 3
Roof Battens — Part 6/Section 3B
Roof Exits — Part 4
Roof Sign — Part 10/Section 2
Roof Skeleton — Part 6/Section 3B
Room Height — Part 2, Part 3

The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement for determining the head room.

Room Index — Part 8/Section 1
Root Cause Analysis — Part 12
Roping Multiple — Part 8/Section 5A
Rotation — Part 6/Section 6
Round Trip Time (RTT) — Part 8/Section 5A
Routine Test — Part 6/Section 2
Row Housing/Row Type Building — Part 3

S

S-N Curve — Part 6/Section 6
Saddle — Part 9/Section 1, Part 9/Section 2
Safe Load — Part 6/Section 2
Safety Circuit — Part 8/Section 5B
Safety Devices — Part 8/Section 5B
Safety Gear — Part 8/Section 5A
Sanctioned Plan — Part 2
Sand — Part 6/Section 2

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Sand, Coarse — Part 6/Section 2
Sand, Fine — Part 6/Section 2
Sand, Medium — Part 6/Section 2
Sandwich Concrete Panels — Part 6/Section 7A, Part 6/ Section 7B
Sandwich, Structural — Part 6/Section 3A
Sanitary Appliances — Part 9/Section 2
Sanitary Land Filling — Part 12
Sanitary Waste — Part 12
Sap Stain — Part 6/Section 3A
Sapwood — Part 6/Section 3A
Scaffold — Part 7
Scope Creep — Part 12
Screen — Part 10/Section 1
Secondary Collection — Part 12
Secondary Member — Part 6/Section 6
Secondary Storage — Part 12
Sediment — Part 10/Section 1
Seismic Mass of Floor — Part 6/Section 1
Seismic Mass of Structure — Part 6/Section 1
Seismic Mode — Part 8/Section 5A
Seismic Stand-by Mode — Part 8/Section 5A
Seismic Trigger Level — Part 8/Section 5A
Seismic Weight of Floor — Part 6/Section 1.
Seismic Weight of Structure — Part 6/Section 1
Seismic Zone Factor — Part 6/Section 1
Segregation — Part 9/Section 3
Seismic Zone and Seismic Coefficient — Part 6/ Section 4
Selective Collective Automatic Operation — Part 8/ Section 5A
Self-Compacting Concrete — Part 6/Section 7A, Part 6/Section 7B
Semi-Compact Section — Part 6/Section 6
Semi-Detached Building — Part 3
Separation Section — Part 6/Section 4
Sensible Cooling — Part 8/Section 3
Sensible Heat — Part 8/Section 3
Server — Part 8/Section 6
Service — Part 8/Section 2
Service Life — Part 12
Service Lift — Part 8/Section 5A
**Service Pipe* — Part 9/Section 1, Part 9/Section 4
Service Road — Part 2, Part 3
Service Shut-Off Valve (Isolation Valve) — Part 9/ Section 4
Serviceability Limit State — Part 6/Section 6

* Definitions are different.

Set-Back Line — Part 2, Part 3

A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing can be constructed towards the site boundaries.

Sewer — Part 9/Section 2
Shade Factor — Part 8/Section 3
Shading Coefficient — Part 6/Section 8
Shake — Part 6/Section 3A
Shallow Area — Part 9/Section 1
Shallow Foundation — Part 6/Section 2
Shear Connectors — Part 6/Section 7A, Part 6/ Section 7B
Shear Force — Part 6/Section 6
Shear Lag — Part 6/Section 6
Shear Stress — Part 6/Section 6
Shear Wall — Part 6/Section 4
Sheathing — Part 6/Section 5B
Sheave — Part 8/Section 5A
Sheet Glass — Part 6/Section 8
Shelterbelt — Part 10/Section 1
Shielding Effect — Part 8/Section 2
Shock Current — Part 8/Section 2
Short-Circuit Current — Part 8/Section 2
Short Column — Part 6/Section 5B
Shrinkage Loss — Part 6/Section 5B
Shrub — Part 10/Section 1
Shutdown/Outage — Part 12
Sick Building Syndrome (SBS) — Part 8/Section 3
Sign — Part 10/Section 2
Sign Area — Part 10/Section 2
Sign Copy — Part 10/Section 2
Sign Face — Part 10/Section 2
Sign Structure — Part 10/Section 2
Signal Operation — Part 8/Section 5A
Silt — Part 6/Section 2
Silver — Part 6/Section 3B
Single Automatic Operation — Part 8/Section 5A
Single Floor Flight Time — Part 8/Section 5A
Single Floor Transit Time — Part 8/Section 5A
Single-Speed Alternating Current Control– Part 8/ Section 5A
Site (Plot) — Part 2, Part 3, Part 4

A parcel (piece) of land enclosed by definite boundaries.

Site, Corner — Part 3
Site, Depth of — Part 3

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Site, Double Frontage — Part 3
Site, Interior or Tandem — Part 3
Skimmer — Part 9/Section 1
Skirt Deflector — Part 8/Section 5B
Skirting — Part 8/Section 5B
Sky Component (SC) — Part 8/Section 1
Sky Lobby — Part 8/Section 5A
Sky Sign — Part 10/Section 2
Skylight — Part 6/Section 8
Skylight Roof Ratio (SRR) — Part 11
Slack Rope Switch — Part 8/Section 5A
Slender Column — Part 6/Section 5B
Slender Section — Part 6/Section 6
Slenderness Ratio — Part 6/Section 3B, Part 6/Section 4, Part 6/Section 6
Slip Resistance — Part 6/Section 6
Sliver — Part 6/Section 3B
Slop Hopper (Slop Sink) — Part 9/Section 2
Slope of Grain — Part 6/Section 3A
Sloped Overhead Glazing — Part 6/Section 8
Smart City/Building/Home — Part 8/Section 6
**Smoke Barrier* — Part 4, Part 8/Section 3
Smoke Compartment — Part 4
Smoke Damper — Part 8/Section 3
Smoke Management — Part 8/Section 3
Snag Point — Part 8/Section 5A
Snow Load — Part 6/Section 6
Snug Tight — Part 6/Section 6
Soakaway — Part 9/Section 2
Socket-Outlet — Part 8/Section 2
Soffit (Crown) — Part 9/Section 2
Soft Landscape– Part 10/Section 1
Soft Rock — Part 6/Section 2
Soil Appliances — Part 9/Section 2
Soil Densification — Part 6/Section 2
Soil, Highly Organic and Other Miscellaneous Soil — Part 6/Section 2
Soil Pipe — Part 9/Section 2
*Soil Reinforc*ement — Part 6/Section 2
Soil Waste — Part 9/Section 2
Soil, Black Cotton — Part 6/Section 2
Soil, Coarse Grained — Part 6/Section 2
Soil, Fine Grained — Part 6/Section 2
Soil, Highly Organic and Other Miscellaneous Soil Materials — Part 6/Section 2
Solar Energy Absorption — Part 6/Section 8
Solar Energy Transmittance (Direct) — Part 6/Section 8
Solar Heat Gain Coefficient (SHGC) — Part 6/Section 8
Solar Load — Part 8/Section 1
*Solar Reflectance Ind*ex — Part 11
Solid-State d.c. Variable Voltage Control — Part 8/Section 5A
Solidity Ratio — Part 6/Section 1
Sound — Part 8/Section 4, Part 8/Section 5A
Sound Exposure Level — Part 8/Section 4
Sound Knot — Part 6/Section 3A
Sound Level Difference — Part 8/Section 4
Sound Power — Part 8/Section 4
Sound Power Level — Part 8/Section 4
Sound Pressure Level, L_p — Part 8/Section 4, Part 8/Section 5B
Sound Pressure Level, $L_{p,A}$ — Part 8/Section 5A
Sound Pressure, p — Part 8/Section 4
Sound Receiver — Part 8/Section 4
Sound Reduction Index, R — Part 8/Section 4
Sound Source — Part 8/Section 4
Space — Part 3
Space Factor — Part 8/Section 2
Space Frame — Part 6/Section 4
Spaced Column — Part 6/Section 3A
Spandrel — Part 6/Section 8
Specified Compressive Strength of Masonry — Part 6/Section 4
Spectrum — Part 8/Section 4
Speech Interference Level (SIL) — Part 8/Section 4
Splicing — Part 8/Section 6
Split — Part 6/Section 3A
Splits — Part 6/Section 3B
Spot Elevation — Part 10/Section 1
Spot Faults — Part 6/Section 8
Spray-Head System– Part 8/Section 1
Spread (or Isolated or Pad) Foundation/Footing — Part 6/Section 2
Spring Buffer– Part 8/Section 5A
Spring Buffer Load Rating– Part 8/Section 5A
Spring Buffer Stroke– Part 8/Section 5A
Stability Limit State — Part 6/Section 6
Stabilization — Part 12
Stack Effect — Part 8/Section 1, Part 8/Section 3
Stack Pressure — Part 4
Stack Vent — Part 9/Section 2
Stain — Part 6/Section 8
Staircover (or Mumty) — Part 3
Stakeholder — Part 12

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Standardized Impact Sound Pressure Level — Part 8/Section 4
Standby Supply System — Part 8/Section 2
Standardized Level Difference — Part 8/Section 4
Static Pressure — Part 8/Section 3, Part 9/Section 1
Station — Part 4
Stationary Equipment — Part 8/Section 2
Station Platform — Part 4
Step Voltage — Part 8/Section 2
Stickability — Part 6/Section 6
Stiffener — Part 6/Section 6
Stock/Standard Sizes — Part 6/Section 8
Stop Tap — Part 9/Section 1
Stop-Cock — Part 9/Section 1
Storage — Part 9/Section 3
Storage Buildings — Part 6/Section 1
Storage Tank — Part 9/Section 1
Storey — Part 3

The portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.

Storey, Topmost — Part 3
Street — Part 2, Part 3

Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme and includes all bunds, channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

Street/Outdoor Furniture — Part 10/Section 1
Street Level or Grade — Part 2, Part 3

The officially established elevation or grade of the centre line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

Street Line — Part 2, Part 3, Part 10/Section 2

The line defining the side limits of a street.

Strain — Part 6/Section 6
Strain Hardening — Part 6/Section 6
Strength — Part 6/Section 6
Strength Limit State — Part 6/Section 6
Stress — Part 6/Section 6
Stress Analysis — Part 6/Section 6
Stress at Transfer — Part 6/Section 5B
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Stress Range — Part 6/Section 6
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Switch Disconnector Fuse — Part 8/Section 2
Switch — Part 8/Section 2
Switch, Linked — Part 8/Section 2
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System — Part 6/Section 7A, Part 6/Section 7B
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Tactile Ground Surface Indicators — Part 3
Tactile Guiding Blocks — Part 3
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Telecommunication Media and Connecting Hardware — Part 8/Section 6
Tendon — Part 6/Section 5B
Tensile Stress — Part 6/Section 6
Tempered Fire Resistant Glass — Part 6/Section 8
Tempered or Toughened Glass — Part 6/Section 8
Temporary Sign — Part 10/Section 2
Terminal Devices — Part 8/Section 3
Terminal Slow Down Switch — Part 8/Section 5A
Terminal Stopping Device Final — Part 8/Section 5A
Terminal Stopping Switch Normal– Part 8/Section 5A
Termite — Part 6/Section 3A
Terrain Category — Part 6/Section 1
Test Load — Part 6/Section 6
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Thermal Adaptation — Part 8/Section 3
Thermal Capacity — Part 11
Thermal Conductance (C) — Part 11
Thermal Conductivity (k) — Part 11
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Thermal Energy Storage — Part 8/Section 3
Thermal Insulation Material — Part 8/Section 3
Thermal Reflectivity — Part 11
Thermal Resistance (R) — Part 11
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Thermal Transmittance, U-Value — Part 6/Section 8
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Total Settlement — Part 6/Section 2
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Tree Drip Line — Part 10/Section 1
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Z

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* Definitions are different.

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NATIONAL BUILDING CODE OF INDIA

PART 2 ADMINISTRATION

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 2) covers the administrative aspects, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner and all related professionals.

A need for codifying and unifying administrative provisions in different development control rules and building byelaws had been felt, particularly in regard to the applicability of such provisions, desirable qualifications for the enforcing Authority and the representative of the owner and responsibilities and duties of the Authority and the owner.

It is expected that the town and country planning department, department of local bodies, municipal administration, urban development, etc, as the case may be will coordinate the administrative provisions of this Part and the same given in the State Town and Country Planning Act, Municipalities Act/Municipal Corporation/Local Bodies Act, Development Authorities Act, etc.

This Part recommends the setting up of a 'Board of Appeal'. The 'Board of Appeal' gives the owner/architect/engineer an opportunity to defend the schemes which are based on conventional or new methods of design and construction or using new materials, which have been otherwise rejected by the Authority.

This Part also emphasizes the need for setting up an Arts Commission for metropolitan areas to safeguard existing aesthetics in the event of new schemes proposed for buildings of public importance or buildings coming up in an important area near historic/monumental buildings. The Commission can assist the civic authorities in reviewing plans for development from the stand point of assuring good taste and regard for often threatened natural beauties. The Commission can serve as a means whereby the government and public bodies and individuals could get advice on artistic questions in connection with building schemes.

The first version of this Part was brought out in 1970, which was subsequently revised in 1983 and 2005. As a result of implementing 1970 version of this Part in rewriting building byelaws and development control rules of some municipal corporations and municipalities, some useful suggestions were emerged. These were incorporated in the first revision to the extent possible. The significant changes in 1983 version of this Part included the new administrative provisions related to development control rules, additional information to be furnished/indicated in the building plan for multistoreyed and special buildings and modified provisions regarding submission of building plans by Government Departments to the Authority.

In the second revision, number of modifications were incorporated based on the experience gained over the years then. The provisions of this Part were thoroughly reviewed in the context of the natural calamities faced by the country then, such as the devastating earthquake in Gujarat in the year 2001, and provisions were modified accordingly to further ensure structural adequacy of the buildings. Structural design of buildings in accordance with the provisions of the Code and construction and supervision thereof by competent professionals to ensure structural safety were given due importance in the revision. Other significant modifications incorporated in the 2005 revision were: inclusion of the concept of team of building officials; provision of single window approach for permit for all services; provisions regarding computerization of approval process for building permit; provision to certify safety of buildings against natural disaster by engineer/structural engineer and owner; provision of two stage permit for high rise residential buildings and special buildings; provisions regarding inspection of completed and occupied building by the Authority from safety point of view; provision empowering engineers/architects for sanctioning plans of residential buildings up to 500 m^2; and modifications in the provisions for architectural control to effectively take care of the urban aesthetics, and inclusion of architectural engineer, landscape architect and urban designer among the registered professionals for the concerned applicable works.

In this third revision, number of modifications have been incorporated based on the experience gained over the years specially in the implementation of techno-administrative and techno-legal regime encountered and with a

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view to strengthening the structural safety mechanism in building permit process. The significant modifications made in this revision are as follows:

a) Geotechnical engineer has been included among the registered professionals for the concerned applicable works;
b) With a view to ensuring ease of doing business in the built environment sector, a detailed provision for streamlining the approval process in respect of different agencies has been incorporated in the form of an integrated approval process through single window approach for enabling expeditious approval process, avoiding separate clearances from various authorities;
c) Provision on computerization of approval process has been detailed enabling online submission of plans, drawings and other details, and sanction thereof aiding in quicker approval process;
d) Provision has been made for getting the design, drawings and details of buildings peer reviewed/proof checked in case of important projects and projects having high complexity and sensitivity, before approving the same;
e) Responsibility of the owner seeking occupancy permit from the Authority has been detailed;
f) Provision of periodic audit of designated public buildings for accessibility for the elderly and persons with disabilities, has been included;
g) Qualification and competence of builder/constructor has been added along with the form for their engagement;
h) Form for certificate for subsurface investigation, wherever applicable, has been added;
j) Form for certificate for completed structural design work as per structural safety requirements has been included;
k) Form for certificate for supervision of work has been rationalized;
m) Form for certificate for completed work by constructor, has been added; and
n) Form for completion certificate has been rationalized.

The Sectional Committee responsible for the revision of the Code had examined the use of the words ‘surveyor/ building surveyor/supervisor’, etc, under various building byelaws with varying qualifications in different states. It was decided not to use the generic word ‘surveyor’ or such other words. The Sectional Committee had, on the other hand recommended association of various professionals for various job responsibilities depending upon their qualifications/competence.

The Sectional Committee observed that this Part has been so formulated as to ensure quality and safety in the whole gamut of activities primarily divided into planning, design, execution and supervision. This has been ensured by obtaining certification from the registered professionals involved in planning, design and supervision. Apart from these, various other persons are involved whose contribution may be duly taken into account depending on the type, nature, magnitude and complexity of the project, such as fire protection engineer, security system specialist, environment specialist/sustainability specialist, accessibility specialist, interior designer, project management consultant, etc, in proper planning, design, erection, commissioning and operation of buildings and built environment.

Also, it was noted that the words ‘licencing/licensed, etc’ were in use by local bodies in different states. The Sectional Committee, however, decided for use of words ‘registration/registered, etc’ for the same, which may be adopted uniformly. The registration requirements of professionals are given in Annex A.

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NATIONAL BUILDING CODE OF INDIA

PART 2 ADMINISTRATION

SECTION 1 GENERAL

1 SCOPE

This Code (Part 2) covers the administrative aspects of the Code, such as applicability of the Code, organization of building department for enforcement of the Code, procedure for obtaining development and building permits, and responsibility of the owner.

NOTE — This Code is called the National Building Code of India, hereinafter referred to as 'the Code'.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

2.1 Accessory Use — Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

2.2 Alteration — A change from one type of occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

2.3 Approved — Approved by the Authority having jurisdiction.

2.4 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.5 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, verandah, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents/ *Shamianahs*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.6 Building, Height of — The vertical distance measured, in the case of flat roofs from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof, and in the case of gables facing the road, the midpoint between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

2.7 Building Line — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time to time as decided by the Authority.

2.8 Conversion — The change of occupancy or premises to any occupancy or use requiring additional occupancy permit.

2.9 Development — 'Development' with grammatical variations means the carrying out of building, engineering, mining or other operations in, or over, or under land or water, or in the use of any building or land, and includes redevelopment and layout and subdivision of any land; and 'to develop' shall be construed accordingly.

2.10 Drain — A conduit or channel for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

2.11 Drainage — The removal of any liquid by a system constructed for the purpose.

2.12 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy, an occupancy shall be deemed to include the subsidiary occupancies which are contingent upon it.

2.13 Occupier — It includes any person for the time being, paying or liable to pay rent or any portion of rent of the building in respect of which the ward is used, or compensation or premium on account of the occupation of such building and also a rent-free tenant, but does not include a lodger, and the words 'occupy' and 'occupation' do not refer to the lodger.

An owner living in or otherwise using his own building shall be deemed to be the occupier thereof.

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2.14 Operational Construction/Installation — A construction/installation put up by Government Departments for operational purposes (*see* **12.1.2.1**).

2.15 Owner — A person, a group of persons or a body having a legal interest in land and/or building thereon. This includes freeholders, leaseholders or those holding a sublease, who will have a legal right to occupation and have liabilities in respect of safety or building condition.

In case of lease or sublease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

2.16 Permit — A permission or authorization in writing by the Authority to carry out work regulated by the Code.

2.17 Registered Architect, Engineer, Structural Engineer, Geotechnical Engineer, Supervisor, Town Planner, Landscape Architect, Urban Designer — A qualified architect, engineer, structural engineer, geotechnical engineer, supervisor, town planner, landscape architect or urban designer who has been registered by the Authority or by the body governing such profession and constituted under a statute, as may be applicable. The registration requirements of these professionals shall be as given in Annex A.

NOTES

1 Unless specified otherwise, the world 'engineer' shall mean 'civil engineer' or 'architectural engineer'.

2 The word 'licencing/licensed', etc, if used by the Authority in the above context, shall be deemed to mean 'registration/ registered', etc.

2.18 Road — *See* **2.25**.

2.19 Road Line — *See* **2.27**.

2.20 Room Height — The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement for determining the head room.

2.21 Sanctioned Plan — The set of plans, specifications and other details submitted in connection with a building or development and duly approved and sanctioned by the Authority.

2.22 Service Road — A road/lane provided at the rear or side of a plot for service purposes.

2.23 Set-Back Line — A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing can be constructed towards the site boundaries.

2.24 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.25 Street — Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme and includes all bunds, channels, ditches, storm-water drains, culverts, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

2.26 Street Level or Grade — The officially established elevation or grade of the centre line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

2.27 Street Line — The line defining the side limits of a street.

2.28 To Erect — To erect a building means,

a) to erect a new building on any site whether previously built upon or not;
b) to re-erect any building of which portions above the plinth level have been pulled down, burnt or destroyed.

2.29 Unsafe Building — Buildings which are structurally and constructionally unsafe or insanitary or not provided with adequate means of egress or which constitute a fire hazard or are otherwise dangerous to human life or which in relation to existing use constitute a hazard to safety or health or public welfare, by reason of inadequate maintenance, dilapidation or abandonment.

3 APPLICABILITY OF THE CODE

3.1 All Parts of the Code and their Sections shall apply to all buildings described in **3.2** to **3.8**, as may be applicable.

3.2 Where a building is erected, the Code applies to the design and construction of the building.

3.3 Where the whole or any part of the building is removed, the Code applies to all parts of the building whether removed or not.

3.4 Where the whole or any part of the building is demolished the Code applies to any remaining part and to the work involved in demolition.

3.5 Where a building is altered (*see* **12.4** and **12.4.1**), the Code applies to the whole building whether existing or new except that the Code applies only to part, if that part is completely self contained with respect to facilities and safety measures required by the Code.

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3.6 Where the occupancy of a building is changed the Code applies to all parts of the building affected by the change.

3.7 Where development of land is undertaken the Code applies to the entire development of land.

3.8 Existing Buildings/Development

Nothing in the Code shall require the removal, alteration or abandonment, nor prevent continuance of the use or occupancy of an existing building/development, unless in the opinion of the Authority, such building/development constitutes a hazard to the safety of the adjacent property or the occupants of the building itself.

4 INTERPRETATION

4.1 The heading which appears at the beginning of a clause or sub-clause of the Code shall be deemed to be a part of such clause or sub-clause, respectively.

4.2 The use of present tense includes the future tense, the masculine gender includes the feminine and the neuter, the singular number includes the plural and the plural includes the singular. The word 'person' includes a corporation as well as an individual; writing includes printing and typing and 'signature' includes thumb impression made by a person who cannot write if his name is written near to such thumb impression.

5 ALTERNATIVE MATERIALS, METHODS OF DESIGN AND CONSTRUCTION, AND TESTS

5.1 The provisions of the Code are not intended to prevent the use of any material or method of design or construction not specifically prescribed by the Code, provided any such alternative has been approved.

5.2 The Authority may approve any such alternative provided it is found that the proposed alternative is satisfactory and conforms to the provisions of relevant parts regarding material, design and construction and that material, method, or work offered is, for the purpose intended, at least equivalent to that prescribed in the Code in quality, strength, compatibility, effectiveness, fire and water resistance, durability and safety.

5.3 Tests

Whenever there is insufficient evidence of compliance with the provisions of the Code or evidence that any material or method of design or construction does not conform to the requirements of the Code or in order to substantiate claims for alternative materials, design or methods of construction not specifically prescribed in the Code, the Authority may require tests sufficiently in advance as proof of compliance. These tests shall be made by an approved agency at the expense of the owner.

5.3.1 Test methods shall be specified by the Code for the materials or design or construction in question. If there are no appropriate test methods specified in the Code, the Authority shall determine the test procedure. For methods of test for building materials, reference may be made to Part 5 'Building Materials' of the Code.

5.3.2 Copies of the results of all such tests shall be retained by the Authority for a period of not less than two years after the acceptance of the alternative material.

SECTION 2 ORGANIZATION AND ENFORCEMENT

6 DEPARTMENT OF BUILDINGS

6.1 The department of buildings shall be created by the Authority and a team of building officials shall be appointed to carry out work of such department.

6.2 Appointment of Team of Building Officials

The team of building officials shall be appointed by the Authority. The team shall comprise officials drawn from concerned disciplines such as engineer, architect, town planner, landscape architect and urban designer as may be decided by the Authority. For scrutiny of layout plans of plots of one hectare and above in metro cities and two hectares and above in other places, town planner shall be part of the team of building officials. For plots of five hectares and above, landscape architect shall also be part of the team. An urban designer shall also be required to be the part of team of building officials for examining proposals on integrated urban design and development for residential/business/institutional and assembly building.

NOTE — Metro cities are cities with population more than 1 000 000.

6.3 Organization

In the department of buildings, such number of officers, technical assistants, inspectors and other employees shall be appointed to assist the team of building officials as shall be necessary for the administration of the Code and as authorized by the Authority.

6.4 Delegation of Powers

The Authority may designate one of the building officials who shall exercise all the powers of the team of building officials. The work of the team of building officials may be outsourced to competent professional/agency/group as may be deemed necessary.

6.5 Qualification of Building Officials

The qualification of building officials scrutinizing the plans and carrying out inspection of buildings shall not

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in any case be less than those prescribed in Annex A.

6.5.1 In small local bodies having insufficient resources to appoint such officials with the above qualifications, two or three such bodies contiguously located could join together and share the services of one team of building officials.

6.6 Qualifications of Assistant

No person shall be appointed as assistant unless he has got the qualifications prescribed in Annex A for a registered supervisor.

6.7 Restriction on Employees

No official or employee connected with the department of buildings except one whose only connection is that of a member of the Board of Appeals, established under **8** shall be engaged directly or indirectly in a work connected with the furnishing of labour, materials or appliances for the construction, alteration or maintenance of a building, or the preparation of plans or of specifications thereof unless he is the owner of building; nor shall such official or employee engage in any work which conflicts with his official duties or with the interests of the department.

6.8 Records

Proper records of all applications received, permits and orders issued, inspections made shall be kept and copies of all papers and documents connected with the administration of its duties shall be retained and all such records shall be open to public inspection at all appropriate times.

7 POWER AND DUTIES OF TEAM OF BUILDING OFFICIALS

The team of building officials shall enforce all the provisions of the Code and shall act on any question relative to the mode or manner of construction and the materials to be used in the erection, addition, alteration, repair, removal, demolition, installation of service equipment and the location, use, occupancy and maintenance of all buildings except as may otherwise be specifically provided.

7.1 Application and Permits

The team of building officials shall receive all applications and issue permits (*see* **12.10**) for the erection and alteration of buildings and examine the premises for which such permits have been issued and enforce compliance with the Code.

7.2 Building Notices and Orders

The team of building officials shall issue all necessary notices or orders to remove illegal or unsafe conditions, to require the necessary safeguards during construction, to require adequate exit facilities in existing buildings and to ensure compliance with all the requirements of safety, health and general welfare of the public as included in the Code.

7.3 Right of Entry

Upon presentation of proper credentials and with advance notice, the team of building officials or its duly authorized representative may enter at any reasonable time any building or premises to perform any duty imposed upon him by the Code.

7.4 Inspection

The team of building officials shall make all the required inspections or it may accept reports of inspections of authoritative and recognized services or individuals; and all reports of inspections shall be in writing and certified by a responsible officer of such authoritative service or by the responsible individual or engage any such expert opinion as he may deem necessary to report upon unusual technical issues that may arise, subject to the approval of the Authority.

7.5 Construction Not According to Plan

Should the team of building officials determine at any stage that the construction is not proceeding according to the sanctioned plan or is in violation of any of the provisions of the Code, or any other applicable Code Regulation, Act or Byelaw, it shall notify the owner, and all further construction shall be stayed until correction has been effected and approved.

7.5.1 Should the owner fail to comply with the requirements at any stage of construction, the Authority shall issue a notice to the owner asking explanation for non-compliance. If the owner fails to comply within 14 days from the date of receiving the notice, the Authority shall be empowered to cancel the building permit issued and shall cause notice of such cancellation to be securely pasted upon the said construction, if the owner is not traceable at his address given in the notice. Pasting of such a notice shall be considered sufficient notification of cancellation to the owner thereof. No further work shall be undertaken or permitted upon such construction until a valid building permit thereafter has been issued. If the owner, in violation of the notice for cancellation, continues the construction, the Authority may take all necessary means to stop such work and further appropriate actions including demolitions. The owner shall, however, have right to appeal against cancellation of permit, to the board of appeal, within a stipulated period, as may be decided by the Authority.

7.6 Modification

Wherever practical difficulties are involved in carrying

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out any provision of the Code, the team of building officials may vary or modify such provisions upon application of the owner or his representative provided the spirit and intent of the Code shall be observed and public welfare and safety be assured. The application for modification and the final decision of the team of building officials shall be in writing and shall be officially recorded with the application for the permit in the permanent records of the Department of Building Inspection.

7.7 Occupancy Violations

Wherever any building is being used contrary to provisions of the Code, the team of building officials may order such use discontinued and the building or portion thereof, vacated by the notice served on any person, causing such use to be discontinued. Such person shall discontinue the use within 10 days after receipt of such notice or make the building or portion thereof, comply with the requirements of the Code.

8 BOARD OF APPEALS

In order to determine the suitability of alternative materials or methods of design or construction and to provide for reasonable interpretation of the provisions of the Code or in the matter of dispute relating to an ongoing construction *vis-a-vis* the sanctioned plan, a Board of Appeals consisting of members who are qualified by experience and training and to pass judgement upon matters pertaining to building construction, shall be appointed by the Authority. A representative of the team of building officials shall be an *ex-officio* member and shall act as secretary to the Board. The Board shall adopt reasonable rules and regulations for conducting its investigations and shall render all decisions and findings in writing to the team of building officials with a duplicate copy to the appellant and may recommend such modifications as are necessary.

9 VIOLATIONS AND PENALTIES

9.1 Offences and Penalties

9.1.1 Any person who contravenes any of the provisions of the Code or any requirements of obligations imposed on him by virtue of the Code, or who interferes with or obstructs any person in the discharge of his duties, shall be guilty of an offence and the Authority shall levy suitable penalty or take other actions as per the Code (*see also* **7.5** and **15**).

NOTE — The penalty may be in the form of collection of arrears of tax.

9.1.2 The buildings/developments violating any applicable statutory rules shall be demolished/brought within the limits as prescribed in such rules at the expense of the owner. The buildings coming up in the vicinity of an aerodrome in violation of the height restriction laid down by the Directorate General of Civil Aviation shall be accordingly demolished/brought within the limits prescribed by DGCA rules.

9.1.3 The registered architect, engineer, structural engineer, supervisor, town planner, landscape architect, urban designer and utility service engineer (*see* Annex A) responsible for the services rendered for supervision of the construction/development and for the completion certificate; in the event of violation of the provisions of the Code, shall be liable to penalties as prescribed by the Authority including cancellation of registration done by it or make such recommendation to the statutory body governing such profession.

9.2 Further Obligation of Offender

The conviction of any person for an offence under the provision of **9.1** shall not relieve him from the duty of carrying out the requirements or obligations imposed on him by virtue of the provisions of the Code; and if such requirements or obligations are not complied with in accordance with an order made under provisions of **9.1**, the Authority under the provisions of the Code may, if necessary and advisable, enter upon the premises in respect of which a conviction has been made and carry out at the expense of the convicted person, the requirements or obligations referred to in the said order and the expense, if not paid on demand, may be recovered with cost in a court.

9.3 Conviction No Bar to Further Prosecution

The conviction of any person under the provisions of this part for failing to comply with any of the said requirements or obligations shall not operate as a bar to further prosecution under this part for any subsequent failure on the part of such person to comply.

10 POWER TO MAKE RULES

The Authority may make rules for carrying out the provisions and intentions of the Code provided that any rule shall not be in direct/indirect conflict or nullify/ dilute any of the provisions of the Code.

SECTION 3 PERMIT AND INSPECTION

11 DEVELOPMENT/BUILDING PERMIT

11.1 Permit Required

11.1.1 No person shall carry out any development, erect, re-erect or make alterations or demolish any building or cause the same to be done without first obtaining a separate permit for each such development/building from the Authority. No permit shall, however, be required for works referred to in **12.1.2.1** and **12.4.1**.

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11.1.2 The development/building permit shall take into cognizance the provisions under the relevant Town Planning Act/Development Act/Municipal Act/any other applicable statutes for layout, building plans, water supply, sewerage, drainage, electrification, etc, as provided in the said Act/statute. Also, if so directed by the Authority, the permit shall take care of the need for landscape development plan in the layout and building plans.

11.1.3 Specific approvals shall be obtained from Airports Authority of India, Ministry of Environment, Forest and Climate Change, Fire Services Department, Pollution Control Board, designated authorities under Factories Act/Cinema Regulation Act, Urban Arts Commission, designated Coastal Regulation Zone Authority, Archaeological Survey of India, Heritage Committee and any such other authority as may be applicable. Approval of Fire Services Department shall be required for buildings of height 15 m or above and for such other buildings/special buildings referred to in Part 4 'Fire and Life Safety' of the Code.

11.1.4 *Integrated Approval Process*

11.1.4.1 In order to facilitate ease of doing business and ensure efficient and expeditious clearance from above bodies with the concept of single window clearance approach and thereby final approval by the Authority within the stipulated time frame, the Authority may constitute a Development/Building Permit Approval Committee consisting of representatives of the team of building officials, representatives of all bodies/organizations from whom clearance for development/building permit clearance is required.

Recommendations from such Committee shall be summarily utilized by the team of building officials in sanctioning process. The Committee may meet once in 15/30 days depending upon the work load. The first response/invalid notice/non-compliance intimation shall be issued by the Authority to the owner within 30 days of submission of the plans to the Authority (*see also* **12.10.2**).

11.1.4.2 It would be more appropriate that all the above authorities may make the information available in public domain delineating clearly the situations requiring their clearance. This information being available to the Authority as well, should be utilized by the Authority in deciding on the required sanction or otherwise without the need to go to the above multiple authorities. This can be achieved by providing, for necessary reference of the Authority, simplified environmental guidelines by the Ministry of Environment, Forest and Climate Change; colour coded zoning maps for Airports depicting restrictions imposed near airports, by Airports Authority of India; information on categorization of monuments with concerned degree of restrictions, by National Monuments Authority; etc.

The above could be further facilitated, if such requirements in respect of clearances from all such authorities be integrated in the Development Control Rules of the Master/Development Plan of the concerned city/town. The areas unaffected by any of the restrictions should be clearly marked out and mapped, preferably on a GIS platform. Area zones of differential control regulations (within the city) by any of these authorities may also be mapped accordingly so as to result in a composite map of the city/town with various control regulations by different authorities, clearly marked on the map. The sites which are located outside the restricted/regulated areas would not require availing clearance from the respective authorities.

Such integrated approval by the Authority shall be accorded within the time limit of 30 days (*see also* **12.10.2**).

11.1.5 The Authority shall permit a registered architect/ engineer to approve the building proposals including plans, and certify completion of building for issue of related regulatory building permits and occupancy certificate for residential buildings designed by self or otherwise, on plot size up to 500 m^2. The responsibility of compliance with respect to provisions of Code shall rest with the registered architect/engineer. However, the plans shall be required to be submitted to the Authority for information and records.

NOTE — Where the experience clearly shows that satisfactory building permit activities are being carried out through the above empowerment of professionals, the Authority may extend such provision for larger areas and other building occupancies.

11.2 Pre-Code Development/Building Permit

If any development/building, permit for which had been issued before the commencement of the Code, is not wholly completed within a period of three years from the date of such permit, the said permission shall be deemed to have lapsed and fresh permit shall be necessary to proceed further with the work in accordance with the provisions of the Code.

12 APPLICATION FOR DEVELOPMENT/ BUILDING PERMIT

12.1 Application

Every owner who intends to develop, erect, re-erect or make alterations in any place in a building shall give an application in writing to the Authority of his said intention in the prescribed form (*see* Annex B) and such notice shall be accompanied by plans and statements in triplicate as required under **12.2** and **12.3** except for special buildings (high rise, non-residential) where

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additional copies may be submitted as desired by the Authority. The Authority shall permit submission of plans/documents in electronic form.

12.1.1 *Computerization of Approval Process*

The Authority should progressively computerize the approval process. This may involve facilitating submission of building plans and other documents and requisite fee online by uploading the same through the designated portal of the Authority as well as sanction online. It may also require instituting appropriate procedure for registration and traceability along with responsibility of the applicant making such submissions.

12.1.2 Regarding submission of plans by Government Departments, the procedure shall be as given in **12.1.2.1** and **12.1.2.2**.

12.1.2.1 The operational construction/installation of the Government, whether temporary or permanent, which is essential for the operation, maintenance, development or execution of any of the following services may be exempted from the point of view of the byelaws:

a) Railways;
b) National highways;
c) National waterways;
d) Major ports;
e) Airways and aerodromes;
f) Posts and telegraphs, telephones, wireless, broadcasting, and other like forms of communications;
g) Regional grid for electricity;
h) Defence; and
j) Any other service which the Central/State Government may, if it is of opinion that the operation, maintenance, development of execution of such service is essential to the life of the community, by notification, declare to be a service for the purpose of this clause.

In case of construction/installation where no approvals are required, the concerned agencies which are exempted from seeking approval shall submit the drawings/plans/details for information and records of the Authority before construction/installation. The provisions of the Code, as applicable, shall however be followed for all such developments.

12.1.2.2 However, the following construction of the Government departments do not come under the purview of operational construction for the purpose of exemption under **12.1.2.1**:

a) New residential building (other than gate lodges, quarters for limited essential operational staff and the like), roads and drains in railway colonies, hospitals, clubs, institutes and schools, in the case of railways; and
b) A new building, new construction or new installation or any extension thereof in the case of any other services.

12.2 Information Accompanying Notice

The notice shall be accompanied by the key plan, site plan, building plan, services plans, specifications, structural sufficiency certificate and certificate of supervision as prescribed in **12.2.2** to **12.2.8**.

12.2.1 *Sizes of Drawing Sheets and Recommended Notation for Colouring Plans*

12.2.1.1 The size of drawing sheets shall be any of those specified in Table 1.

Table 1 Drawing Sheet Sizes
(*Clause* 12.2.1.1)

Sl No.	Designation	Trimmed Size mm
(1)	(2)	(3)
i)	A0	841 × 1189
ii)	A1	594 × 841
iii)	A2	420 × 594
iv)	A3	297 × 420
v)	A4	210 × 297
vi)	A5	148 × 210

12.2.1.2 The plans shall be coloured as specified in Table 2.

12.2.2 *Key Plan*

A key plan drawn to a scale of not less than 1 : 10 000 shall be submitted along with the application for a development/building permit showing the boundary locations of the site with respect to neighbourhood landmarks. The minimum dimension of the key plan shall be not less than 75 mm.

12.2.3 *Site Plan*

The site plan sent with an application for permit shall be drawn to a scale of not less than 1 : 500 for a site up to one hectare and not less than 1 : 1 000 for a site more than one hectare and shall show,

a) the boundaries of the site and of any contiguous land belonging to the owner thereof;
b) the position of the site in relation to neighbouring street;
c) the name of the streets in which the building is proposed to be situated, if any;
d) all existing buildings standing on, over or under the site including service lines;
e) the position of the building and of all other

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Table 2 Colouring of Plans
(*Clause* 12.2.1.2)

Sl No.	Item	Site Plan			Building Plan		
		White Plan	Blue Print	Ammonia Print	White Plan	Blue Print	Ammonia Print
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Plot lines	Thick black	Thick black	Thick black	Thick black	Thick black	Thick black
ii)	Existing street	Green	Green	Green	—	—	—
iii)	Future street, if any	Green dotted	Green dotted	Green dotted	—	—	—
iv)	Permissible building lines	Thick dotted black	Thick dotted black	Thick dotted black	—	—	—
v)	Open spaces	No colour	No colour	No colour	No colour	No colour	No colour
vi)	Existing work	Black (outline)	White	Blue	Black	White	Blue
vii)	Work proposed to be demolished	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched	Yellow hatched
viii)	Proposed work (*see* Note 1)	Red filled in	Red	Red	Red	Red	Red
ix)	Drainage and sewerage work	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted	Red dotted
x)	Water supply work	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin	Black dotted thin

NOTES
1 For entirely new construction this need not be done; for extension of an existing work this shall apply.
2 For land development, subdivision, layout, suitable colouring notations shall be used which shall be indexed.

buildings (if any) which the applicant intends to erect upon his contiguous land referred to in (a) in relation to:

1) the boundaries of the site and in case where the site has been partitioned, the boundaries of the portion owned by the applicant and also of the portions owned by others;
2) all adjacent street, buildings (with number of storeys and height) and premises within a distance of 12 m of the site and of the contiguous land (if any) referred to in (a); and
3) if there is no street within a distance of 12 m of the site, the nearest existing street;

f) the means of access from the street to the building, and to all other buildings (if any) which the applicant intends to erect upon his contiguous land referred to in (a);
g) space to be left about the building to secure a free circulation of air, admission of light and access for scavenging purposes;
h) the width of the street (if any) in front and of the street (if any) at the side or near the buildings;
j) the direction of north point relative to the plan of the buildings;
k) any physical features, such as wells, drains, etc; and
m) such other particulars as may be prescribed by the Authority.

12.2.4 *Subdivision/Layout Plan*

In the case of development work, the notice shall be accompanied by the subdivision/layout plan which shall be drawn on a scale of not less than 1 : 500 containing the following:

a) Scale used and north point;
b) Location of all proposed and existing roads with their existing/proposed/prescribed widths within the land;
c) Dimensions of plot along with building lines showing the setbacks with dimensions within each plot;
d) Location of drains, sewers, public facilities and services, and electrical lines, etc;
e) Table indicating size, area and use of all the plots in the subdivision/layout plan;
f) A statement indicating the total area of the site, area utilized under roads, open spaces for parks, playgrounds, recreation spaces and development plan reservations, schools, shopping and other public places along with their percentage with reference to the total area of the site proposed to be subdivided; and
g) In case of plots which are subdivided in built-up areas in addition to the above, the means of access to the subdivision from existing streets.

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12.2.5 *Building Plan and Details*

The plan of the buildings and elevations and sections accompanying the notice shall be drawn to a scale of 1 : 100. The plans and details shall,

a) include floor plans of all floors together with the covered area clearly indicating the size and spacings of all framing members and sizes of rooms and the position of staircases, ramps and liftwells;
b) show the use or occupancy of all parts of the buildings;
c) show exact location of essential services, for example, WC, sink, bath and the like;
d) include at least one elevation from the front showing height of building and rooms and also the height of parapet.
e) include at least one section through the staircase.
f) include the structural arrangements with appropriate sections showing type/ arrangement of footings, foundations, basement walls; structural load bearing walls, columns and beams, and shear walls; and arrangement/spacing of framing members, floor slabs and roof slabs with the material used for the same.
g) show all street elevations;
h) give dimensions of the projected portions beyond the permissible building line;
j) include terrace plan indicating the drainage and the slope of the roof; and
k) give indications of the north point relative to the plan.

NOTE — The requirement of 1 : 100 is permitted to be flexible for specific details needed for further illustration; and also for drawings for these in electronic form.

12.2.5.1 *Building plan for high rise/special buildings*

For all high rise buildings which are 15 m or more in height and for special buildings like educational, assembly, institutional, business, mercantile, industrial, storage and hazardous and mixed occupancies with any of the aforesaid occupancies having covered area more than 500 m^2 (*see also* Part 4 'Fire and Lift Safety' of the Code), the building sanction shall be done in two stages. In case of important projects and projects having high complexity and sensitivity, the Authority may get the design, drawings and details of such buildings peer reviewed/proof checked before approving the same.

Stage 1 : Planning clearance

The following additional information shall be furnished/ indicated in the building plan in addition to the items given in **12.2.5** as applicable:

a) Access to fire appliances/vehicles with details of vehicular turning circle and clear motorable accessway around the building;
b) Size (width) of main and alternative staircases along with balcony approach, corridor, ventilated lobby approach;
c) Location and details of lift enclosures;
d) Location and size of fire lift;
e) Smoke stop lobby/door, where provided;
f) Refuse chutes, refuse chamber, service duct, etc;
g) Vehicular parking spaces;
h) Refuge area, if any;
j) *Details of building services* — Air conditioning system with position of fire dampers, mechanical ventilation system, electrical services, boilers, gas pipes, etc;
k) Details of exits including provision of ramps, etc, for hospitals and special risks;
m) Location of generator, transformer and switchgear room;
n) Smoke exhauster system, if any;
p) Details of fire alarm system network;
q) Location of centralized control, connecting all fire alarm systems, built-in-fire protection arrangements and public address system, etc;
r) Location and dimensions of static water storage tank and pump room along with fire service inlets for mobile pump and water storage tank;
s) Location and details of fixed fire protection installations such as sprinklers, wet risers, hose-reels, drenchers, etc; and
t) Location and details of first-aid firefighting equipment/installations.
u) Features relating to accessibility for the elderly and persons with disabilities, shall be in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code for the designated buildings and areas.

Stage 2 : *Building permit clearance*

After obtaining the sanction for planning (Stage 1) from the Authority, a complete set of structural plans, sections, details, design calculations duly signed by engineer/structural engineer (*see* Annex A) along with the complete set of details duly approved in Stage 1 and certificate of completed structural design work (*see* Annex J) shall be submitted. A copy of the subsurface investigation report prepared and duly signed by the geotechnical engineer shall also be submitted. The building plans/details shall be deemed sanctioned for the commencement of construction only after obtaining

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the permit for Stage 2 from the Authority.

12.2.6 *Services Plans*

The services plans shall include all details of building and plumbing services, and also plans, elevations and sections of private water supply, sewage disposal system and rainwater harvesting system, if any (*see* Part 8 'Building Services' and Part 9 'Plumbing Services' of the Code).

12.2.7 *Specifications*

Specifications, both general and detailed, giving type and grade of materials to be used, duly signed by the registered architect, engineer, structural engineer or supervisor shall accompany the application (*see* Annex B).

12.2.8 *Structural Design Sufficiency Certificate*

The application shall be accompanied by structural sufficiency certificate in the prescribed form (*see* Annex C) signed by the engineer/structural engineer (*see* Annex A) and the owner jointly to the effect that the building is safe against various loads, forces and effects including due to natural disasters such as earthquakes, landslides, cyclones, floods, etc as per National Building Code of India and its Part 6 'Structural Design' and other relevant Codes. The engineer/structural engineer shall also have the details to substantiate his design.

12.2.9 *Execution and Supervision*

The notice shall be further accompanied by a certificate in the prescribed form (*see* Annex D) by a builder/ constructor (*see* Annex A) undertaking the execution.

The notice shall also be accompanied by a certificate in the prescribed form (*see* Annex E) by the registered architect/engineer/structural engineer/supervisor/town planner (*see* Annex A) undertaking the supervision (*see* **9.1.3**).

12.3 Preparation and Signing of Plans

The registered architect/engineer/supervisor/town planner/landscape architect/urban designer/utility service engineer shall prepare and duly sign the plans as per their competence (*see* Annex A) and shall indicate his/her name, address, qualification and registration number as allotted by the Authority or the body governing such profession. The structural plans and details shall also be prepared and duly signed by the competent professionals like registered engineer/ structural engineer (*see* Annex A). The plans shall also be duly signed by the owner indicating his address. The type and volume of buildings/development work to be undertaken by the registered professionals may generally be as in Annex A.

12.4 Notice for Alteration Only

When the notice is only for an alteration of the building (*see* **3.5**), only such plans and statements, as may be necessary, shall accompany the notice.

12.4.1 No notice and building permit is necessary for the following alterations, and the like which do not otherwise violate any provisions regarding general building requirements, structural stability and fire and health safety requirements of the Code:

a) Opening and closing of a window or door or ventilator;
b) Providing intercommunication doors;
c) Providing partitions;
d) Providing false ceiling;
e) Gardening;
f) White washing;
g) Painting;
h) Re-tiling and re-roofing;
j) Plastering and patch work;
k) Re-flooring; and
m) Construction of sunshades on one's own land.

12.5 Fees

No notice as referred to in **12.1** shall be deemed valid unless and until the person giving notice has paid the fees to the Authority and an attested copy of the receipt of such payment is attached with the notice.

NOTE — The fees may be charged as a consolidated fee. In the event of a building/development permit is not issued, the fees so paid shall not be returned to the owner, but he shall be allowed to re-submit it without any fees after complying with all the objections raised by the Authority within a period of one year from the date of rejection after which fresh fees shall have to be paid.

12.6 Duration of Sanction

The sanction once accorded shall remain valid up to three years. The permit shall be got revalidated before the expiration of this period. Revalidation shall be subject to the rules then in force.

12.7 Deviations During Construction

If during the construction of a building any departure (excepting for items as given in **12.4.1**) from the sanctioned plan is intended to be made (*see* **7.5**), sanction of the Authority shall be obtained before the change is made. The revised plan showing the deviations shall be submitted and the procedure laid down for the original plan heretofore shall apply to all such amended plans except that the time limit specified under **12.10.2** shall be three weeks in such cases.

12.8 Revocation of Permit

The Authority may revoke any permit issued under the

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provisions of the Code, wherever there has been any false statement, misrepresentation of any material fact in the application on which the permit was based or violation of building permit or in case of noncompliance thereof, and shall state the reasons for revoking the permit.

12.9 Qualification of Architects, Engineers, Structural Engineers, Geotechnical Engineers, Supervisors, Town Planners, Landscape Architects, Urban Designers, Services Personnel and Builder/ Constructor

Architects, engineers, structural engineers, geotechnical engineers, supervisors, town planners, landscape architect, urban designer, utility service engineer and builder/constructor wherever referred in the Code, shall be registered by the Authority or the body governing such profession constituted under a statute, as competent to do the work for which they are employed. A guide for the equivalent technical qualifications and professional experience required for such registration with the Authority is given in Annex A. In case of building and plumbing services, qualifications for engineers for utility services shall be as given in **A-2.9**.

12.9.1 In case the registered professional associated with the preparation and signing of plans or for supervision, is being changed during any stage of building/land development process, the professional shall intimate the Authority in writing about the further non-association with the project.

12.10 Grant of Sanction or Refusal

The Authority may either sanction or refuse the plans and specifications or may sanction them with such modifications or directions as it may deem necessary and thereupon shall communicate its decision to the person giving the notice (*see* Annex F).

12.10.1 The building plans for buildings identified in **12.2.5.1** shall also be subject to the scrutiny of the Fire Authority and the sanction through building permit shall be given by the Authority after the clearance from the Fire Authority (*see also* **11.1.3**).

12.10.2 If within 30 days of the receipt of the notice under **12.1** of the Code, the Authority fails to intimate in writing to the person, who has given the notice, of its refusal or sanction, the notice with its plans and statements shall be deemed to have been sanctioned; provided the fact is immediately brought to the notice of the Authority in writing by the person who has given notice and having not received any intimation from the Authority within fifteen days of giving such written notice. Subject to the conditions mentioned in this clause, nothing shall be construed to authorize any person to do anything in contravention of or against the terms of lease or titles of the land or against any other regulations, byelaws or ordinance operating on the site of the work.

12.10.3 In the case of refusal, the Authority shall quote the reason and relevant sections of the Code which the plans contravene. The Authority shall as far as possible advise all the objections to the plans and specifications in the first instance itself and ensure that no new objections are raised when they are resubmitted after compliance of earlier objections.

12.10.4 Once the plan has been scrutinized and objections have been pointed out, the owner giving notice shall modify the plan to comply with the objections raised and resubmit it. The Authority shall scrutinize the re-submitted plan and if there be further objections, the plan shall be rejected.

13 RESPONSIBILITIES AND DUTIES OF THE OWNER

13.1 Neither the granting of the permit nor the approval of the drawings and specifications, nor inspections made by the Authority during erection of the building shall in any way relieve the owner of such building from full responsibility for carrying out the work in accordance with the requirements of the Code (*see* **9**).

13.2 Every owner shall,

a) permit the Authority to enter the building or premises for which the permit has been granted at any reasonable time for the purpose of enforcing the Code;

b) submit a document of ownership of the site;

c) obtain, where applicable, from the Authority, permits relating to building, zoning, grades, sewers, water mains, plumbing, signs, blasting, street occupancy, electricity, highways, and all other permits required in connection with the proposed work;

d) give notice to the Authority of the intention to start work on the building site (*see* Annex G);

e) give written notice to the Authority intimating completion of work up to plinth level;

f) submit the certificate of engagement of builder/constructor(s) for the buildings given in **12.2.5.1** (*see* Annex D), certificate for sub-surface investigation, where applicable (*see* Note 1) (*see* Annex H), certificate for completed structural design work as per structural safety requirements (*see* Annex J); certificate for supervision and execution of work (*see* Annex K); certificate for completed work by builder/constructor(s) (*see* Annex M) (*see* Note); and give written notice to the

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Authority regarding completion of work described in the permit (*see* Annex N);

NOTE — *See* **3.1** and **3.1.1** of Part 6 'Structural Design, Section 2 Soils and Foundations' of the Code.

g) give written notice to the Authority in case of termination of services of a professional engaged by him; and

h) obtain an occupancy permit (*see* Annex P) from the Authority prior to any,

1) occupancy of the building or part thereof after construction or alteration of that building or part, or

2) change in the class of occupancy of any building or part thereof.

13.2.1 *Temporary Occupancy*

Upon the request of the holder of the permit, the Authority may issue a temporary certificate of occupancy for a building or part thereof, before the entire work covered by permit shall have been completed, provided such portion or portions may be occupied safely prior to full completion of building without endangering life or public welfare.

13.3 Documents at Site

13.3.1 Where tests of any materials are made to ensure conformity with the requirements of the Code, records of the test data shall be kept available for inspection during the construction of the building and for such a period thereafter as required by the Authority.

13.3.2 The person to whom a permit is issued shall during construction keep pasted in a conspicuous place on the property in respect of which the permit was issued,

a) a copy of the building permit; and

b) a copy of the approved drawings and specifications referred in **12**.

14 INSPECTION, OCCUPANCY PERMIT AND POST-OCCUPANCY INSPECTION

14.1 Generally all construction or work for which a permit is required shall be subject to inspection by the Authority and certain types of construction involving unusual hazards or requiring constant inspection shall have continuous inspection by special inspectors appointed by the Authority.

14.2 Inspection, where required, shall be made within 7 days following the receipt of notification, after which period the owner will be free to continue the construction according to the sanctioned plan. At the first inspection, the Authority shall determine to the best of its ability that the building has been located in accordance with the approved site plans. The final inspection of the completion of the work shall be made within 21 days following the receipt of notification [*see* **13.2**(f)] for the grant of occupancy certificate.

14.2.1 The owner/concerned registered architect/ engineer/structural engineer/town planner will serve a notice/completion certificate to the Authority that the building has been completed in all respects as per the approved plans. The deviations shall also be brought to the notice of the Authority (with relevant documents). The team of building officials or its duly authorized representative shall then visit the site and occupancy certificate shall be given in one instance.

14.2.2 The occupancy certificate should clearly state the use/type of occupancy of the building. However, the applicant can apply for change of use/occupancy permitted within the purview of the Master Plan/Zonal Plan/Building Bye laws, where so required.

14.3 When inspection of any construction operation reveals that any lack of safety precautions exist, the Authority shall have right to direct the owner to stop the work immediately until the necessary remedial measures to remove the violation of safety precautions are taken.

14.4 Periodic Occupancy Renewal

14.4.1 For buildings covered in **12.2.5.1,** after completion of the building and obtaining the occupancy certificate, periodic inspections of building shall be made by the Fire Authority to ensure the fire safety of the building and compliance with the provisions of fire and life safety requirements (*see* Part 4 'Fire and Life Safety' of the Code). Periodic occupancy renewal certificate shall be made available by the Authority/ Fire Authority which shall also include safe keep of firefighting installations and equipment for such buildings.

14.4.2 All buildings covered under **12.2.5.1** shall be subjected to periodic physical inspection by a team of multi-disciplinary professionals of local Authority. The work by team of professionals may be outsourced by the authority to competent professionals as may be deemed necessary. The team shall ensure the compliance of byelaws, natural lighting, ventilation, etc besides structural safety, electrical safety and accessibility (for designated public buildings and areas as per **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code). After checking, the team shall be required to give the certificate for above aspects. If any shortcoming/ deficiencies or violations are noticed during inspection, the Authority shall ensure the compliance of these within a specified time frame of six months. If not complied with, the building shall be declared unsafe/ unfit. The period of inspection shall usually be 3 to 5 years but in any case not more than 5 years.

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15 UNSAFE BUILDING

15.1 All unsafe buildings shall be considered to constitute danger to public safety and shall be restored by repairs or demolished or dealt with as otherwise directed by the Authority (*see* **15.2** to **15.5**).

15.2 Examination of Unsafe Building

The Authority shall examine or cause to be examined every building reported to be unsafe or damaged, and shall make a written record of such examination.

15.3 Notice to Owner, Occupier

Whenever the Authority finds any building or portion thereof to be unsafe, it shall, in accordance with established procedure for legal notice, give to the owner and occupier of such building written notices stating the defects thereof. This notice shall require the owner or the occupier within a stated time either to complete specified repairs or improvements or to demolish and remove the building or portion thereof.

15.3.1 The Authority may direct in writing that the building which in his opinion is dangerous, or has no provision for exit if caught fire, shall be vacated immediately or within the period specified for the purpose; provided that the Authority concerned shall keep a record of the reasons for such action with him.

If any person does not comply with the orders of vacating a building, the Authority may direct the police to remove the person from the building and the police shall comply with the orders.

15.4 Disregard of Notice

In case the owner or occupier fails, neglects, or refuses to comply with the notice to repair or to demolish the said building or portion thereof, the Authority shall cause the danger to be removed whether by demolition or repair of the building or portion thereof or otherwise.

15.5 Cases of Emergency

In case of emergency, which, in the opinion of the Authority involves imminent danger to human life or health, the decision of the Authority shall be final. The Authority shall forthwith or with such notice as may be possible promptly cause such building or portion thereof to be rendered safe by retrofitting/strengthening to the same degree of safety or removed. For this purpose, the Authority may at once enter such structure or land on which it stands, or abutting land or structure, with such assistance and at such cost as may be deemed necessary. The Authority may also get the adjacent structures vacated and protect the public by an appropriate fence or such other means as may be necessary.

15.6 Costs

Costs incurred under **15.4** and **15.5** shall be charged to the owner of the premises involved. Such costs shall be charged on the premises in respect of which or for the benefit of which the same have been incurred and shall be recoverable as provided under the laws (*see* Note).

NOTE — The costs may be in the form of arrears of taxes.

16 DEMOLITION OF BUILDING

Before a building is demolished, the owner shall notify all utilities having service connections within the building, such as water, electric, gas, sewer and other connections. A permit to demolish a building shall not be issued until a release is obtained from the utilities stating that their respective service connections and appurtenant equipment, such as meters and regulators have been removed or sealed and plugged in a safe manner.

17 VALIDITY

17.1 Partial Invalidity

In the event any part or provision of the Code is held to be illegal or void, this shall not have the effect of making void or illegal any of the other parts or provisions thereof, which may or shall be determined to be legal, and it shall be presumed that the Code would have been passed without such illegal or invalid parts or provisions.

17.2 Segregation of Invalid Provisions

Any invalid part of the Code shall be segregated from the remainder of the Code by the court holding such part invalid, and the remainder shall remain effective.

17.3 Decisions Involving Existing Buildings

The invalidity of any provision in any clause of the Code as applied to existing buildings and structures shall not be held to effect the validity of such section in its application to buildings hereafter erected.

18 ARCHITECTURAL CONTROL

18.1 Compliance with the provisions of the Code is adequate for normal buildings. But for major public building complexes or buildings coming up in an important area near historic/monumental buildings and areas of heritage, the aesthetics of the whole scheme may also have to be examined, *vis-a-vis* existing structures. In addition, any development which may mar the general characteristics and environment of historical, architectural or other monuments should also be subject to the provisions of this clause. This clause is intended to cover very few structures to come up in

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the vicinity of other declared/historically important structures, and the scrutiny shall be limited to the external architectural features only so as to ensure an aesthetic continuance of the existing structures with the new. The scrutiny shall not deal with the routine building plan scrutiny from other requirements of Code from the point of view of structural safety and functional requirements.

18.2 An Urban Arts Commission shall be established at the city/state level on issues related to urban aesthetics, through a statute. This statutory authority/ commission established by an Act of State Legislative Assembly, shall accord approval to all major buildings/ important development projects having bearing on the urban aesthetics, depending upon the importance of the area with respect to natural or built heritage or projects on plot areas above 1 ha and located in specifically identified areas. The Urban Arts Commission shall act as guardian of urban architecture; mainly with regard to building form and envelope, the relationship between the building, and the ambient environment *vis-a-vis* other dependents should be seen in depth.

18.3 The Commission may work in the following manner:

a) The Commission may select only the important buildings as in **18.1** and examine the same. The person responsible for the schemes, say an architect or an engineer, may examine either alone or with the owner. A study of the plans, elevations, models, etc, should be made. The architect/engineer should explain in general terms the purposes which the building is to serve and the main conditions which have influenced him in preparing the design.

b) The Commission after full discussion, may communicate their decision in writing to the parties concerned. The Commission may recommend a change in the whole scheme or suggest modifications in the existing scheme, if so required.

18.4 The Urban Arts Commission should also be charged with advising the city government, on schemes which will beautify the city and add to its cultural vitality.

ANNEX A

[*Foreword and Clauses* 2.17, 6.5, 6.6, 9.1.3, 12.2.5.1, 12.2.8, 12.2.9, 12.3 *and* 12.9]

GUIDE FOR THE QUALIFICATIONS AND COMPETENCE OF PROFESSIONALS

A-1 ESSENTIAL REQUIREMENTS

Every building/development work for which permission is sought under the Code shall be planned, designed and supervised by registered professionals. The registered professionals for carrying out the various activities shall be: (a) Architect, (b) Engineer, (c) Structural engineer, (d) Geotechnical engineer, (e) Supervisor, (f) Town planner, (g) Landscape architect, (h) Urban designer, and (j) Utility service engineer. Requirements of registration for various professionals by the Authority or by the body governing such profession and constituted under a statute, as applicable to practice within the local body's jurisdiction, are given in **A-2.1** to **A-2.8**. The competence of such registered personnel to carry out various activities is also indicated in **A-2.1.1** to **A-2.8.1**.

The qualification and competence of the engineers for utility services and of builder/constructor shall be as prescribed in **A-2.9** and **A-2.10**, respectively.

A-2 REQUIREMENTS FOR REGISTRATION AND COMPETENCE OF PROFESSIONALS

A-2.1 Architect

The minimum qualifications for an architect shall be the qualifications as provided for in the *Architects Act*, 1972 for registration with the Council of Architecture.

A-2.1.1 *Competence*

The registered architect shall be competent to carryout the work related to the building/development permit as given below:

a) Preparation of all plans and information connected with building permit except engineering services of high rise/special

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buildings given in **12.2.5.1**.

b) Issuing certificate of supervision and completion of all buildings pertaining to architectural aspects.

c) Preparation of subdivision/layout plans and related information connected with development permit of area up to 1 hectare for metro-cities, and 2 hectare for other places.

d) Issuing certificate of supervision for development of land of area up to 1 hectare for metro-cities, and 2 hectare for other places.

A-2.2 Engineer

The minimum qualifications for an engineer shall be graduate in civil engineering/architectural engineering of recognized Indian or foreign university, or the Corporate Member of Civil Engineering Division/ Architectural Engineering Division of the Institution of Engineers (India) or the Member of the statutory body governing such profession, as and when established.

A-2.2.1 *Competence*

The registered engineer shall be competent to carryout the work related to the building/development permit as given below:

a) Preparation of all plans and information connected with building permit.

b) Structural details and calculations of buildings including subsurface investigation on plot up to 500 m^2 and up to 5 storeys or 16 m in height.

c) Issuing certificate of supervision and completion for all buildings.

d) Preparation of subdivision/layout plans and related information connected with development permit of area up to 1 hectare for metro-cities, and 2 hectare for other places.

e) Preparation of all service plans and related information connected with development permit.

f) Issuing certificate of supervision for development of land for all area.

A-2.3 Structural Engineer

The minimum qualifications for a structural engineer shall be graduate in civil engineering of recognized Indian or foreign university, or Corporate Member of Civil Engineering Division of Institution of Engineers (India), and with minimum 3 years experience in structural engineering practice with designing and field work.

NOTE — The 3 years experience shall be relaxed to 2 years in the case of post graduate degree of recognized Indian or foreign university in the branch of structural engineering. In case of doctorate in structural engineering, the experience required would be one year.

A-2.3.1 *Competence*

The registered structural engineer shall be competent to prepare the structural design, calculations and details for all buildings and carry out supervision.

A-2.3.1.1 In case of buildings having special structural features, as decided by the Authority, which are within the horizontal areas and vertical limits specified in **A-2.2.1**(b) and **A-2.5.1**(a) shall be designed only by structural engineers.

A-2.4 Geotechnical Engineer

The minimum qualifications for a geotechnical engineer shall be graduate in civil engineering of recognized Indian or foreign university, or Corporate Member of Civil Engineering Division of Institution of Engineers (India), and with minimum 3 years experience in geotechnical engineering practice with designing and field work.

NOTE — The 3 years experience shall be relaxed to 2 years in the case of post graduate degree of recognized Indian or foreign university in the branch of geotechnical engineering. In case of doctorate in geotechnical engineering, the experience required would be one year.

A-2.4.1 *Competence*

The registered geotechnical engineer shall be competent to carry out subsurface investigations and give report thereof. These may *inter-alia* include performing various tests required to determine engineering properties of sub-strata and ground water and making recommendations about the type of foundation, soil bearing capacity and the depth at which the foundations shall be placed, considering the structural system and loads supplied by the engineer/structural engineer.

A-2.5 Supervisor

The minimum qualifications for a supervisor shall be diploma in civil engineering or architectural assistantship, or the qualification in architecture or engineering equivalent to the minimum qualification prescribed for recruitment to non-gazetted service by the Government of India plus 5 years experience in building design, construction and supervision.

A-2.5.1 *Competence*

The registered supervisor shall be competent to carryout the work related to the building permit as given below:

a) All plans and related information connected with building permit for residential buildings on plot up to 200 m^2 and up to two storeys or 7.5 m in height; and

b) Issuing certificate of supervision for buildings as per (a).

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A-2.6 Town Planner

The minimum qualification for a town planner shall be the Associate Membership of the Institute of Town Planners or graduate or post-graduate degree in town and country planning.

A-2.6.1 *Competence*

The registered town planner shall be competent to carryout the work related to the development permit as given below:

a) Preparation of plans for land subdivision/ layout and related information connected with development permit for all areas.
b) Issuing of certificate of supervision for development of land of all areas.

NOTE — However, for land layouts for development permit above 5 hectare in area, landscape architect shall also be associated, and for land development infrastructural services for roads, water supplies, sewerage/drainage, electrification, etc, the registered engineers for utility services shall be associated.

A-2.7 Landscape Architect

The minimum qualification for a landscape architect shall be the bachelor, master's degree in landscape architecture or equivalent from recognized Indian or foreign university.

A-2.7.1 *Competence*

The registered landscape architect shall be competent to carryout the work related to landscape design for building/development permit for land areas 5 hectare and above. In case of metro-cities, this limit of land area shall be 2 hectare and above.

NOTE — For smaller areas below the limits indicated above, association of landscape architect may also be considered from the point of view of desired landscape development.

A-2.8 Urban Designer

The minimum qualification for an urban designer shall be the master's degree in urban design or equivalent from recognized Indian or foreign university.

A-2.8.1 *Competence*

The registered urban designer shall be competent to carryout the work related to the building permit for urban design for land areas more than 5 hectare and campus area more than 2 hectare. He/she shall also be competent to carryout the work of urban renewal for all areas.

NOTE — For smaller areas below the limits indicated above, association of urban designer may be considered from the point of view of desired urban design.

A-2.9 Engineers for Utility Services

For buildings identified in **12.2.5.1**, the work of building and plumbing services shall be executed under the planning, design and supervision of competent personnel. The qualification for registered mechanical engineer (including HVAC), electrical engineer and plumbing engineers for carrying out the work of Air conditioning, Heating and Mechanical Ventilation, Electrical Installations, Lifts and Escalators and Water Supply, Drainage, Sanitation and Gas Supply installations respectively shall be as given in Part 8 'Building Services' and Part 9 'Plumbing Services' of the Code or as decided by the Authority taking into account practices of the national professional bodies dealing with the specialist engineering services.

Such an approach shall be followed for association of other/multi-disciplinary professionals for taking inputs and associating with their areas of specialization.

A-2.10 BUILDER/CONSTRUCTOR

The minimum qualification for the builder/constructor or his representative for execution of respective works shall be as given in **A-2.1**, **A-2.2**, **A-2.3**, **A-2.4**, **A-2.5**, **A-2.6**, **A-2.7**, **A-2.8** and **A-2.9** for the concerned professional.

A-2.10.1 Competence

The qualified builder/constructor or his representative shall be competent to carry out execution of work, which shall have the same extent as for supervision by such professional as prescribed in **A-2.1.1**, **A-2.2.1**, **A-2.3.1**, **A-2.4.1**, **A-2.5.1**, **A-2.6.1**, **A-2.7.1**, **A-2.8.1** and **A-2.9**.

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ANNEX B

(*Clauses* 12.1 *and* 12.2.7)

FORM FOR FIRST APPLICATION TO DEVELOP, ERECT, RE-ERECT OR TO MAKE ALTERATION IN ANY PLACE IN A BUILDING

To

.....

.....

.....

Sir,

I hereby give notice that I intend to develop, erect, re-erect or to make alteration in the building No. .....or to ..... on/in Plot No.....in Colony/Street..... *Mohalla*/*Bazar*/Road.....City .....and in accordance with the building code of .....Part 2, Clauses .....and I forward herewith the following plans and specifications in triplicate duly signed by me and ..... the Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1)], Registration No. .....

(Name in block letters)

1) Key plan
2) Site plans
3) Subdivision/layout plan
4) Building plans
5) Services plans
6) Specifications, general and detailed[2)]
7) Title of ownership of land/building
8) Certificate for structural design sufficiency
9) Certificate for engagement of builder/constructor(s), where applicable
10) Certificates for supervision

I request that the development/construction may be approved and permission accorded to me to execute the work.

Signature of owner .....

Name of the owner .....

(in block letters)

Address of owner .....

.....

.....

.....

Date .....

[1)] Strike out whichever is not applicable.

[2)] A format may be prepared by the Authority for direct use.

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ANNEX C

(*Clause* 12.2.8)

FORM FOR CERTIFICATE FOR STRUCTURAL DESIGN SUFFICIENCY

With respect to the building work of erection, re-erection or for making alteration in the building No. ..... or to ..... on/in Plot No. ..... in Colony/ Street ..... *Mohalla*/*Bazar*/Road .....City ....., we certify that the structural design of the building for which building plans are being submitted for approval shall be done and submitted for approval, to satisfy the structural safety requirements for all situations including natural disasters, as applicable, as stipulated in National Building Code of India and its Part 6 'Structural Design' and other relevant Codes; and the information given therein is factually correct to the best of our knowledge and understanding.

	Signature of owner with date	Signature of the registered engineer/structural engineer[1)] with date and registration No.
Name (in block letters):	.....	.....
Address :	.....	.....

[1)] Strike out whichever is not applicable. The entries shall be in respect of the professional who would do the structural design.

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ANNEX D

[*Clauses* 12.2.9 *and* 13.2(f)]

FORM FOR ENGAGEMENT OF BUILDER/CONSTRUCTOR

(*Before the Commencement Stage of a Project*)

With respect to the building work of erection, re-erection or for making alteration in the building No. ..... or to ..... on/in Plot No. ..... Colony/ Street ..... *Mohalla*/*Bazar*/Road .....City .....
I certify that the following builder/constructor is engaged by me towards carrying out/executing the construction:

Name and details of the builder/constructor or his representative including:

.....

.....

.....

.....

	Signature of the builder/ constructor or his representative (who has agreed for the execution of above work) with date	Signature of owner with date
Name (in block letters):	.....	.....
Address:	.....	.....

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ANNEX E

(*Clause* 12.2.9)

FORM FOR SUPERVISION

I hereby certify that the development, erection, re-erection or material alteration in/of building No. ..... or the ..... on/in Plot No. ..... in Colony/Street ..... *Mohalla*/*Bazar*/Road ..... City ..... shall be carried out under my supervision and I certify that all the materials (type and grade) and the workmanship of the work shall be generally in accordance with the general and detailed specifications submitted along with, and that the work shall be carried out according to the sanctioned plans.

Signature of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/ Urban Designer [1)] .....

Name of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] ..... (in block letters)

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] .....

Address of Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)]

.....

.....

.....

.....

Date .....

[1)] Strike out whichever is not applicable. The entries shall be in respect of the professional who would supervise the work.

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ANNEX F

(*Clause* 12.10)

FORM FOR SANCTION OR REFUSAL OF DEVELOPMENT/BUILDING PERMIT

To

.....

.....

.....

.....

Sir,

With reference to your application ..... dated ..... for grant of permit for the development, erection, re-erection or material alteration in the building No. ..... or to ..... on/in Plot No.....in Colony/Street..... *Mohalla*/*Bazar*/Road ..... City..... I have to inform you that the sanction has been granted/refused by the Authority on the following grounds:

1.

2.

3.

4.

5.

6.

Office stamp .....

Office (Communication) No. .....

Date .....

Signature of the Authority .....

Name, Designation and Address of the Authority .....

.....

.....

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ANNEX G

[*Clause* 13.2 (d)]

FORM FOR NOTICE FOR COMMENCEMENT

I hereby certify that the development, erection, re-erection or material alteration in/of building No. ..... or the ..... on/in Plot No..... in Colony/Street ..... *Mohalla*/*Bazar*/Road ..... City ..... will be commenced on ..... as per your permission, vide No..... dated ..... under the supervision of[1] ..... Registered Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[2], Registration No..... and in accordance with the plans sanctioned, vide No..... dated..... .

Signature of owner .....

Name of owner .....
(in block letters)

Address of owner .....

.....

.....

Date .....

---

[1] Only professional who would supervise the work shall be named.
[2] Strike out whichever is not applicable.

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ANNEX H

[*Clause* 13.2(f)]

FORM FOR CERTIFICATE FOR SUBSURFACE INVESTIGATION

With respect to the building work of erection, re-erection or for making alteration in the building No..... or to ..... on/in Plot No. ..... in Colony/ Street ..... *Mohalla*/*Bazar*/Road .....City ....., we certify that we have carried out subsurface investigation at site and have performed various tests required to determine engineering properties of soil substrata and ground water based on which we have given recommendations about the type of foundation, soil bearing capacity and the depth at which the foundations shall be placed, considering the structural system and loads supplied by the structural engineer to enable the engineer/structural engineer to design the foundations and other structures below ground, as stipulated in National Building Code of India and its Part 6 'Structural Design, Section 2 Soils and Foundations' and other relevant Codes.

I am enclosing a copy of the report of subsurface investigation carried out as above and submitted to the Structural Engineer.

	Signature of owner with date	Signature of the registered Engineer/ Structural Engineer/ Geotechnical Engineer[1)] and registration No. with date
Name (in block letters) :	.....	.....
Address :	.....	.....

[1)] Strike out whichever is not applicable. The professional who has done the subsurface investigation shall sign.

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ANNEX J

[*Clause* 13.2(f)]

FORM FOR CERTIFICATE FOR COMPLETED STRUCTURAL DESIGN WORK AS PER STRUCTURAL SAFETY REQUIREMENTS

With respect to the building work of erection, re-erection or for making alteration in the building No. ..... or to ..... on/in Plot No. ..... in Colony/ Street ..... *Mohalla*/*Bazar*/Road ..... City ....., we certify that the structural design, structural drawings and details of the building which has been done by us satisfy the structural safety requirements for all situations including natural disasters, as applicable, as stipulated in National Building Code of India and its Part 6 'Structural Design' and other relevant Codes considering the report of subsurface investigation, where applicable.

	Signature of owner with date	Signature of the registered engineer/ structural engineer[1)]/ and with date and registration No.
Name (in block letters) :	.....	.....
Address :	.....	.....

[1)] Strike out whichever is not applicable. The professional who has done the structural design shall sign.

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ANNEX K

[*Clause* 13.2(f)]

FORM FOR CERTIFICATE FOR SUPERVISION OF WORK

With respect to the building work of erection, re-erection or for making alteration in the building No. ..... or to ..... on/in Plot No. ..... in Colony/ Street ..... *Mohalla*/*Bazar*/Road .....City ....., we certify,

a) that the building has been constructed according to the sanctioned plans, specifications, details and structural drawings issued to the site by the Engineer/Structural Engineer (one set of drawings as executed enclosed); and

b) that the construction has been done under our supervision and guidance and records of supervision have been maintained.

Any subsequent changes from the completion drawings shall be the responsibility of the owner.

	Signature of owner with date	Signature of the registeredArchitect/ Engineer/Structural Engineer/Supervisor/ Town Planner/Landscape Architect/Urban Designer [1)] and registration No.
Name (in block letters) :	.....	.....
Address :	.....	.....

[1)] Strike out whichever is not applicable. The professional who has supervised the work shall sign.

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ANNEX M

[*Clause* 13.2(f)]

FORM FOR CERTIFICATE FOR COMPLETED WORK BY BUILDER/CONSTRUCTOR

With respect to the building work of erection, re-erection or for making alteration in the building No..... or to.....on/in Plot No.....in Colony/Street .....*Mohalla*/*Bazar*/Road .....City....., we certify,

a) that the building has been constructed by us according to the sanctioned plans, structural drawings and details issued to the site by the Engineer/Structural Engineer[1)]; and

b) that the work has been completed with high level of workmanship observing due diligence and all the materials have been used strictly in accordance with the general and detailed specifications.

	Signature of owner with date with date	Signature of representative of the builder/constructor
Name (in block letters) :	.....	.....
Address :	.....	.....

[1)] Substitute by details of relevant services and the concerned constructor in case of execution of services works.

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ANNEX N

[*Clause* 13.2 (f)]

FORM FOR COMPLETION CERTIFICATE

I hereby certify that the development, erection, re-erection or material alteration in/of building No. ..... or the ..... on/in Plot No..... in Colony/Street ..... *Mohalla*/*Bazar*/Road ..... City ..... has been supervised by me and has been completed on ..... according to the plans sanctioned, vide No. ..... dated..... . The work has been completed to my best satisfaction, the workmanship and all the materials (type and grade) have been used strictly in accordance with general and detailed specifications subject to compliance the minimum parameters specified in National Building Code of India. No provisions of the Code, no requisitions made, conditions prescribed or orders issued thereunder have been transgressed in the course of the work. The land is fit for construction for which it has been developed or redeveloped or the building is fit for use for which it has been erected, re-erected or altered, constructed and enlarged.

I hereby also enclose the plans, drawings, details, reports and certificates of the building/work as executed, as follows:

1) Plans of completed works
2) Structural design, drawings and details
3) Services drawings and details (mechanical/electrical/plumbing/fire)
4) Certificate for subsurface investigation along with a copy of report
5) Certificate for completed structural design work as per structural safety requirements
6) Certificate for supervision of execution of work
7) Certificate for completed work by the builder/constructor

Permission to occupy or use the building may be granted.

Any subsequent change from completion drawings shall be the responsibility of the owner.

Signature of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer[1)] .....

Name of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] ..... (in block letters)

Registration No. of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/ Landscape Architect/ Urban Designer [1)] .....

Address of Architect/Engineer/Structural Engineer/Supervisor/Town Planner/Landscape Architect/Urban Designer [1)] .....

.....

Signature of the owner

Date .....

[1)] Strike out whichever is not applicable.

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ANNEX P

[*Clause* 13.2(h)]

FORM FOR OCCUPANCY PERMIT

The work of erection, re-erection or alteration in/of building No. .....or the .....on/in Plot No.....in Colony/Street..... *Mohalla*/*Bazar*/Road .....City .....completed under the supervision of ..... Architect/ Engineer/Structural Engineer/Supervisor, Registration No.....has been inspected by me. The building can be permitted/not permitted for occupation for.....occupancy subjected to the following:

1.

2.

3.

One set of completion plans duly certified is returned herewith.

Signature of the Authority .....

Office stamp

Date .....

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NATIONAL BUILDING CODE OF INDIA

PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 3) covers development control rules, including such aspects as subdivision and layout rules, land use classifications, open spaces, area and height limitations, means of access, and parking spaces. This Part also covers the general building requirements, including those of various parts of buildings.

It is expected that for proper coordination and enforcement of the development control rules and general building requirements, the departments concerned, namely, the town and country planning department, urban development authority, urban local body and the building department, will coordinate the total development and building activity at both organizational and technical levels.

Particular attention is invited to Table 5 on floor area ratio (FAR) limitations. It is emphasized that the floor area of a single storey building is limited in absolute terms by the type of construction and occupancy class. Also, the absolute floor areas for different types of construction and different occupancies have a definite ratio among them. The ratios as recommended in the American Iron and Steel Institute Publication of 1961 'Fire protection through modern building codes' have been generally adopted in this Part and Table 5 has been developed on this basis. This, Table 5 is repeated in Part 4 'Fire and Life Safety' of the Code also, for convenience of reading.

Limitation of areas and heights of buildings are regulated by specifying floor area ratio (FAR) or floor space index (FSI) and ground coverage. The significance of the contribution of different types of construction giving different fire resistances has not been taken cognizance of in specifying FAR for different occupancies, in the present development control rules and municipal byelaws of the country. Table 5, therefore, gives the comparative ratios of FAR between types of buildings and occupancy classes and these have been specified mainly from the fire protection aspect of buildings. To arrive at the actual FAR for different buildings coming up in different areas, the Authority should further modify them, by taking into consideration other aspects like population density of any area, parking facilities required, the traffic load (road width) and the services available. The heights of buildings shall also be regulated, keeping in view the local fire fighting facilities.

In some state byelaws, the FAR (or FSI) has been expressed in the form of percentage. However, the Committee responsible for the preparation of this Code is of the opinion that, it being a ratio should be expressed only in the form of a ratio, as done in this Part.

It is particularly to be borne in mind by the Authority that the ratios are definitive and it may assess the particular FAR for a type of construction and for an occupancy and establish a new table, but retaining the comparative ratios as given in Table 5.

Keeping in view the enormous problems faced by the country with regard to the ever increasing squatter settlements/ pavement dwellers in urban areas (cities of all sizes), it is imperative that all the urban local bodies and urban development authorities sooner or later evolve schemes for their rehabilitation. The resources are meagre and the problems are enormous. There has been a tendency on the part of a number of urban development authorities/ urban local bodies to link space norms with affordability. Affordability is an important criterion but at the same time a public agency may not ignore the basic minimum needs of the family to be housed (including the mental, physical and social health of the marginalized groups, which is linked with shelter). The urban local bodies shall have to evolve appropriate policies for their integration with the overall development process and generate/ allocate resources and more importantly adopt a planning process, which are people friendly and inclusive. Therefore, keeping in view the needs of low income housing, to cater to Economically Weaker Sections of Society (EWS) and Low Income Group (LIG), the requirements on planning, design of layout/shelter have been rationalized and the same are provided in this Part. This information is based on the provisions of IS 8888 (Part 1):1993 'Guide for requirements of low income housing: Part 1 Urban areas (*first revision*)'.

It is important that the fruits of development are equally shared by all cross-section of the society irrespective of their age and abilities. This Code therefore covered provisions for buildings and built environment to ensure a barrier-free

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environment for elders and persons with disabilities. The goal of barrier free design is to provide an environment that supports the independent functioning of individuals so that they can participate without assistance, in everyday activities. It has been intended to progressively update these provisions and make the same more effective and elaborate based on experience gained with the implementation of the Code and feedback received from stakeholders. As a conscious decision, opportunity has been taken in this revision of the Code to further mainstream the issue of barrier free environment by covering the requirements at greater length. The concept of universal design has also been included herein that promotes the usability of built environment by all without discrimination. It is worthwhile to note that *The Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act*, 1995 in its Chapter VIII 'Non-Discrimination', Section 44 to 46 mandates accessibility in public buildings and transportation systems. National policy for persons with disabilities also emphasizes the role of barrier-free environment as one that enables people with disabilities to move about safely and freely, and use the facilities within the built environment. Therefore, to the maximum extent possible, buildings/places/transportation systems for public use should be made barrier free. India has also signed and ratified the UN Convention on Rights of Persons with Disabilities that casts an obligation on the member states in its Article 9'Accessibility', to enable persons with disabilities to live independently and participate fully in all aspects of life.

Further, city development process would need a dynamic approach to take care of urban renewal and also development needs in dense core areas of the cities. Innovative approaches in planning and design with participatory models of public private-people's partnership become necessary to solve the emerging development needs. With this in view, many city development authorities have evolved innovative planning and development tools like transferable development rights (TDR) where the developer would receive a portion of the development rights in a new location, keeping in view the constraints in the existing land area and the development potential. Such development rights may be transferred into outskirts or new developed areas where land availability is assured. This would encourage the professionals and developers to participate in urban renewal and at the same time ensure that the developments in both the inner core areas and new areas take place in a planned manner. The TDR concept should be increasingly encouraged by the authority dealing with urban renewal, redevelopment projects including housing and redevelopment projects for slum dwellers.

Transit oriented development (TOD), as a concept, integrates land uses and mass transportation such as bus rapid transit (BRT) and rail based transit like metro-rail, mono-rail, light-rail, ring-rail, etc. The basic objective is to plan cities in a manner where people conveniently walk and use public transport for most of their trips and, thus, reduce dependence on private mode and provide benefits to the city which include reduction in congestion, delays and accidents on roads; reduction of pollution caused by automobiles; and improvement in liveability, mobility and convenience of the citizens. TOD makes city compact and increases its efficiency and functioning. The TOD is desirable as it, (a) reduces/discourages private vehicle dependency and induces public transport use though planning, designing, policy measures and enforcement; and (b) provides easy access to public transport, within walking distance, to a majority of people, through densification and enhanced connectivity.

Some of the planning and design principles applied to create TOD include creation of,

a) pedestrian and non-motorized transport friendly environment;
b) efficient public and para-transport system supporting the transit system;
c) multi-modal interchange and street connectivity;
d) mixed land uses and appropriate intensity of development; and
e) well designed and integrated parking thus requiring reduced parking requirements in comparison to the norms given in this Part.

TOD concept may be suitable for all newly planned green field cities. However, it can also be applied to existing brown field cities where new expansion/development are taken up backed up with effective mass rapid transport system and new nodes. The Authorities may take up appropriate studies to evaluate suitability of TOD concept under relevant situations.

Urbanization in India is taking place at a rapid pace. As per the 2011 Census, 31.16 percent of the country's population resides in urban areas. This figure was 27.8 percent in 2001. The urban component is expected to rise to around 40 percent by 2020. As Indian cities continue to grow demographically and spatially, the challenge of improving urban infrastructure is enormous. While the number of urban centres has increased manifold between 1901 and 2011, the urban population increased six fold, resulting in a top-heavy urban settlement hierarchy with a large number of primate settlements. It is expected that the number of towns and cities which was 7 933 as per Census, 2011 is likely to cross the 10 000 mark in next two decades. As a result of liberalization, the demographic

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trends of urbanization are accompanied by both challenges and opportunities in the management and financing of urban development.

Unprecedented urbanization has been fuelled by rapid economic growth and even more rapid industrialization especially in the past three decades or so. With globalization, this trend of rapid economic growth and urbanization is likely to accentuate further. In 1901, Kolkata was the only metropolitan city (million plus) in the country. The number of metropolitan cities increased to 5 in 1951, 12 in 1981, 23 in 1991, 35 in 2001 and 53 in 2011. The 53 metropolitan cities together account for a population of about 158 million in 2011, that is, 42 percent of urban population of the country. It is expected that this number would be about 85 by 2051.

Going by the present trends, by 2051, India would be the most populous country with 1.70 billion people and 0.19 ha per capita land availability. By 2051, 820 million people will live in urban settlements constituting about 50 percent of the total population. Cities in the country would emerge as centres of both hope and despair: while being engines of economic and social development they may also be congested centres of poverty and environmental degradation. The million plus cities constitute 42 percent of the total urban population, while the Class I (more than 1 lakh population) towns constituted 60.04 percent, followed by 11 percent in Class II (50 000-100 000 population) towns, 15.4 percent in Class III (20 000- 50 000 population) towns and the rest 13.56 percent constituted by Class IV, V and VI towns (less than 20 000 population).

Further, in the Indian practice, mega-cities (cities over 50 lakhs population) are 8 in number; metro-cities (cities having 10 to 50 lakhs population) are 45 in number. These 53 cities above 10 lakhs population is likely to be above 70 by 2021. The other cities are either small or medium towns or cities with different population limits. Urbanization in above cities and towns (mega-cities, metro-cities, small and medium towns and cities) will be different in nature and the development challenges are also different keeping in view the extent of urbanization, industrialization, commercialization and the nature of transportation needs. Therefore, the Code provisions should be appropriately utilized depending upon the need of hierarchy of cities for which the administrative and technical requirements have been covered in the Code for various facets of the activity.

The first version of this Part was formulated in 1970. As a result of incorporation of this Part in the revised development control rules and building byelaws of some municipal corporations and municipalities, some useful suggestions had emerged. The first revision of this Part was brought out in 1983, where these suggestions were incorporated to the extent possible. The major modifications incorporated in the first revision included:

a) Addition of development control rules giving guidance on means of access, community spaces and other aspects required for planning layouts.
b) Addition of provisions regarding plot sizes and frontage for different types of buildings, such as detached, semi-detached, row type and special housing schemes.
c) Requirements of open spaces for other occupancies, such as educational, institutional, assembly, industrial buildings, etc were included.
d) Provisions relating to interior open space were elaborated, including requirements for ventilation shaft.
e) Requirements of open spaces for group housing development were covered.
f) Requirements of off-street parking spaces were covered.
g) Requirements for greenbelts and landscaping including norms for plantations of shrubs and trees were covered.
h) Requirements of certain parts of buildings, such as loft, store room, garage, basement, chimney, parapet, cabin, boundary wall, wells, septic tanks, office-cum-letter box room, meter room were included.
j) Special requirements of low income housing were covered.

The term Development Control Rules used in this Part encompasses the related aspects comprehensively with a view to promoting orderly development of an area.

The major modifications incorporated in the second revision included:

a) Terminology given in this Part were made exhaustive by incorporating definitions of additional terms used, such as access, chimney, to erect, etc, and number of terms pertaining to cluster planning for housing.
b) Detailed planning norms/open spaces for various amenities such as educational facilities, health care facilities, socio-cultural facilities, distribution services, police, civil defence and home guards, and fire services were included.

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c) Off-street parking requirements were also included for cities with population, (1) between 1 000 000 and 5 000 000, and (2) above 5 000 000 (*see* Annex A).

d) Special requirements for low income housing were modified and updated based on the revision of concerned Indian Standard namely IS 8888:1978 as IS 8888 (Part 1):1993 'Guide for requirements of low income housing : Part 1 Urban area (*first revision*)'. Single room dwelling was discouraged, guidelines for water seal latrine were incorporated, and cluster planning approach were recommended.

e) Requirements for cluster planning for housing were added based on the guidelines given in IS 13727:1993 'Guide for requirements of cluster planning for housing'.

f) Special requirements for low income housing for rural habitat planning were added.

g) Special requirements for development planning in hilly areas were added.

h) The requirements for buildings and facilities for the physically challenged were revised, with listing of additional categories of physically challenged; modifications in requirements of ramps, stairs, doors, handrails and controls; and incorporation of additional requirements regarding windows.

In this third revision, following major modifications have been incorporated:

a) Definitions of additional terms have been included and some of the existing definitions have been modified in the terminology clause.

b) Reference of IS 3861 : 2002 'Method of measurement of plinth, carpet and rentable areas of buildings (*second revision*)' has been added for correct interpretation of plinth area and built-up area.

c) Land use classification has been modified.

d) A new clause on footpaths giving guidance on width of footpath to be adopted based on expected pedestrian traffic as also recommended width of footpath corresponding to adjacent land use, has been added.

e) Provisions on Transferable Development Rights (TDR) has been included.

f) Provisions on Accommodation Reservation (AR) have been included.

g) Provisions for buildings on podium including permitted uses in podium, general requirements for the same and requirements for fire tender movement have been incorporated under the clause on means of access.

h) Planning norms for amenities have been modified and new amenities have been covered.

j) Requirements for minimum clearances from an overhead electric supply line have been modified based on current *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations,* 2010 taking into account effect of sag and wind pressure.

k) Provisions for sunken courtyard have been added for meeting the light and ventilation requirements for basement area.

m) For height restrictions in the vicinity of aerodromes, reference to concerned notification of the Ministry of Civil Aviation, Govt of India has been made.

n) Considering that high density developments are being increasingly promoted in master plans and development policies, maximum coverage and floor area ratio for densities 200 to 400 dwelling units/ hectare have been added.

p) Provisions for underground or multi-storeyed parking as also mechanized parking of vehicles has been included.

q) Provisions relating to basements have been reviewed and updated keeping in view the latest developments.

r) Requirements for accessibility in buildings and built environment for elders and persons with disabilities have been thoroughly revised and updated.

s) Provisions for solar energy utilization have been included.

t) Norms for off-street parking spaces have been revised.

u) Special requirements for low income housing have been updated.

w) Special requirements for development planning in hilly areas have been updated.

The information contained in this Part is also based on the following Indian Standards:

IS 4963 : 1987	Recommendations for buildings and facilities for physically handicapped (*first revision*)

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IS 8888 (Part 1) : 1993 Guide for requirements of low income housing : Part 1 Urban area (*first revision*)

IS 13727 : 1993 Guide for requirements of cluster planning for housing

IS 4963 : 1987 is under revision, the provisions of revised version of this standard shall be referred when available.

In revising the provisions of this Part, assistance has also been derived from the following publications:

Urban and Regional Development Plans Formulation and Implementation Guidelines, 2014, Town and Country Planning Organization

IRC : 103-2012 Guidelines for Pedestrian Facilities (*first revision*)

ISO 21542 : 2011 Building construction — Accessibility and usability of the built environment

Planning a barrier free environment, 2011 prepared by Office of the Chief Commissioner for Persons with Disabilities, Ministry of Social Justice and Empowerment, Government of India

Harmonized guidelines and space standards for barrier free built environment for persons with disability and elderly persons, Ministry of Urban Development, 2016

All standards cross-referred here or in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Part of the Code is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part.

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NATIONAL BUILDING CODE OF INDIA

PART 3 DEVELOPMENT CONTROL RULES AND GENERAL BUILDING REQUIREMENTS

1 SCOPE

This Part deals with the development control rules and general building requirements to ensure health and safety of the public.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

2.1 Access — A clear approach to a plot or a building.

2.2 Accessory Use — Any use of the premises subordinate to the principal use and customarily incidental to the principal use.

2.3 Alteration — A change from one occupancy to another, or a structural change, such as an addition to the area or height, or the removal of part of a building, or any change to the structure, such as the construction of, cutting into or removal of any wall, partition, column, beam, joist, floor (including a mezzanine floor) or other support, or a change to or closing of any required means of ingress or egress or a change to the fixtures or equipment.

2.4 Approved — Approved by the Authority having jurisdiction.

2.5 Authority Having Jurisdiction — The Authority which has been created by a statute and which for the purpose of administering the Code/Part may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.6 Back-to-Back Cluster — Clusters when joined back to back and/or on sides (*see* Fig. 1).

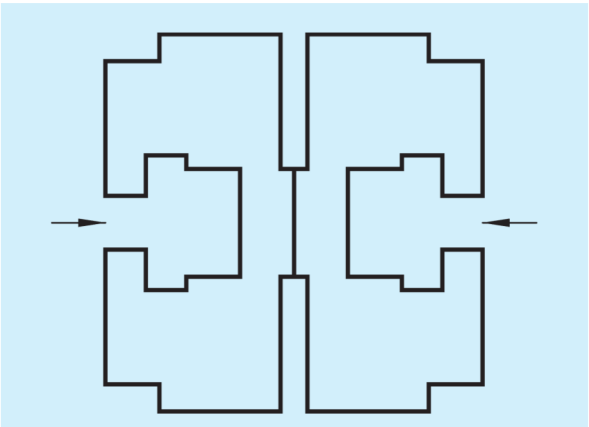


FIG. 1 BACK TO BACK CLUSTER

2.7 Balcony — A horizontal projection, with a handrail or balustrade or a parapet, to serve as passage or sitting out place.

2.8 Basement or Cellar — The lower storey of a building, below or partly below ground level.

2.9 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof, whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *Verandah*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, *Shamianahs*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.10 Building, Height of — The vertical distance measured in the case of flat roofs, from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of last livable floor of the building adjacent to the external walls; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof; and in the case of gables facing the road, the mid-point between the eaves level and the ridge. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights. *See* **9.4.2.1**.

2.11 Building Envelope — The horizontal spatial limits up to which a building may be permitted to be constructed on a plot.

2.12 Building Line — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme. The building line may change from time to time as decided by the Authority.

2.13 Cabin — A non-residential enclosure constructed of non-load bearing partition.

2.14 Canopy — A projection over any entrance.

2.15 Carpet Area — The covered area of the usable rooms at any floor level (excluding the area of the wall) {*see* accepted standard [3(1)]}.

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2.16 *Chhajja* — A sloping or horizontal structural overhang usually provided over openings on external walls to provide protection from sun and rain.

2.17 Chimney — An upright shaft containing one or more flues provided for the conveyance to the outer air of any product of combustion resulting from the operation of heat producing appliance or equipment employing solid, liquid or gaseous fuel.

2.18 Chowk or Courtyard — A space permanently open to the sky, enclosed fully or partially by building and may be at ground level or any other level within or adjacent to a building.

2.19 Chowk, Inner — A chowk enclosed on all sides.

2.20 Chowk, Outer — A chowk one of whose sides is not enclosed.

2.21 Closed Clusters —Clusters with only one common entry into cluster open space (*see* Fig. 2).

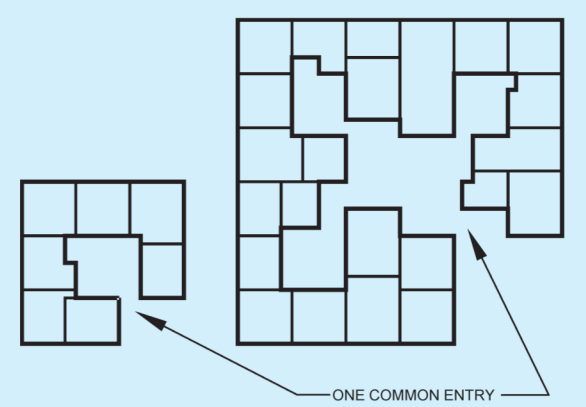


FIG. 2 CLOSED CLUSTER

2.22 Cluster — Plots or dwelling units or housing grouped around an open space (*see* Fig. 3). Ideally housing cluster should not be very large. In ground and one storeyed structures not more than 20 houses should be grouped in a cluster. Clusters with more dwelling units will create problems in identity, encroachments and of maintenance.

2.23 Cluster Court Town House — A dwelling in a cluster plot having100 percent or nearly 100 percent ground coverage with vertical expansion, generally limited to one floor only and meant for self use.

2.24 Cluster Plot — Plot in a cluster.

2.25 Cooking Alcove — A cooking space having direct access from the main room without any inter-communicating door.

2.26 Covered Area — Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded

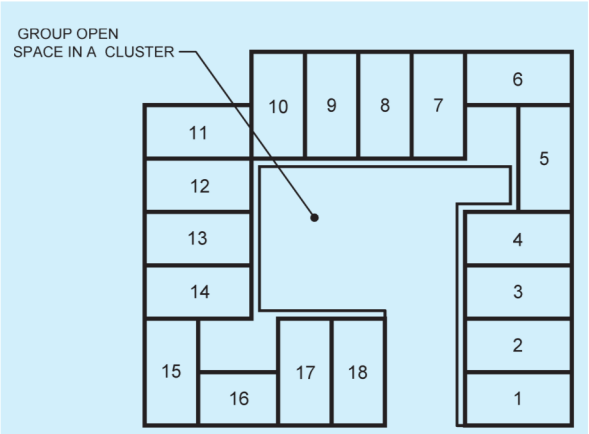


FIG. 3 CLUSTER

from covered area (*see* Table 5) :

a) Garden, rockery, well and well structures, plant nursery, water pool, swimming pool (if uncovered), platform round a tree, tank, fountain, bench, *Chabutra* with open top and unenclosed on sides by walls and the like;

b) Drainage culvert, conduit, catch-pit, gully pit, chamber, gutter and the like;

c) Compound wall, gate, unstoreyed porch and portico, canopy, slide, swing, uncovered staircase, ramps areas covered by *Chhajja* and the like; and

d) Watchmen's booth, pump house, garbage shaft, electric cabin or sub-stations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this Part, covered area equals the plot area minus the area due for open spaces.

2.27 *'Cul-de-Sac'* Cluster

Plots/dwelling units when located along a pedestrianized or vehicular '*cul-de-sac*' road (*see* Fig. 4).

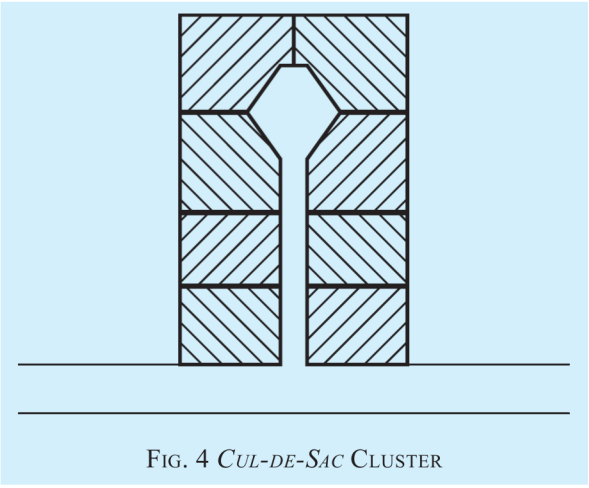


FIG. 4 *CUL-DE-SAC* CLUSTER

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2.28 Density — The residential density expressed in terms of the number of dwelling units per hectare.

NOTE — Where such densities are expressed exclusive of community facilities and provision of open spaces and major roads (excluding incidental open spaces), these will be net residential densities. Where these densities are expressed taking into consideration the required open space provision and community facilities and major roads, these would be gross residential densities at neighbourhood level, sector level or town level, as the case may be. The provision of open spaces and community facilities will depend on the size of the residential community.

Incidental open spaces are mainly open spaces required to be left around and in between two buildings to provide lighting and ventilation.

2.29 Detached Building — A building detached on all sides.

2.30 Development — 'Development' with grammatical variations means the carrying out of building, engineering, mining or other operations, in, or over, or under land or water, on the making of any material change, in any building or land, or in the use of any building, land, and includes redevelopment and layout and subdivision of any land; and 'to develop' shall be construed accordingly.

2.31 Drain — A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water borne wastes in a building drainage system.

2.32 Drainage — The removal of any liquid by a system constructed for the purpose.

2.33 Dwelling Unit/Tenement — An independent housing unit with separate facilities for living, cooking and sanitary requirements.

2.34 Escalator — A power driven, inclined, continuous moving stairway used for raising or lowering passengers.

2.35 Exit — A passage, channel or means of egress from any building, storey or floor area to a street or other open space of safety.

2.36 External Faces of Cluster — Building edges facing the cluster open spaces.

2.37 Fire Separation — The distance in metres measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of a street or other public space for the purpose of preventing the spread of fire.

2.38 Floor — The lower surface in a storey on which one normally walks in a building. The general term 'floor' unless specifically mentioned otherwise shall not refer to a 'mezzanine floor'.

2.39 Floor Area Ratio (FAR) — The quotient obtained by dividing the total covered area (plinth area) on all floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

2.40 Gallery — An intermediate floor or platform projecting from a wall of an auditorium or a hall providing extra floor area, additional seating accommodation, etc. It shall also include the structures provided for seating in stadia.

2.41 Garage, Private — A building or a portion thereof designed and used for parking of private owned motor driven or other vehicles.

2.42 Garage, Public — A building or portion thereof, other than a private garage, designed or used for repairing, servicing, hiring, selling or storing or parking motor driven or other vehicles.

2.43 Group Housing — Housing for more than one dwelling unit, where land is owned jointly (as in the case of cooperative societies or the public agencies, such as local authorities or housing boards, etc) and the construction is undertaken by one Agency.

2.44 Group Open Space — Open space within a cluster.

Group open space is neither public open space nor private open space. Each dwelling unit around the cluster open space have a share and right of use in it. The responsibility for maintenance of the same is to be collectively shared by all the dwelling units around.

2.45 Habitable Room — A room occupied or designed for occupancy by one or more persons for study, living, sleeping, eating, kitchen if it is used as a living room, but not including bathrooms, water-closet compartments, laundries, serving and store pantries, corridors, cellars, attics, and spaces that are not used frequently or during extended periods.

2.46 Independent Cluster — Clusters surrounded from all sides by vehicular access roads and/or pedestrian paths (*see* Fig. 5).

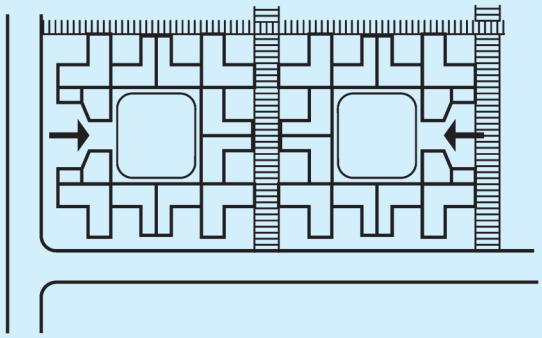


FIG. 5 INDEPENDENT CLUSTER

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2.47 Interlocking Cluster — Clusters when joined at back and on sides with at least one side of a cluster common and having some dwelling units opening onto or having access from the adjacent clusters.

Dwelling units in such clusters should have at least two sides open to external open space. Houses in an interlocking cluster may have access, ventilation and light from the adjacent cluster and should also cater for future growth (*see* Fig. 6).

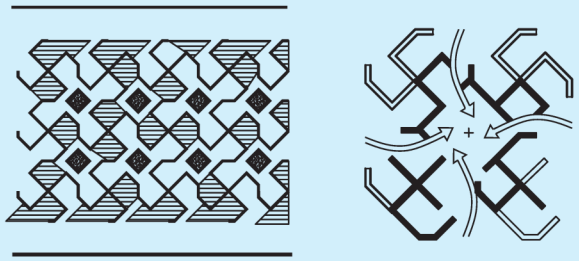


FIG. 6 INTERLOCKING CLUSTER

2.48 Internal Faces of Cluster — Building edges facing the adjacent cluster open space (as in case of interlocking cluster) of the surrounding pedestrian paths or vehicular access roads.

2.49 Ledge or *Tand* — A shelf-like projection, supported in any manner whatsoever, except by means of vertical supports within a room itself but not having projection wider than 1 m.

2.50 Lift — An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car or platform. The word 'elevator' is also synonymously used for 'lift'.

2.51 Loft — A structure providing intermediate storage space in between two floors with a maximum height of 1.5 m, without having a permanent access.

2.52 Master Plan — A master plan formulated under any relevant act (Town and Country Planning or Development Act or Municipal Act) for any town, approved and notified by the State Government.

2.53 Mezzanine Floor — An intermediate floor between two floors of any storey forming an integral part of floor below.

2.54 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purposes of classification of a building according to occupancy; an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

2.55 Occupancy, Mixed — A multiple occupancy where the occupancies are intermingled.

2.56 Open Clusters — Clusters where cluster open spaces are linked to form a continuous open space (*see* Fig. 7).

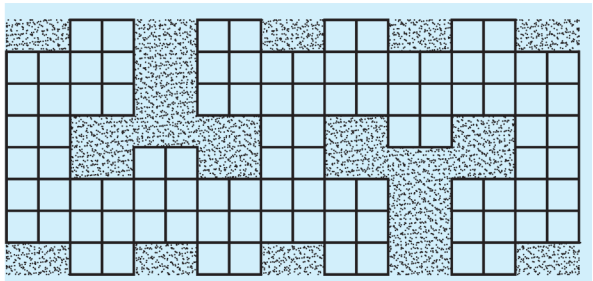


FIG. 7 OPEN CLUSTER

2.57 Open Space — An area, forming an integral part of the plot, left open to the sky.

NOTE — The open space shall be the minimum distance measured between the front, rear and side of the building and the respective plot boundaries.

2.58 Open Space, Front — An open space across the front of a plot between the building line and front boundary of the plot.

2.59 Open Space, Rear — An open space across the rear of a plot between the rear of the building and the rear boundary of the plot.

2.60 Open Space, Side — An open space across the side of the plot between the side of the building and the side boundary of the plot.

2.61 Owner — A person, a group of persons or a body having a legal interest in land and/or building thereon. This includes free holders, leaseholders or those holding a sublease, who will have a legal right to occupation and have liabilities in respect of safety or building condition.

In case of lease or sublease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/ lessee till the allotment/lease subsists.

Note — For the purpose of the Code, the word 'owner' will also cover the generally understood terms like 'client', 'user', etc.

2.62 Parapet — A low wall or railing built along the edge of a roof or floor.

2.63 Parking Space — An area enclosed or unenclosed, covered or open, sufficient in size to park vehicles, together with a drive-way connecting the parking space with a street or alley and permitting ingress and egress of the vehicles.

2.64 Partition — An interior non-load bearing barrier, one storey or part-storey in height.

2.65 Plinth — The portion of a structure between the surface of the surrounding ground and surface of the floor, immediately above the ground.

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2.66 Plinth Area — The built up covered area measured at the floor level of the basement or of any storey {*see* accepted standard [3(1)]}.

2.67 Porch — A covered structure supported on pillars or otherwise for the purpose of pedestrian or vehicular approach to a building.

2.68 Road — *See* 'Street'.

2.69 Road Line — *See* 'Street Line'.

2.70 Room Height — The vertical distance measured from the finished floor surface to the finished ceiling surface. Where a finished ceiling is not provided, the underside of the joists or beams or tie beams shall determine the upper point of measurement.

2.71 Row Housing/Row Type Building — A row of buildings, with only front, rear and interior open spaces, where applicable.

2.72 Semi-Detached Building — A building detached on three sides.

2.73 Service Road/Lane — A road/lane provided adjacent to a plot(s) for access or service purposes as the case may be.

2.74 Set-Back Line — A line usually parallel to the plot boundaries and laid down in each case by the Authority, beyond which nothing may be constructed towards the plot boundaries.

2.75 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.76 Site, Corner — A site at the junctions of and fronting on two or more intersecting streets.

2.77 Site, Depth of — The mean horizontal distance between the front and rear site boundaries.

2.78 Site, Double Frontage — A site, having a frontage on two streets, other than a corner plot.

2.79 Site, Interior or Tandem — A site access to which is by a passage from a street whether such passage forms part of the site or not.

2.80 Staircover (or *Mumty*) — A structure with a roof over a staircase and its landing built to enclose only the stairs for the purpose of providing protection from weather and not used for human habitation.

2.81 Storey — The portion of a building included between the surface of any floor and the surface of the floor next above it, or if there be no floor above it, then the space between any floor and the ceiling next above it.

2.82 Storey, Topmost — The uppermost storey in a building whether constructed wholly or partly on the roof.

2.83 Street — Any means of access, namely, highway, street, lane, pathway, alley, stairway, passageway, carriageway, footway, square, place or bridge, whether a thoroughfare or not, over which the public have a right of passage or access or have passed and had access uninterruptedly for a specified period, whether existing or proposed in any scheme, and includes all bunds, channels, ditches, storm-water drains, culverts, footpaths, sidewalks, traffic islands, roadside trees and hedges, retaining walls, fences, barriers and railings within the street lines.

2.84 Street Level or Grade — The officially established elevation or grade of the central line of the street upon which a plot fronts and if there is no officially established grade, the existing grade of the street at its mid-point.

2.85 Street Line — The line defining the side limits of a street.

2.86 To Erect — To erect a building means,

a) to erect a new building on any site whether previously built upon or not; and

b) to re-erect any building of which portions above the plinth level have been pull down, burnt or destroyed.

2.87 Tower-Like Structures — Structures shall be deemed to be tower-like structures when the height of the tower-like portion is at least twice the height of the broader base at ground level.

2.88 *Verandah* — A covered area with at least one side open to the outside with the exception of 1 m high parapet on the upper floors to be provided on the open side.

2.89 Volume to Plot Area Ratio (VPR) — The ratio of volume of building measured in cubic metre to the area of the plot measured in square metre, and expressed in metre.

2.90 Water Closet— A water flushed plumbing fixture designed to receive human excrement directly from the user of the fixture. The term is used sometimes to designate the room or compartment in which the fixture is placed.

2.91 Window — An opening to the outside other than a door, which provides all or part of the required natural light or ventilation or both to an interior space.

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3 LAND USE CLASSIFICATION AND USES PERMITTED

3.1 Land Use Classification

The land use classification may be as indicated below:

Sl No.	*Level 1*					*Level 2*		
	N[1]	A-N[2]	Use Category	Colour Code[3), 4)]	Colour Code Description	N	A-N	Use Zone
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	1	R	Residential		Yellow	11	R-1	Primary residential zone
						12	R-2	Unplanned/Informal residential zone
ii)	2	C	Commercial		Red	21	C-1	Retail shopping zone
						22	C-2	General business and commercial district centres
						23	C-3	Wholesale, godowns, warehousing/regulated markets
						24	C-4	Service sector
						25	C-5	Regulated/Informal/Weekly markets
iii)	3	I	Industry		Purple	31	I-1	Service and light industry
						32	I-2	Extensive and heavy industry
						33	I-3	Special industrial zone - Hazardous, noxious and chemical
iv)	4	PS	Public and semi-public		Dark blue	41	PS-1	Govt/Semi Govt/Public offices
						42	PS-2	Govt land (use undetermined)
						43	PS-3	Police headquarter/Station, police line
						44	PS-4	Educational and research
						45	PS-5	Medical and health
						46	PS-6	Social, cultural and religious (including cremation and burial grounds)
						47	PS-7	Utilities and services
v)	5	M	Mixed use		Light yellow background with vertical hatching in black	51	M-1	Mixed industrial use zone
						52	M-2	Mixed residential zone
						53	M-3	Mixed commercial zone
vi)	6	P	Recreational		Light green	61	P-1	Playgrounds/Stadium/Sports complex
						62	P-2	Parks and gardens – Public open spaces
						63	P-3	Multi-open space (*Maidan*)

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
vii)	7	T	Transportation and communication		Brown/Grey[5)]	71	T-1	Roads/Bus rapid transit system (BRTS)
						72	T-2	Railways/Mass rapid transit system (MRTS)
						73	T-3	Airport
						74	T-4	Seaports and dockyards
						75	T-5	Bus depots/Truck terminals and freight complexes
						76	T-6	Transmission and communication
viii)	8	A	Primary activity		Dark green	81	PA-1	Agriculture
						82	PA-2	Forest and horticulture
						83	PA-3	Poultry and dairy farming
						84	PA-4	Rural settlements
						85	PA-5	Brick kiln and extractive areas
						86	PA-6	Others (Fishing, pottery, etc)
ix)	9	E	Protective and undevelopable use zone		Light blue	91	E-1	Water bodies
						92	E-2	Special recreation zone/Protective areas, such as sanctuaries/reserve forests and eco-sensitive zone
						93	E-3	Undevelopable use zone
x)	10	S	Special area		Pink	101	S-1	Old built-up (Core) area
						102	S-2	Heritage and conservation areas
						103	S-3	Scenic value areas
						104	S-4	Government restricted area (such as defence)
						105	S-5	Other uses/spot zone (*see* Note 5)

NOTES

1 Overall, there could be 43 use zones at the development plan level within 10 land use categories at the perspective plan level as given in the above table.

2 Areas of informal activities may be identified in the above land use categories at level 2 for 1 to 7 level 1 use zones only.

3 Mixed use zone shall be identified at the development plan level, having dominant use and mixed use.

4 Use permissions for different activities, as specified in the next section on simplified use zone regulations may be provided at the project/action plan level or with the approval of the Statutory Authority as the case may be.

5 The process of changing/relaxing/modifying land use of part or 'spot' of a 'zone' in a particular land use is termed as 'Spot Zoning'. Spot zoning may be done for comparatively smaller area in a particular land use zone in such a way that it does not affect the overall development plan.

6 Use zone regulations for the use permissibility (from the suggestive list) could be decided by the town planner depending upon the requirement/feasibility.

7 Appropriate code in terms of both numerical and alphabetic (letter) are provided to facilitate the reference and to have a simplified procedure to follow.

[1)] Numeric code.
[2)] Alpha-numeric code.
[3)] This colour code is for Level 1 land uses.
[4)] For subsequent levels of land uses different shades of Level 1 land use colour may be used along with relevant alpha-numeric code for clarity.
[5)] For transportation and communication facilities, brown colour, and for roads, grey colour may be used. If so decided by the planning agency, different shades of grey may be used for both roads and facilities.

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3.2 The various building uses and occupancies (*see* **7**) permitted on the various zones shall be as given in the Master Plan of the town/city concerned.

3.3 Uses to be in Conformity with the Zone

Where the use of buildings or premises is not specifically designated on the Development/Master Plan or in the absence of Development Plan, shall be in conformity with the zone in which they fall.

3.4 Uses as Specifically Designated on Development/ Master Plan

Where the use of a site is specifically designated on the Development/Master Plan, it shall be used only for the purpose so designated.

3.5 Non-Conforming Uses

No plot shall be put to any use, occupancy or premises other than the uses identified in **3.1**, except with the prior approval of the Authority.

3.6 Fire Safety

Buildings shall be so planned, designed and constructed as to ensure fire safety and this shall be done as per Part 4 'Fire and Life Safety' of the Code.

3.7 Transferable Development Rights (TDR)

3.7.1 Transferable development rights (TDR) is a compensation, in the form of floor area ratio (FAR) or development right, which shall entitle the owner for construction of built-up area, as per applicable regulations, on designated sites. The FAR credit shall be issued, in a certificate called as development right certificate (DRC). The DRC is transferrable in full or part thereof.

3.7.2 *Development Right Certificate*

The development right certificate (DRC) shall be issued by the local body or the competent authority as per regulations and shall contain the following information:

a) Built-up area or FAR credit to which the owner is entitled;
b) Place and usage zone from which the DRC is generated (originating plot);
c) Place where the FAR credit shall be used (receiving plot); and
d) Details of development rights transferred and remaining.

3.7.3 *TDR Eligibility*

TDR may be granted for,

a) Lands earmarked for various public purposes including road widening, which are subjected to acquisition, and are proposed in the plan or regulations prepared under the applicable town planning/municipal or any other legislation;
b) Development or construction of the amenity on the reserved land;
c) Heritage structure or precinct under the provision of development control regulations or any other applicable regulations;
d) *In-lieu* of constructing housing for slum dwellers, slum redevelopment, disused mill sites, etc; and
e) Purposes as may be notified by the Government as per notification.

3.8 Accommodation Reservation (AR)

Accommodation reservation (AR) is a planning tool for development of public amenities reserved in a redevelopment plan wherein local authority is not required to acquire the land by incurring expenditure on payment of compensation. In case of AR, the owner of land earmarked as public amenity, in the redevelopment plan, shall be permitted to develop his land, using full permissible FAR on the plot, subject to handing over the built-up area for the proposed use to the local body/Authority, free of all encumbrances, in lieu of full permissible FAR granted to him. The area utilized for the amenity shall not form part of FAR calculation.

4 MEANS OF ACCESS

4.1 Every building/plot shall abut on a public/private means of access like streets/roads duly formed.

4.2 Every person who erects a building shall not at any time erect or cause or permit to erect any building which in any way encroaches upon or diminishes the area set apart as means of access required in the Code. No buildings shall be erected so as to deprive any other building of the means of access.

4.3 Width of Means of Access

The residential plots shall abut on a public means of access like street/road. Plots which do not abut on a street/road shall abut/front on a means of access, the width and other requirements of which shall be as given in Table 1.

Table 1 Width and Length of Means of Access

(*Clause* 4.3)

Sl No.	Width of Means of Access	Length of Means of Access *Max*
	m	m
(1)	(2)	(3)
i)	6.0	75
ii)	7.5	150
iii)	9.0	250
iv)	12.0	400
v)	18.0	1 000
vi)	24.0	above 1 000

NOTE — If the development is only on one side of the means of access, the prescribed widths may be reduced by 1m in each case.

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In no case, development on plots shall be permitted unless it is accessible by a public street of width not less than 6 m.

4.3.1 *Other Buildings*

For all assembly buildings like, theatres, cinema houses, assembly halls, stadia; educational buildings; markets, hospitals; industrial buildings and other buildings which attract large crowd, the means of access shall not be less than the following:

Sl No.	*Width of Means of Access* m	*Length of Means of Access* m
i)	12.0	200
ii)	15.0	400
iii)	18.0	600
iv)	24.0	above 600

Further, in no case shall the means of access be lesser in width than the internal accessways in layouts and subdivision.

4.3.2 *Footpaths and Pathways*

4.3.2.1 *Footpaths*

4.3.2.1.1 Footpath should be normally designed for a pedestrian Level of Service (LOS) B, thereby providing wide pedestrian facilities for safe, pleasant and comfortable walking. Under resource constraint, LOS C may be adopted for deciding the width of footpath mentioned in Table 2. The width of footpaths depends upon the expected pedestrian traffic and may be fixed with the help of the following norms subject to not being less than 1.8 m.

Table 2 Capacity of Footpath and Design

(*Clause* 4.3.2.1.1)

Sl No.	Width of Foothpath	Design Flow in Number of Persons Per Hour			
		In Both Directions		All in One Direction	
	m	LOS B	LOS C	LOS B	LOS C
(1)	(2)	(3)	(4)	(5)	(6)
i)	1.8	1 350	1 890	2 025	2 835
ii)	2.0	1 800	2 520	2 700	3 780
iii)	2.5	2 250	3 150	3 375	4 725
iv)	3.0	2 700	3 780	4 050	5 670
v)	3.5	3 150	4 410	4 725	6 615
vi)	4.0	3 600	5 040	5 400	7 560

The land use adjacent to roads significantly influences generation of pedestrian traffic. Recommended width of footpath along various land uses are given in Table 3.

Table 3 Required Width of Footpath as per Adjacent Land Use

(*Clause* 4.3.2.1.1)

Sl No.	Description	Width m
(1)	(2)	(3)
i)	Minimum free walkway width and residential/mixed use areas	1.8
ii)	Commercial/Mixed use areas	2.5
iii)	Shopping frontages	3.5 to 4.5
iv)	Bus stops	3
v)	High intensity commercial areas	4

4.3.2.1.2 The footpath shall be level, non-slip and continuous, and shall be provided with tactile orientation, kerb and kerb ramp. The footpath shall comply with the requirements given in **B-2** other than for width which shall be as per **4.3.2.1.1**.

4.3.2.2 *Pathways*

The approach to the buildings from road/street/internal means of access shall be through paved pathway complying with requirements in **B-2**. The length of the pathway shall not be more than 30 m. The safety concern of cyclists and pedestrians should be addressed by encouraging the construction of segregated rights of way for bicycles and pedestrians.

4.3.2.2.1 In the case of special housing schemes for low income group and economically weaker section of society developed up to two storeyed row/cluster housing scheme, the main means of access through pedestrian pathway width shall be 3 m subject to provisions of **9.4.1**(a). The pedestrian pathway shall not serve more than 8 plots on each side of the pathway; the length of the pathway shall be not more than 60 m.

4.3.3 The length of the main means of access shall be determined by the distance from the farthest plot (building) to the public street. The length of the subsidiary accessway shall be measured from the point of its origin to the next wider road on which it meets.

4.3.4 In the interest of general development of an area, the Authority may require the means of access to be of larger width than that required under **4.3** and **4.3.1**.

4.3.5 In existing built-up areas in the case of plots facing street/means of access less than 4.5 m in width, the plot boundary shall be shifted to be away by 2.25 m from the central line of the street/means of accessway to give rise to a new street/means of accessway of 4.5 m width.

4.4 The means of access shall be levelled, metalled, flagged, paved, sewered, drained, channelled, lighted,

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laid with water supply line and provided with trees for shade to the satisfaction of the Authority free of encroachment by any structure or fixture so as not to reduce its width below the minimum required under **4.3** and shall be maintained in a condition to the satisfaction of the Authority.

4.4.1 If any private street or any other means of access to a building is not levelled, metalled, flagged or paved, sewered, drained, channelled, lighted or laid with water supply line or provided with trees for shade to the satisfaction of the Authority, who may, with the sanction of the Authority, by written notice require the owner or owners of the several premises fronting or adjoining the said street or other means of access or abutting thereon or to which access is obtained through such street or other means of access or which shall benefit by works executed, to carry out any or more of the aforesaid requirements in such manner as he shall direct.

4.4.2 If any structure or fixture is set upon a means of access so as to reduce its width below the minimum required, the Authority may remove the same further and recover the expenses so incurred from the owner.

4.5 Access from Highways/Important Roads

No premises other than highway amenities like petrol pumps, motels, etc, shall have an access direct from highways and such other roads not less than 52 m in width, which the Authority with the approval of the highway authority shall specify from time to time. For all other buildings, the access to the plot from the highway shall be only through a service road/lane as per the stipulation of the highway authority. The Authority shall maintain a register of such roads which shall be open to public inspection at all times during office hours. The portion of such roads on which direct access may be permitted shall be as identified in the Development Plan. However, in the case of existing development on highways/other roads referred to above, the operation of this clause shall be exempted. These provisions shall, however, be subject to the provisions of the relevant State Highway Act, and *The National Highway Act*, 1956.

4.6 For high rise buildings and special buildings (*see* Part 4 'Fire and Life Safety' of the Code), the following additional provisions of means of access shall be ensured:

a) The width of the main street on which the building abuts shall not be less than 12 m and one end of this street shall join another street not less than 12 m in width.

b) The road shall not terminate in a dead end; except in the case of residential building, up to a height of 30 m.

c) The approach to the building and open spaces on all its sides shall be not less than 6 m in width, and a turning radius of minimum 9 m shall be provided for fire tender movement of fire tenders weighing up to 45 t. The same shall be hard surface capable of taking the mass of fire tender, weighing up to 45 t minimum. For heavier fire tenders, the minimum width, turning radius and the hard surface capable of taking the fire tender loads shall be as per the requirement laid down by the Fire Department. The layout for the open space for fire tender movement shall be done in consultation with the Chief Fire Officer of the city, which shall be kept free of obstructions and shall be motorable. The compulsory open spaces around the building shall not be used for parking.

d) The main entrance to the plot shall be of adequate width to allow easy access to the fire engine and in no case shall it measure less than 6 m. The entrance gate shall fold back against the compound wall of the premises, thus leaving the exterior accessway within the plot free for movement of fire tender. If the main entrance at the boundary wall is built over, the minimum clearance shall be 4.5 m.

4.6.1 *Buildings on Podium*

4.6.1.1 Podium is a horizontal projection (platform) extending beyond the building footprint on one or more sides, and may consist of one or more levels (*see* Fig. 8A).

4.6.1.2 *Uses permitted*

Podium may be used for the following purposes:

a) *Parking of vehicles* — When used for parking, one WC, two urinals and two washbasins for every 500 cars or part thereof, shall be provided on each podium floor. At least one accessible toilet complying with the requirements given in **B-9** shall be provided preferably near the accessible parking.

   Provision for driver's rest room for non-residential building shall be made.

b) Fire and building services/utilities in accordance with the provisions of other Parts/ Sections of the Code.

c) Topmost podium slab which is open to sky maybe landscaped and/or be used as recreational open space; subject to provision of 1.6 m high parapet wall.

d) Other habitable uses may be allowed by counting it in FAR subject to light, ventilation and fire safety requirements.

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Uses proposed in (a) to (c), shall not be counted towards FAR.

4.6.1.3 *Requirements*

Following requirements shall be satisfied for buildings constructed on podium:

a) A podium may be permitted in a plot of area 1 500 m^2 or more.

b) A podium, if provided with ramp, may be permitted in one or more levels, however the total height shall not exceed 30.0 m above ground level.

c) In case a podium is not provided with ramp, but provided with car lift only, the same may also be permitted in one or more levels, however, the total height shall not exceed 9.0 m above ground level.

d) Requirements for ramp for vehicles (*see* Fig. 8B):

1) One way ramp of clear width of minimum 3.0 m and two way ramp with clear width of minimum 6.0 m shall be provided for LMV.

2) One way ramp of clear width of minimum 4.5 m and two way ramp with clear width of minimum 9.0 m shall be provided for LCV.

3) One way ramp of clear width of minimum 6.0 m and two way ramp with clear width of minimum 12.0 m shall be provided for HMV.

4) Ramp slope shall be maximum 1 in 8.

5) After a 40 m length of continuous ramp, a flat surface of minimum 6.0 m length shall preferably be provided (*see* Fig. 8B).

6) If podium is accessible to fire tender, minimum 7.5 m wide ramp shall be required for fire engine access with maximum slope of 1 in 10.

e) Podium shall not be permitted in required minimum front open space.

f) Podium, if accessible to fire tender, shall be so designed so as to take the load of fire tender weighing up to 45 t minimum or as per the requirement laid down by the Fire Department.

g) Requirement of accessibility for elders and persons with disabilities shall be ensured in compliance with the provisions of Annex B which may require providing ramps with specified gradient or accessible lifts for access to different levels.

4.6.1.4 *Requirements for fire tender movement*

a) Buildings having height more than 15 m above ground level shall necessarily be accessible by fire tender, as follows (*see* Fig. 9A):

1) For buildings having floor area less than 10 000 m^2, fire tenders shall have access to at least one-third of the perimeter of building which shall be minimum 6.0 m wide and having 9.0 m turning radius.

2) For buildings having floor area more than 10 000 m^2, fire engine shall have an access to at least to half of the perimeter of building which shall be minimum 6.0 m wide and having 9.0 m turning radius.

b) If podium is not accessible by fire tender, the podium may be such that it is not extended beyond the building footprint to an extent more than 11.0 m on the side where fire tender access is provided (*see* Fig. 9B and Fig. 9C). Such restriction shall not apply in case podium is accessible by fire engine (*see* Fig. 9D).

c) Minimum 6.0 m driveway width and 9.0 m width at turning shall be available for fire tender movement all around the podium.

NOTE — The width and turning radius of ramp for fire tender access, and requirements of motorable open space for fire tender movement given above pertain to fire tender weighing up to 45 t and its operability. For heavier fire tenders, these shall be as per the requirement laid down by the Fire Department [*see also* 4.6 (c)].

4.7 *Cul-de-sacs* giving access to plots and extending from 150 m to 275 m in length with an additional turning space at 150 m will be allowed only in residential areas, provided *cul-de-sacs* would be permissible only on straight roads and further provided the end of *cul-de-sacs* shall be higher in level than the level of the starting point of such dead end road. The turning space, in this case shall be not less than 81 m^2 in area, with no dimension less than 9 m.

4.8 Intersection of Roads

For intersection junctions of roads meeting at right angles as well as other than right angles, the rounding off or cut off or splay or similar treatment shall be done, to the approval of the Authority, depending upon the width of roads, the traffic generated, the sighting angle, etc, to provide clear sight distance.

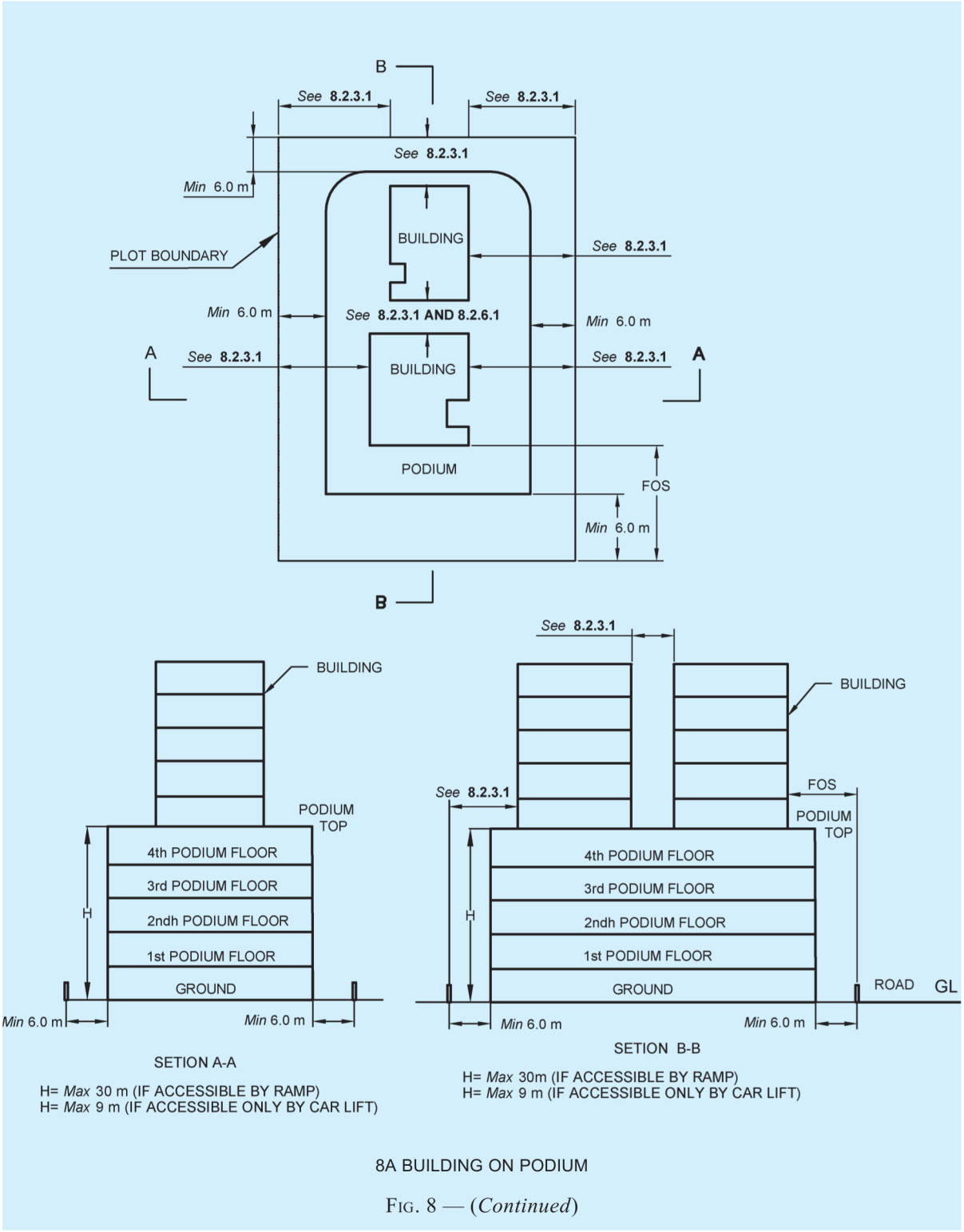
4.9 The building line shall be set back at least 3 m from internal means of access in a layout of buildings in a plot subject to provisions of **8.2.1**.

5 COMMUNITY OPEN SPACES AND AMENITIES

5.1 Residential and Commercial Zones

In any layout or sub-division of land measuring 0.3 ha or more in residential and commercial zones, the community open spaces shall be reserved for recreational purposes which shall as far as possible

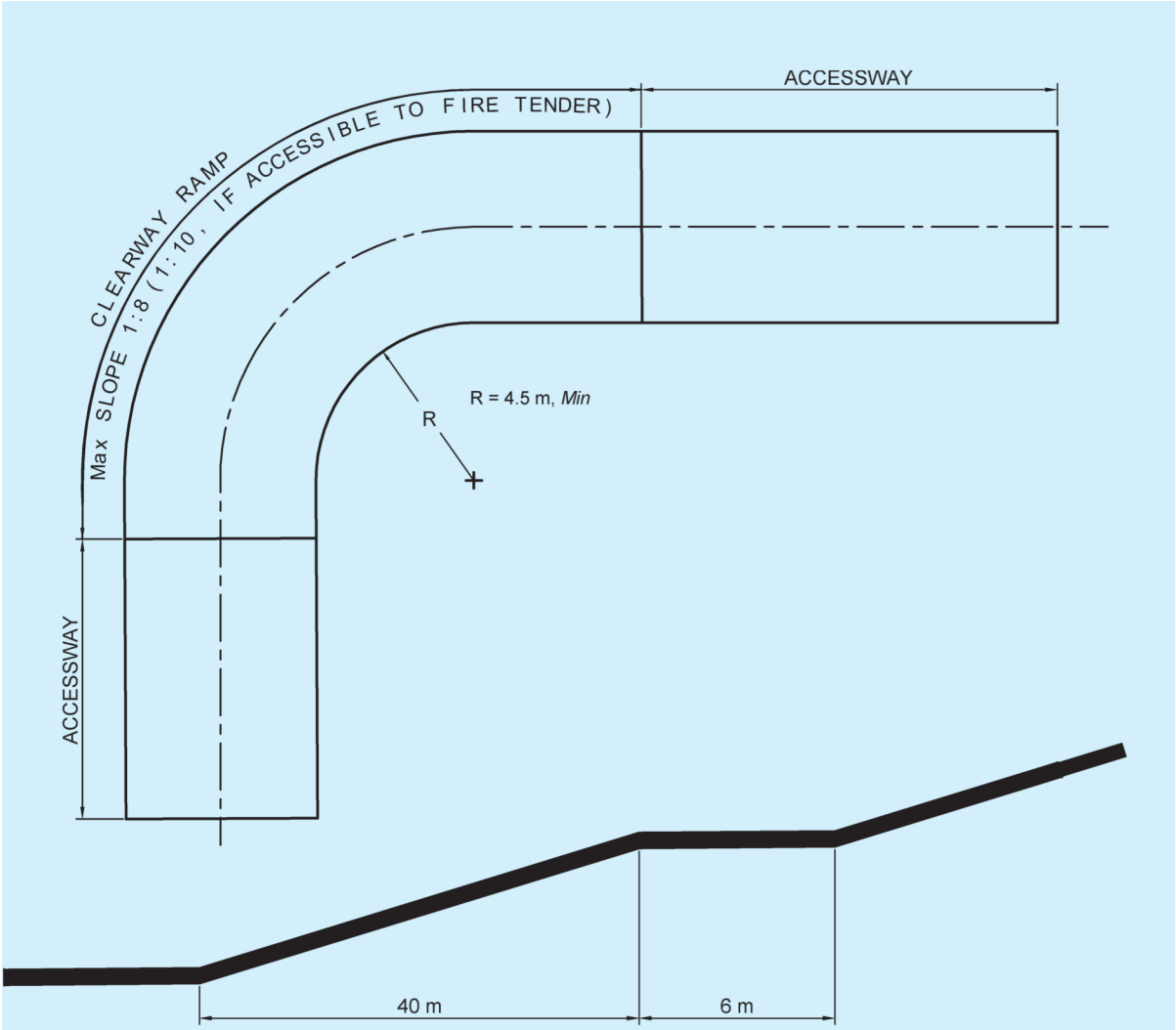
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8A BUILDING ON PODIUM

FIG. 8 — (*Continued*)

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MAXIMUM CONTINUOUS RAMP LENGTH AND
MINIMUM LENGTH OF THE RAMP LANDING

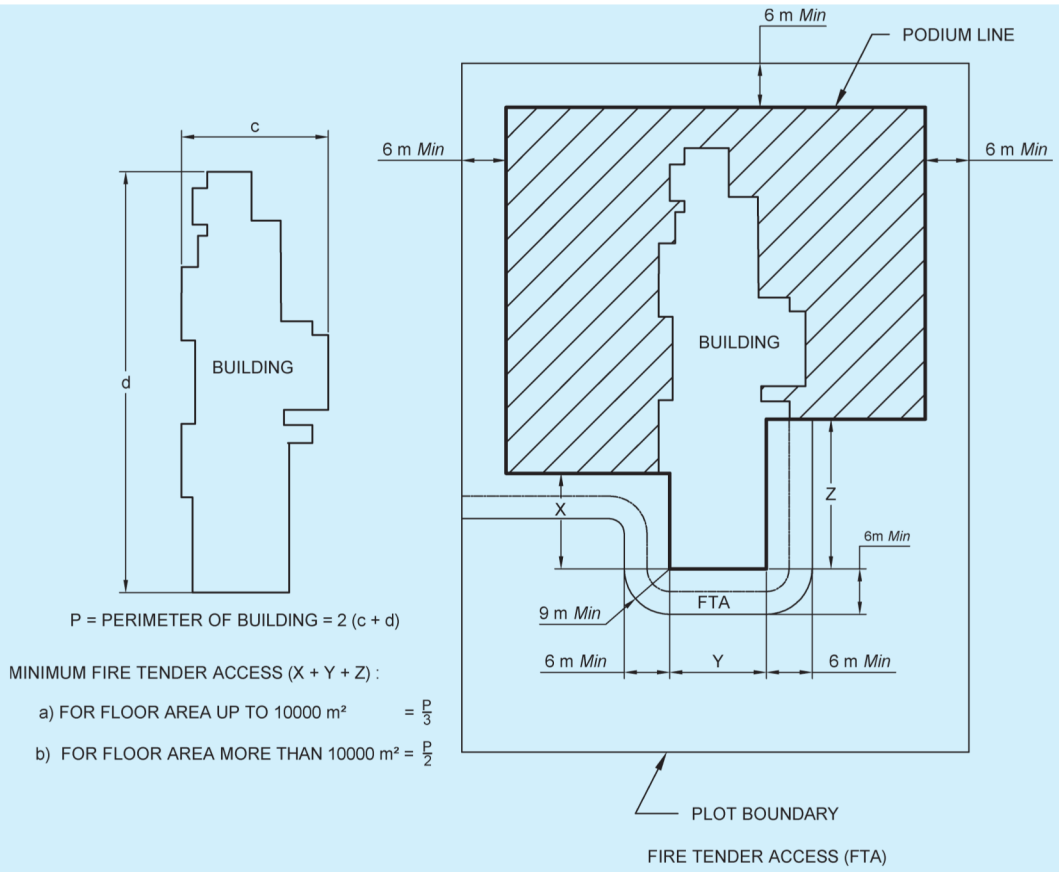
MINIMUM CLEAR RAMP WIDTH, m

	ONE WAY	TWO WAY
LMV	3.0	6.0
LCV	4.5	9.0
HMV	6.0	12.0
FIRE TENDER	7.5	

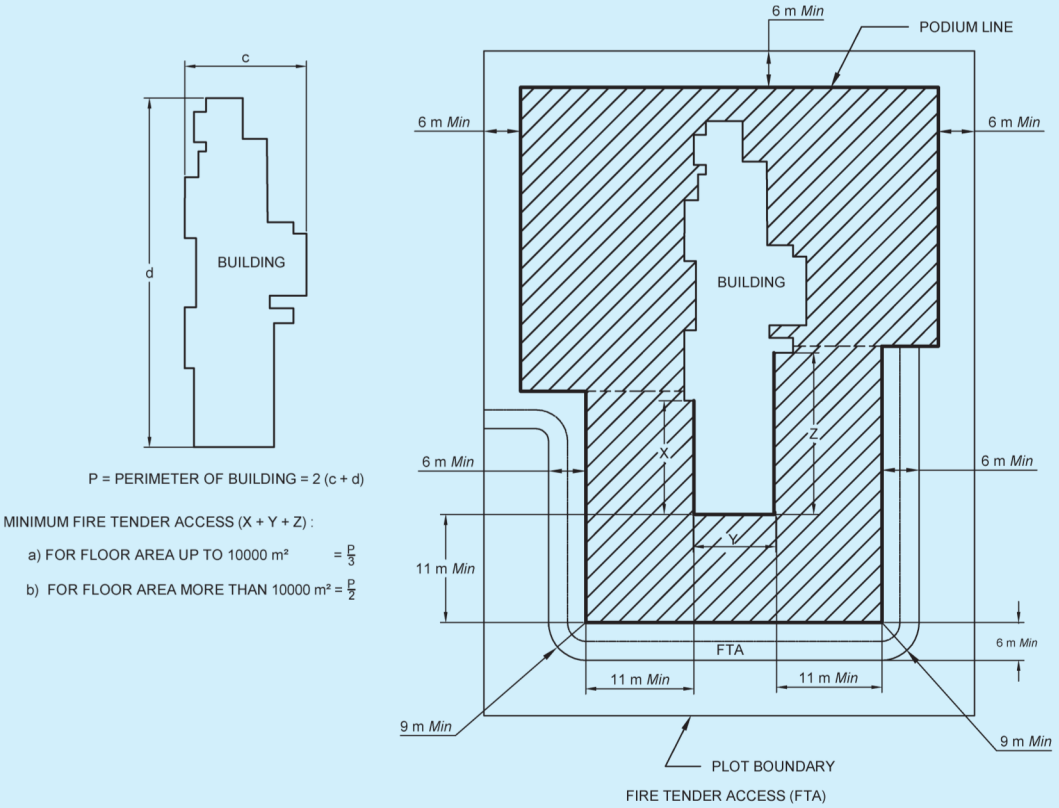
8B RAMPS FOR PODIUM

FIG. 8 BUILDINGS ON PODIUM AND THEIR RAMPS

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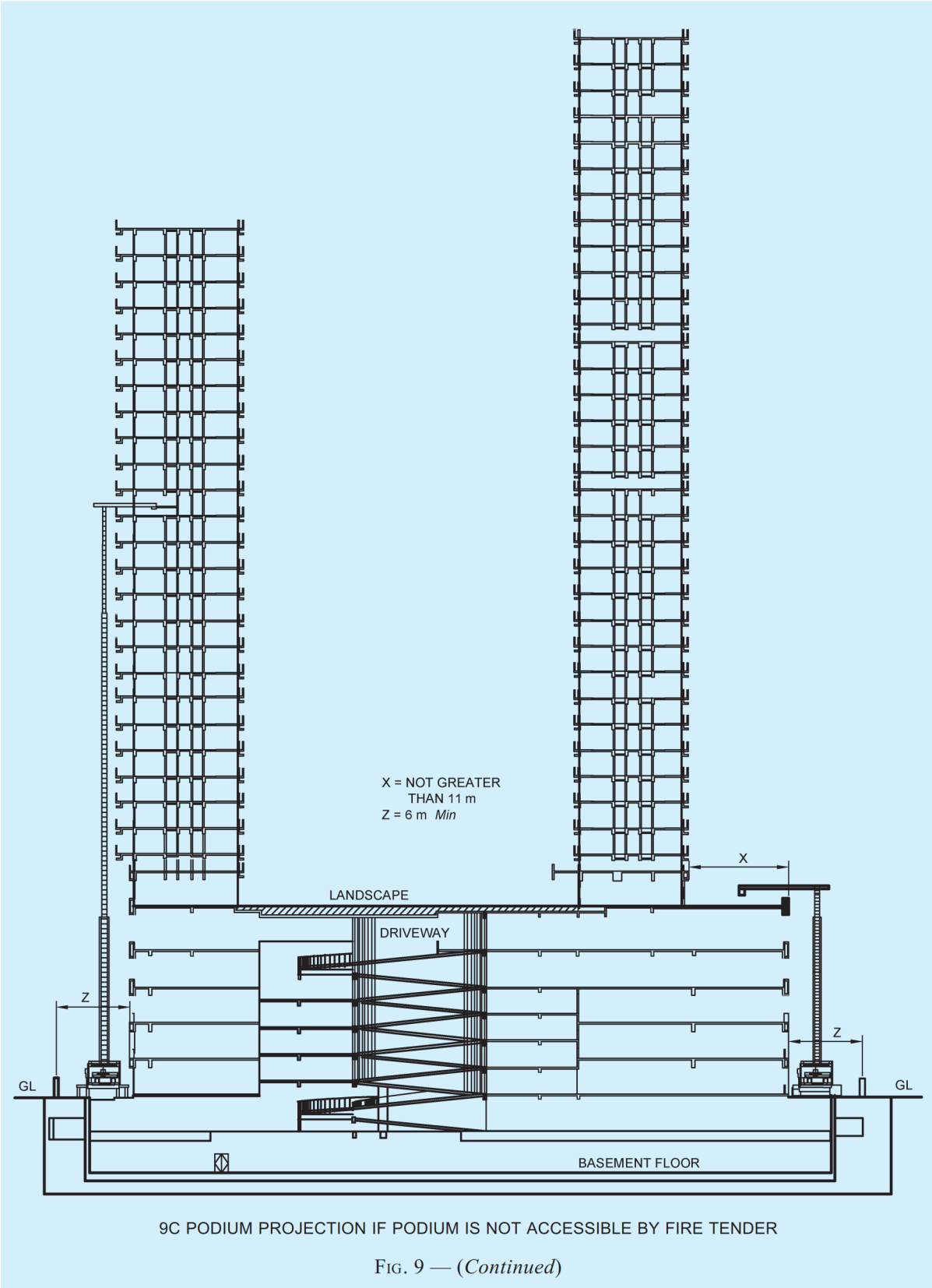
9A EMERGENCY VEHICLE ACCESS REQUIREMENT IN CASE PODIUM IS NOT ACCESSIBLE BY FIRE TENDER



9B EXTENT OF PODIUM PROJECTION ALLOWED BEYOND BUILDING ON SIDE HAVING FIRE TNEDER ACCESS (IF PODIUM IS NOT ACCESSIBLE BY FIRE TENDER)

FIG. 9 — (*Continued*)

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9C PODIUM PROJECTION IF PODIUM IS NOT ACCESSIBLE BY FIRE TENDER

FIG. 9 — (*Continued*)

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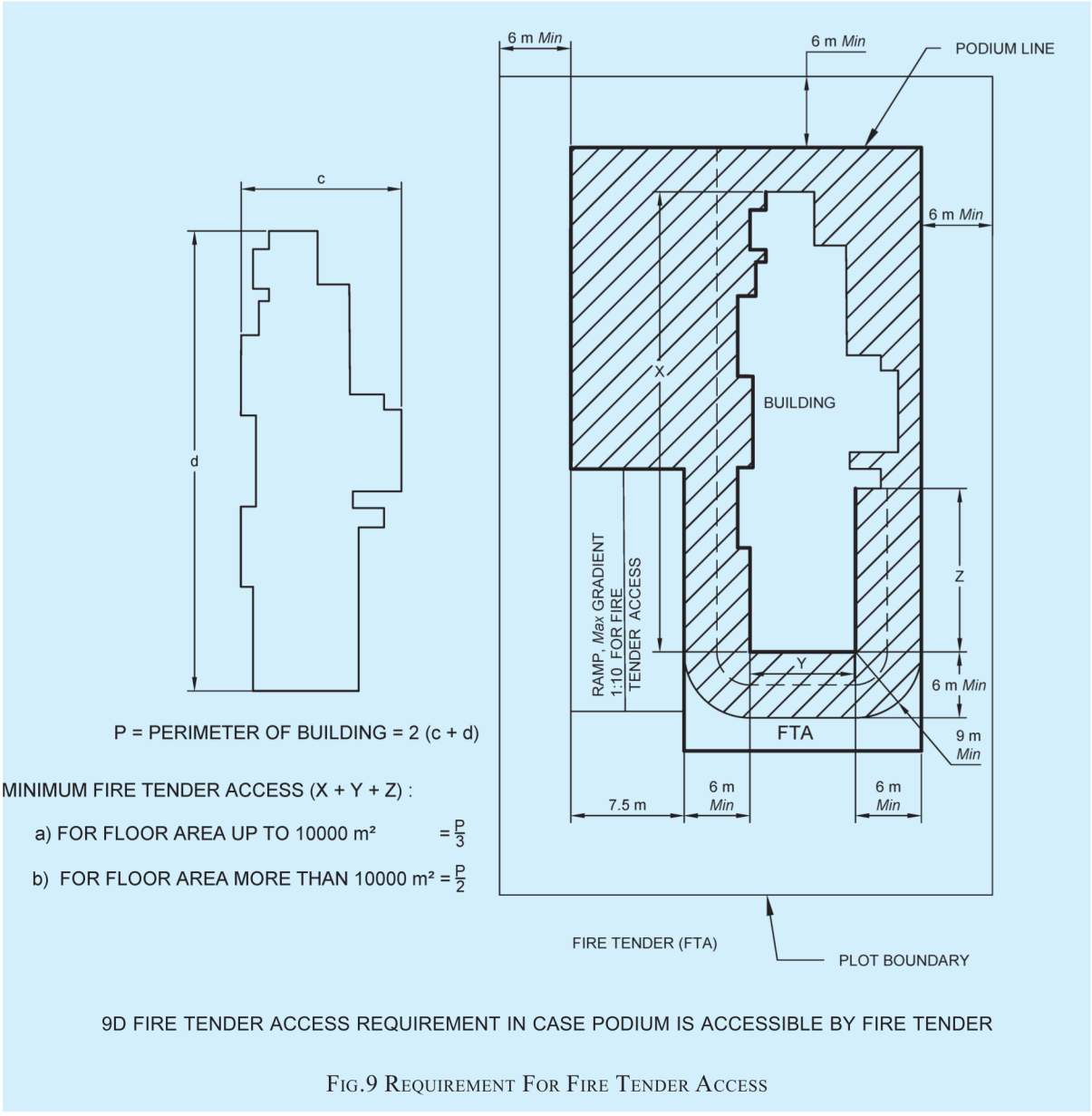


FIG.9 REQUIREMENT FOR FIRE TENDER ACCESS

be provided in one place or planned out for the use of the community in clusters or pockets.

5.1.1 The community open spaces shall be provided catering to the needs of area of layout, population for which the layout is planned and the category of dwelling units. The following minimum provision shall be made:

a) 15 percent of the area of the layout, or

b) 0.3 to 0.4 ha/1 000 persons; for low income housing, the open spaces shall be 0.3 ha/1 000 persons.

5.2 No recreational space shall generally be less than 450 m^2.

5.2.1 The minimum average dimension of such recreational space shall be not less than 7.5 m; if the average width of such recreational space is less than 24 m, the length thereof shall not exceed 2.5 times the average width. However, depending on the configuration of the site, commonly open spaces of different shapes may be permitted by the Authority, as long as the open spaces provided serve the needs of the immediate community contiguous to the open spaces.

5.2.2 In such recreational spaces, a single storeyed structure as pavilion or gymnasia up to 25 m^2 in area may be permitted; such area may be excluded from FAR calculations.

5.3 Each recreational area and the structure on it shall have an independent means of access. Independent means of access may not be insisted upon if recreational space is approachable directly from every building in the layout. Further, the building line shall be at least 3 m away from the boundary of recreational open space.

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5.4 Industrial Zones

In the case of sub-division of land in industrial zones of area 0.8 hectare or more, 5 percent of the total area shall be reserved as amenity open space which shall also serve as a general parking space; when such amenity open space exceeds 1 500 m^2, the excess area could be utilized for the construction of buildings for banks, canteens, welfare centers and such other common purposes considered necessary for the industrial user, as approved by the Authority.

5.4.1 In all industrial plots measuring 1 000 m^2 or more in area, 10 percent of the total area shall be provided as an amenity open space to a maximum of 2 500 m^2. Such an amenity open space shall have a means of access and shall be so located that it could be conveniently utilized as such by the persons working in the industry.

5.5 Other Amenities

In addition to community open spaces, the layouts shall provide for the amenities as given in **5.5.1** to **5.5.13**. These provisions may be modified based on specific requirements, as decided by the Authority.

5.5.1 *Educational Facilities*

	Land Area Required, Min
a) *Pre-Primary to secondary education*	
1) Pre-primary, nursery school — 1 for every 2 500 population	
i) Area per school	0.08 ha
ii) Location of pre-primary/nursery school	to be located near a park
2) Primary school (class 1 to 5) — 1 for every 5 000 population	
i) Strength of the school — 500 students	
ii) Area per school:	0.40 ha
a) School building area	0.20 ha
b) Play field area (with a minimum of 18 m × 36 m to be ensured for effective play)	0.20 ha (which is inclusive of the limited parking requirement for functional uses)
3) Senior secondary school (class 6 to 12) — 1 for every 7 500 population	
i) Strength of the school — 1 000 students	
ii) Area per school:	1.80 ha
a) School building area	0.60 ha
b) Play field area (with a minimum of 68 m × 126 m to be ensured for effective play)	1.00 ha
c) Parking area	0.20 ha
4) Integrated school without hostel facility (class 1 to 12) — 1 for every 90 000 to 100 000 population	
i) Strength of the school — 1 500 students	
ii) Area per school:	3.50 ha
a) School building area	0.70 ha
b) Play field area	2.50 ha
c) Parking	0.30 ha
iii) Location	To be located near a sport facility
5) Integrated school with hostel facilities (class 1 to 12) — 1 for every 90 000 to 100 000 population	
i) Strength of school — 1 500 students	
ii) Area per school:	3.90 ha
a) School building area	0.70 ha
b) Play field area	2.50 ha
c) Residential (including hostel area)	0.40 ha
d) Parking area	0.30 ha
iii) Location	To be located near a sport facility
6) School for children with disabilities (Class 1 to 12) — 1 for every 45 000 population	
i) Strength of the school — 400 students	
ii) Area per school:	0.70 ha
a) School building area	0.20 ha

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b) Play field area	0.30 ha
c) Parking area	0.20 ha
iii) Location	To be located near a park or sport facility

NOTE — The schools should be inclusive providing education to all children including those with disabilities. However it may be required to have exclusive schools in case of certain disabilities, such as, speech, hearing, sight and multiple disabilities.

7) School for children with intellectual and developmental disabilities — 1 for every 1 000 000 population

i) Area per school	0.20 ha
ii) Location of pre-primary/nursery school	To be located near a park and non-noise polluting zone

The schools should preferably face service roads and roads with less traffic intensity.

b) *Higher education — General*

1) College — 1 for every 125 000 population

i) Strength of the college — 1 000 to 1 500 students	
ii) Area per college:	5.00 ha
a) College building area	1.80 ha
b) Play field area	2.50 ha
c) Residential (including hostel area)	0.40 ha
d) Parking area	0.30 ha

2) University campus

Area:	10.00 ha to 60.00 ha
i) Residential (if included) area	25 percent of total land area
ii) Sports and cultural activities	15 percent of total land area
iii) Parks and landscape including green belt	15 percent of total land area

c) *Technical education*

1) Technical education centre (A) — 1 for every 1 000 000 population to include 1 industrial training institute (ITI) and 1 polytechnic

i) Strength of ITI — 400 students	
ii) Strength of polytechnic — 500 students	
iii) Area per technical education centre:	4.00 ha
a) Area for ITI	1.60 ha
b) Area for polytechnic	2.40 ha

2) Technical education centre (B) — 1 for every 1 000 000 population to include 1 ITI, 1 technical centre and 1 coaching centre

Area per technical education centre:	4.00 ha
i) Area for ITI	1.60 ha
ii) Area for technical centre	2.10 ha
iii) Area for coaching centre	0.30 ha

d) *Professional education*

1) Engineering college — 1 for every 1 000 000 population

i) Strength of the college — 1 500 students	
ii) Area per college	6.00 ha

2) Medical college — 1 for every 1 000 000 population

Area of site including space for general hospital	15.00 ha

3) Nursing and paramedic institute — 1 for every 1 000 000 population

Plot area per institute (subject to Nursing Council of India/Ministry of Health Norms)	0.20 ha

4) Veterinary institute Area — As per Veterinary Council of India/ Ministry of Agriculture norms (subject to availability of land)

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5) Other professional colleges — 1 for every 1 000 000 population	
i) Strength of the college — 250 to 1 500 students	
ii) Area of site:	
a) for students strength up to 250 students	2.00 ha
b) additional area of site for every additional 100 students or part thereof up to total strength of 1 000 students	0.50 ha
c) for strength of college from 1 000 to 1 500 students	6.00 ha

5.5.2 *Health Care Facilities*

	Land Area Required, Min
a) *Dispensary — 1 for every 15 000 population*	
Area	0.08 ha to 0.12 ha
b) *Nursing home, child welfare and maternity centre — 1 for every 45 000 to 100 000 population*	
1) Capacity — 25 to 30 beds	
2) Area 0.20 ha to 0.30 ha	
c) *Poly-clinic with some observation beds — 1 for every 100 000 population)*	
Area	0.20 ha to 0.30 ha
d) *Intermediate hospital (category B) — 1 for every 100 000 population*	
1) Capacity — 80 beds (initially the provision may be for 50 beds including 20 maternity beds)	
2) Total area:	1.00 ha
i) Area for hospital	0.60 ha
ii) Area for residential accommodation	0.40 ha
e) *Intermediate hospital (category A) — 1 for every 100 000 population*	
1) Capacity — 200 beds (initially the provision may be for 100 beds)	
2) Total area:	3.70 ha
i) Area for hospital	2.70 ha
ii) Area for residential accommodation	1.00 ha
f) *General hospital — 1 for every 250 000 population*	
1) Capacity — 500 beds (initially the provision may be for 300 beds)	
2) Total area:	6.00 ha
i) Area for hospital	4.00 ha
ii) Area for residential accommodation	2.00 ha
g) *Multi-speciality hospital — 1 for 100 000 population*	
1) Capacity — 200 beds (initially the provision may be for 100 beds)	
2) Total area:	9.00 ha
i) Area for hospital	6.00 ha
ii) Area for residential accommodation	3.00 ha
h) *Speciality hospital — 1 for every 100 000 population*	
1) Capacity — 200 beds (initially the provision may be for 100 beds)	
2) Total area:	3.70 ha
i) Area for hospital	2.70 ha
ii) Area for residential accommodation	1.00 ha
j) *Family welfare centre — 1 for every 50 000 population*	
Area	500 m^2 to 800 m^2
k) *Diagnostic centre — 1 for every 50 000 population*	
Area	500 m^2 to 800 m^2

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m) *Veterinary hospital for pets and animals — 1 for every 500 000 population*	
Area	0.20 ha
n) *Dispensary for pet animals and birds — 1 for every 100 000 population*	
Area	300 m^2
p) *Rehabilitation centres*	
Area	As per requirement

5.5.3 *Socio-Cultural Facilities*

	Land Area Required, Min
a) *Community room — 1 for every 5 000 population*	
Area	750 m^2
b) *Community hall, Mangal Karyalaya/Kalyana Mandapam/Barat Ghar/ library — 1 for every 15 000 population)*	
Area	2 000 m^2
c) *Recreational club — 1 for every 100 000 population*	
Area	10 000 m^2
d) *Music, dance and drama centre — 1 for every 100 000 population*	
Area	1 000 m^2
e) *Meditation and spiritual centre — 1 for every 100 000 population*	
Area	5 000 m^2
f) *Socio-cultural centre/Exhibition cum fair ground — 1 for every 1 000 000 population*	
Area	15.00 ha
g) *Anganwadi-housing area/cluster — 1 for every 5 000 population*	
Area	200 to 300 m^2
h) *Old age home — 1 for every 500 000 population*	
Area	1000 m^2 *Max*, subject to availability of land
j) *Religious facilities*	
1) At neighbourhood/housing cluster level — 1 for every 5 000 population	
Area	400 m^2
2) At sub-city level in urban extension — 1 for every 1 000 000 population	
Area	4.00 ha
k) *Science centre — 1 for every 1 000 000 population*	
Area	As per requirement
m) *International convention centre — 1 at city level*	
Area	As per requirement
n) *Other facilities*	
1) Orphanage/Children's centre (one each) — 1 for every 1 000 000 population	
Area	1 000 m^2 *Max*, subject to availability of land
2) Centre for support services for persons with disabilities — 1 for every 1 000 000 population	
Area	1 000 m^2 *Max*, subject to availability of land
3) Working women/men hostel — 1 for every 1 000 000 population	
Area	1 000 m^2 *Max*, subject to availability of land
4) Adult education centre — 1 for every 1 000 000 population	
Area	1 000 m^2 *Max*, subject to availability of land
5) Night shelter — 1 for every 1 000 000 population	
Area	1 000 m^2 *Max*, subject to availability of land

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5.5.4 *Distribution Services*

	Land Area Required, Min
a) *Petrol/diesel filling and servicing centre* — May be permitted in central as well as sub-central business district, district centres, community centres (only filling station), residential and industrial use zones in urban areas, along the national highways, state highways, villages identified as growth centres, freight complex, proposed major roads and police/security force services (for captive use only).	
1) Location	
i) Shall not be located on the road having right of way less than 30 m.	
ii) Shall be approved by the explosive/fire department.	
iii) Special cases in old city areas may be considered based on the approval by statutory authorities.	
2) Area/Size	
i) Only filling station	30 m × 17 m
ii) Filling cum service station	36 m × 30 m
iii) Filing cum service station cum workshop	45 m × 36 m
iv) Filling station only for two and three wheelers	18 m × 15 m
b) *Compressed natural gas (CNG) filling centre* — Permitted in all use zones (except in regional parks and developed district parks) and along the national highways, state highways and villages identified as growth centres, freight complex and on proposed major roads.	
1) Location	
i) Shall not be located on the road having right of way less than 30 m.	
ii) Shall be approved by the explosive/fire department.	
2) Area/Size for CNG mother station (including building component — control rooms/office/dispensing room/store, pantry and W.C.)	1 080 m^2 (36 m × 30 m)
c) *LPG godowns/Gas godown — 1 for every 40 000 to 50 000 population* The major concern for its storage and distribution is the location which shall be away from the residential areas and shall have open spaces all around as per *The Explosive Rules*, 2008	
1) Capacity – 500 cylinders or 8 000 kg of LPG	
2) Area (inclusive of guard room)	520 m^2 (26 m × 20 m)
d) *Milk distribution booth — 1 milk booth for every 5 000 population* Area inclusive of service area	150 m^2
e) *Fruit and vegetable distribution booth — 1 booth for every 5 000 population* Area	250 m^2

5.5.5 *Police, Civil Defence and Home Guards*

	Land Area Required, Min
a) *Police station — 1 for every 90 000 population* Area (inclusive of essential residential accommodation; 0.05 ha additional to be provided for civil defence and home guards)	1.50 ha
b) *Police post — 1 for every 40 000 to 50 000 population (not served by a police station)* Area (inclusive of essential residential accommodation)	0.16 ha

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c) *District office and battalion — 1 for every 1 000 000 population*	
Total area:	4.80 ha
1) Area for district office	0.80 ha
2) Area for battalion	4.00 ha
d) *Police line — 1 for every 2 000 000 population*	
Area	4.00 to 6.00 ha
e) *District jail — 1 for every 1 000 000 population*	
Area	10.00 ha
f) *Civil defence and home guards — 1 for every 1 000 000 population*	
Area	2.00 ha
g) *Traffic and police control room*	
Area	As per requirement
h) *Police training institute/college — 1 at city level*	
1) Location — To be located in fringe areas	
2) Area	5.00 ha
j) *Police firing range — 1 at city level*	
1) Location — To be located in fringe areas	
2) Area	Up to 10.00 ha
k) *Police camp including Central Police Organization/security forces (including Central security forces)*	
Area	Up to 10.00 ha
m) *Police booth (to be provided by transport planners)*	
1) Location — at major road intersections	
2) Area	10 to 12 m^2

5.5.6 *Safety Management*

	Land Area Required, Min
a) *Fire station — 1 for every 200 000 population or 1 within 5 to 7 km radius*	
Area inclusive of residential accommodation	1.00 ha
b) *Sub fire station/fire post — 1 within a radius of 3 to 4 km*	
Area inclusive of essential residential accommodation	0.6 ha
c) *Disaster management centre — 1 in each administrative zone*	
Area	1) 1.00 ha along with suitable open area 2) 2.00 ha if soft parking, temporary shelter, parade ground, etc, included
d) *Fire training institute/college*	
Area	3.0 ha

5.5.7 *Telephone, Postal and Banking Facilities*

	Land Area Required, Min
a) *Telephone and Communications*	
1) Telephone exchange of 40 000 lines — 1 for every 400 000 population	
Area	4.00 ha
2) Radio/TV station — 1 for every 500 000 to 800 000 population	
Area	1 700 m^2
3) Remote subscriber unit (RSU) — 1 for 3 km radius	
Area	300 m^2
b) *Postal*	
1) Post office counter without delivery — 1 for every 15 000 population	
Floor area to be provided in local shopping centre	85 m^2
2) Head post office with delivery office — 1 for 250 000 population	
Area	750 m^2
3) Head post office and administrative office — 1 for 500 000 population	
Area	2 500 m^2

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c) *Banking*

1) *Bank with extension counters with ATM facility — 1 for every 15 000 population*
   i) Floor area for counters — 75 m^2
   ii) Floor area for ATM — 6 m^2

2) *Bank with locker, ATM and other banking facilities — 1 for 100 000 population*
   Area — 2 500 m^2

5.5.8 *Sports Facilities*

	Land Area Required, Min
a) *Divisional sports centre — 1 for 1 000 000 population*	
Area	20.00 ha
b) *District sports centre — 1 for 100 000 population*	
Area	8.00 ha
c) *Neighbourhood play area — 1 for 15 000 population*	
Area	1.50 ha
d) *Residential unit play area — 1 for 5 000 population*	
Area	5 000 m^2

5.5.9 *Commercial Centres*

	Land Area Required, Min
a) *Convenience shopping — 1 for every 5 000 population*	
Area	1 500 m^2
b) *Local shopping including service centre — 1 for every 15 000 population*	
Area	4 600 m^2
c) *Community centre with service centre — 1 for every 100 000 population*	
Area	5.00 ha
d) *District centre — 1 at district level/1 for every 500000 population*	
Area	40.00 ha
e) *Sub-city centre — 1 for every 2 500 000 to 5 000 000 population*	
Area	As per requirement
f) *City centre — 1 for every 5 000 000 plus population*	
Area	As per requirement
g) *Local wholesale market/Mandi — 1 for 1 000 000 population*	
Area	10.00 ha
h) *Weekly markets — 1 to 2 locations for every 100 000 population with 300 to 400 units per location*	
Parking and other open spaces with in the commercial centres can be so designed that weekly markets may operate in these areas during non-working hours.	
The area of informal sector should have suitable public conveniences and solid waste disposal arrangements.	
Area per location	0.40 ha
j) *Organized informal eating spaces — 1 for every 100 000 population*	
Area	2 000 m^2

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5.5.10 *Electrical Sub-Station*

	Land Area Required, Min
a) *11 kV sub-station — 1 for 15 000 population*	
Area	500 m^2
b) *66 kV sub-station — 2 for 100 000 population*	
Area for each sub-station	6 000 m^2 (that is, 60 m × 100 m)
c) *220 kV sub-station — 1 for 500 000 population*	
Area	4.00 ha

5.5.11 *Transport*

	Land Area Required, Min
a) *Three wheeler and taxi stand — 1 for 15 000 population*	
Area	500 m^2
b) *Bus terminal — 1 for 100 000 population*	
Area	4 000 m^2
c) *Bus depot — 1 for 500 000 population*	
Area	2.00 ha

5.5.12 *Cremation/Burial Ground*

The site shall not be in proximity to residential areas and should preferably be in urban extension.

	Land Area Required, Min
a) *Electric crematorium — 1 for large size towns*	
Area	2.00 ha
b) *Cremation ground — 1 for 500 000 population*	
Area	2.50 ha
c) *Burial ground — 1 for 500 000 population*	
Area	4.00 ha

5.5.13 *Dhobi Ghat*

	Land Area Required, Min
Dhobi ghat with appropriate arrangements for water and drainage facilities and it shall be ensured that the water bodies are not polluted as a result of such activities 1 for 100 000 population	
Area	5 000 m^2

5.6 Every layout or subdivision shall take into account the provisions of development plan and if the land is affected by any reservation for public purposes, the Authority may agree to adjust the location of such reservations to suit the development.

6 REQUIREMENTS OF PLOTS

6.1 No building shall be constructed on any site, on any part of which there is deposited refuse, excreta or other offensive matter objectionable to the Authority, until such refuse has been removed therefrom and the site has been prepared or left in a manner suitable for building purposes to the satisfaction to the Authority.

6.2 Damp Sites

Wherever the dampness of a site or the nature of the soil renders such precautions necessary, the ground surface of the site between the walls of any building erected thereon shall be rendered damp-proof to the satisfaction of the Authority.

6.3 Surface Water Drains

Any land passage or other area within the curtilage of a building shall be effectively drained by surface water drains or other means.

6.3.1 The written approval of the Authority shall be obtained for connecting any subsoil or surface water drain to a sewer.

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6.4 Distance from Electric Lines

An overhead line shall not cross an existing building as far as possible and no building shall be constructed under an existing overhead line. No accessible point from any *Verandah,* balcony, or the like shall be allowed to be erected or re-erected or any additions or alterations made to a building not having the following minimum clearances from an overhead electric supply line, in accordance with the current *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations,* 2010 as amended from time to time:

a) *Clearance of buildings from lines of voltages and service lines not exceeding 650 V*

1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

2) Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed:

i) For any flat roof, open balcony, *Verandah* roof and lean-to-roof:

a) where the line passes above the building, a vertical clearance of 2.5 m from the highest point, and

b) when the line passes adjacent to the building, a horizontal clearance of 1.2 m from the nearest point, and

ii) For pitched roof:

a) where the line passes above the building, a vertical clearance of 2.5 m immediately under the line, and

b) when the line passes adjacent to the building, a horizontal clearance of 1.2 m.

3) The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

4) Any conductor so situated as to have a clearance less than that specified above shall be adequately insulated and shall be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg.

b) *Clearances from buildings of lines of voltages exceeding 650 V*

1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

2) Where an overhead line of voltage exceeding 650 V passes above or adjacent to any building or part of a building, it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than:

i) For lines of voltages exceeding 650 V : 3.7 m upto and including 33 kV; and

ii) For lines of voltages exceeding 33 kV : 3.7 m plus 0.30 m for every additional 33 kV or part thereof.

3) The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than:

i) For lines of voltages exceeding 650 V and up to and including 11 kV : 1.2 m

ii) For lines of voltages exceeding 11 kV and up to and including 33 kV : 2.0 m

iii) For lines of voltages exceeding 33 kV : 2.0 m plus 0.3 m for every additional 33 kV or part thereof

4) For high voltage direct current (HVDC) systems, vertical clearance and horizontal clearance, on the basis of maximum deflection due to wind pressure, from building shall be maintained as below:

Sl No.	*d.c. Voltage*	*Vertical Clearance*	*Horizontal Clearance*
	kV	m	m
(1)	(2)	(3)	(4)
i)	100	4.6	2.9
ii)	200	5.8	4.1
iii)	300	7.0	5.3
iv)	400	7.0	6.2
v)	500	9.1	7.4
vi)	600	10.3	8.6
vii)	800	12.4	10.7

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6.5 Distance from Water Course/Area

Distance of site from the normal edge of water course/ area may be specified by the Authority, keeping in view the normal maximum flood/tide level.

6.6 Size of Plots

6.6.1 *Residential*

Each plot shall have a minimum size/frontage corresponding to the type of development as given below:

Sl No.	*Type of Development*	*Plot Size* m^2	*Frontage* m
(1)	(2)	(3)	(4)
i)	Detached building	Above 250	above 12
ii)	Semi-detached building	125-250	8 to 12
iii)	Row type building	50-125	4.5 to 8

NOTE — For low income housing, *see* **14**.

6.6.1.1 The minimum size of the site for group housing development shall be as given in the Master Plan and local development control rules.

6.6.2 *Industrial*

The size of the plot shall not be less than 300 m^2 and its width shall not be less than 15 m.

6.6.3 *Other Land Uses*

The minimum size of plots for buildings for other uses not covered under **5.5** shall be as decided by the Authority. Various requirements with respect to cinema buildings shall be in accordance with the good practice [3(2)].

7 CLASSIFICATION OF BUILDINGS

Buildings are classified based on occupancy and types of construction.

7.1 For the purpose of the Code, the following shall be the occupancy classification and types of construction; for more detailed information, reference may be made to Part 4'Fire and Life Safety' of the Code.

7.1.1 *Occupancy Classification*

a) Residential;
b) Educational;
c) Institutional;
d) Assembly;
e) Business;
f) Mercantile (will include both retail and wholesale stores);
g) Industrial (will include low, moderate and high fire hazards);
h) Storage; and
j) Hazardous.

7.1.2 *Types of Construction*

a) Type 1,
b) Type 2,
c) Type 3, and
d) Type 4.

8 OPEN SPACES (WITHIN A PLOT)

8.1 General

Every room intended for human habitation shall abut on an interior or exterior open space or an open *Verandah* open to such interior or exterior open space.

8.1.1 The open spaces inside and around a building have essentially to cater for the lighting and ventilation requirements of the rooms abutting such open spaces, and in the case of buildings abutting on streets in the front, rear or sides, the open spaces provided shall be sufficient for the future widening of such streets.

8.1.2 *Open Spaces Separate for Each Building or Wing*

The open spaces shall be separate or distinct for each building and where a building has two or more wings, each wing shall have separate or distinct open spaces for the purposes of lighting and ventilation of the wings.

However, separation between accessory and main buildings more than 7 m in height shall not be less than 1.5 m; for buildings up to 7 m in height no such separation shall be required.

8.1.3 The open space shall be the minimum distance measured between the front, rear and side of the building and the respective plot boundaries. The front, rear and side of the building shall be the point of the building nearest to the boundary.

8.2 Residential Buildings

8.2.1 *Exterior Open Spaces*

The exterior open spaces for residential buildings up to a height of 10 m shall be in accordance with **8.2.1.1** to **8.2.1.3**.

8.2.1.1 *Front open space*

a) Every building fronting a street shall have a front space, forming an integral part of the site

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as given below:

Sl No.	*Front Open Space, Min* *m*	*Width of Street Fronting the Plot* *m*
(1)	(2)	(3)
i)	1.5[1)]	Up to 7.5[1)]
ii)	3.0	7.5 to 18
iii)	4.5	18 to 30
iv)	6.0	Above 30

[1)] For buildings up to a maximum height 7 m.

NOTE — In case a building abuts two or more streets, the value of open spaces is to be based on the average width of streets, subject to a minimum of 1.8 m for Sl No. (ii), (iii) and (iv).

b) For streets less than 7.5 m in width, the distance of the building (building line) shall be at least 5 m from the centre line of the street (*see* **4.3.5**).

NOTE — This limiting distance has to be determined by the Authority for individual road/street widths taking into account the traffic flow.

8.2.1.2 *Rear open space*

a) Every residential building shall have a rear open space, forming an integral part of the site, of an average width of 3.0 m and at no place measuring less than 1.8 m, except that in the case of a back-to-back sites, the width of the rear open space shall be 3.0 m throughout. Subject to the condition of free ventilation, the open space left up to half the width of the plot shall also be taken into account for calculating the average width of the rear open space. For plots of depths less than 9 m, for buildings up to 7 m in height, the rear open space may be reduced to 1.5 m.

b) *Rear open space to extend the rear wall* — The rear open space shall be co-extensive with the entire face of the rear wall. If a building abuts on two or more streets, such rear open space shall be provided throughout the face of the rear wall. Such rear wall shall be the wall on the opposite side of the face of the building abutting on the wider street unless the Authority directs otherwise.

c) In case of corner plots less than 300 m^2 in area, the rear open space should be 2.4 m minimum.

8.2.1.3 *Side open space*

a) Every semi-detached and detached building shall have a permanently open air space, forming an integral part of the site as given below:

1) For detached buildings there shall be a minimum side open space of 3.0 m on both the sides.

NOTE — For detached residential buildings up to 7 m in height on plots with a frontage less than 12 m (*see* **6.6.1**), one of the side open spaces may be reduced to 1.5 m.

2) For semi-detached buildings, there shall be a minimum side open space of 3.0 m on one side.

NOTE — For semi-detached buildings up to 7 m in height on plots with a frontage less than 9 m (*see* **6.6.1**), the side open spaces may be reduced to 1.5 m.

3) For row-type buildings, no side open is required.

b) In the case of semi-detached buildings, the open spaces provided on one side shall be as in **8.2.1.3** (a) (2) and all habitable rooms shall abut either on this side open space or front and rear open spaces or an interior open space (*see* **8.2.5**).

8.2.2 The provisions of **8.2.1.2** and **8.2.1.3** are not applicable to parking lock-up garages up to 3 m in height located at a distance of 7.5 m from any street line or front boundary of the plot.

8.2.3 The exterior open spaces for residential buildings of height above 10 m shall be in accordance with **8.2.3.1** and **8.2.3.2**.

8.2.3.1 For buildings of height above 10 m, the open spaces (side and rear) shall be as given in Table 4. The front open spaces for increasing heights of buildings shall be governed by **9.4.1**(a).

8.2.3.2 For tower-like structures, as an alternative to **8.2.3.1**, open spaces shall be as given below:

a) Up to a height of 24 m, with one set-back, the open spaces at the ground level, shall be not less than 6 m [*see* Fig. 10A];

b) For heights between 24 m and 37.5 m with one set-back, the open spaces at the ground level, shall be not less than 9 m [*see* Fig. 10B];

c) For heights between37.5 m and 70 m with two set-backs, the open spaces at the ground level, shall be not less than 12 m [*see* Fig. 10C];

d) For heights between 70 m and 120 m with two set-backs, the open spaces at the ground level, shall be not less than 14 m [*see* Fig. 10D];

e) For heights above 120 m and above with two set-backs, the open spaces at the ground level, shall be not less than 16 m [*see* Fig. 10E]; and

f) The deficiency in the open spaces shall be made good to satisfy **8.2.3.1** through the set-backs at the upper levels; these set-backs shall not be accessible from individual rooms/flats at these levels.

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Table 4 Side and Rear Open Spaces for Different Heights of Buildings

(*Clause* 8.2.3.1)

Sl No.	Height of Building	Side and Rear Open Spaces to be Left Around Building
	m	m
(1)	(2)	(3)
i)	10	3
ii)	15	5
iii)	18	6
iv)	21	7
v)	24	8
vi)	27	9
vii)	30	10
viii)	35	11
ix)	40	12
x)	45	13
xi)	50	14
xii)	55	16
xiii)	70	17
xiv)	120	18
xv)	Above 120	20

NOTES

1 For buildings above 24 m in height, there shall be a minimum front open space of 6 m.

2 Where rooms do not derive light and ventilation from the exterior open space, the width of such exterior open space as given in col 3 may be reduced by 1 m subject to a minimum of 3 m and a maximum of 8 m. No further projections shall be permitted.

3 If the length or depth of the building exceeds 40 m, add to col (3) ten percent of length or depth of building minus 4.0 m subject to maximum requirement of 20 m.

8.2.4 The width of the abutting road and the front open space would govern the height of the building (*see* **9.4**).

8.2.5 *Interior Open Spaces*

a) *Inner courtyard* — In case the whole of one side of every room excepting bath, WC and store room, is not abutting on either the front, rear or side open spaces, it shall abut on an inner courtyard, whose minimum width shall be 3 m.

Further, the inner courtyard shall have an area, throughout its height, of not less than the square of one-fifth the height of the highest wall abutting the courtyard. Provided further that, when any room (excluding staircase bay, bathroom and water-closet) is dependent for its light and ventilation on an inner courtyard, the dimension shall be such as is required for each wing of the building.

Where only water-closet and bath room are abutting on the inner courtyard, the size of the inner courtyard shall be in line with the provision for ventilation shaft as given in **8.2.5** (b).

b) *Ventilation shaft* — For ventilating the spaces for water-closets and bath rooms, if not opening on to front, side, rear or interior open spaces, these shall open on to the ventilation shaft, the size of which shall not be less than the values given below:

Sl No.	*Height of Building*	*Size of Ventilation Shaft*	*Minimum One Dimension of the Shaft*
	m	m^2	m
(1)	(2)	(3)	(4)
i)	Up to 10	1.2	0.9
ii)	12	2.8	1.2
iii)	18	4.0	1.5
iv)	24	5.4	1.8
v)	30	8.0	2.4
vi)	Above 30	9.0	3.0

NOTES

1 For buildings of height above 30 m, a mechanical ventilation system shall be installed besides the provision of minimum ventilation shaft.

2 For fully air conditioned residential/business buildings, the ventilation shaft need not be insisted upon, provided the air conditioning system works in an uninterrupted manner, also, provided there is an alternative source of power supply.

c) *Outer courtyard* — The minimum width of the outer courtyard (as distinguished from its depth) shall be not less than 2.4 m. If the width of the outer courtyard is less than 2.4 m, it shall be treated as a notch and the provisions of outer courtyard shall not apply. However, if the depth of the outer courtyard is more than the width, the provisions of **8.1.2** shall apply for the open spaces to be left between the wings when any habitable room depends on light and ventilation from such outer courtyard.

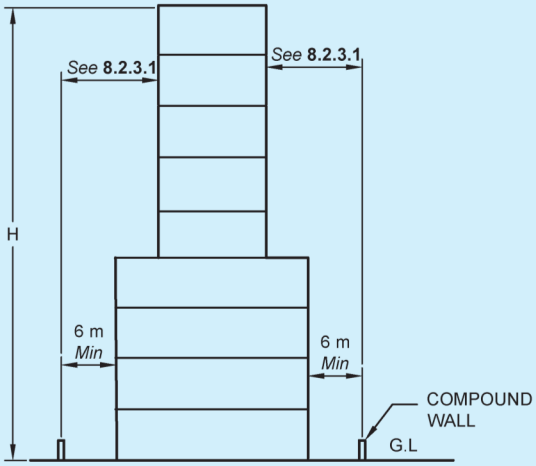
d) *Sunken courtyard* — Sunken courtyard up to 3 m in depth from the ground level as 'light well' within building envelope shall be permitted for light and ventilation for basement area, provided all concerns relating to drainage are taken care of.

8.2.6 *Joint Open Air Space*

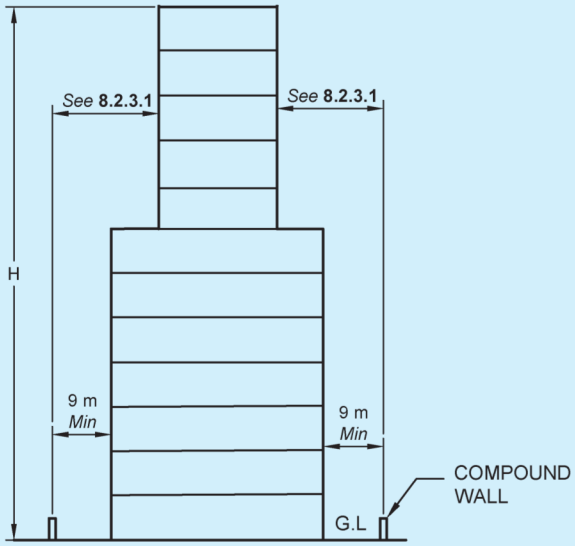
Every such interior or exterior open air space, unless the latter is a street, shall be maintained for the benefit of such building exclusively and shall be entirely within the owner's own premises.

8.2.6.1 If such interior or exterior open air space is intended to be used for the benefit of more than one building belonging to the same owner, the width of such open air space shall be the one specified for the tallest building as specified in **8.2.3** abutting on such open air space [*see* Fig. 8A].

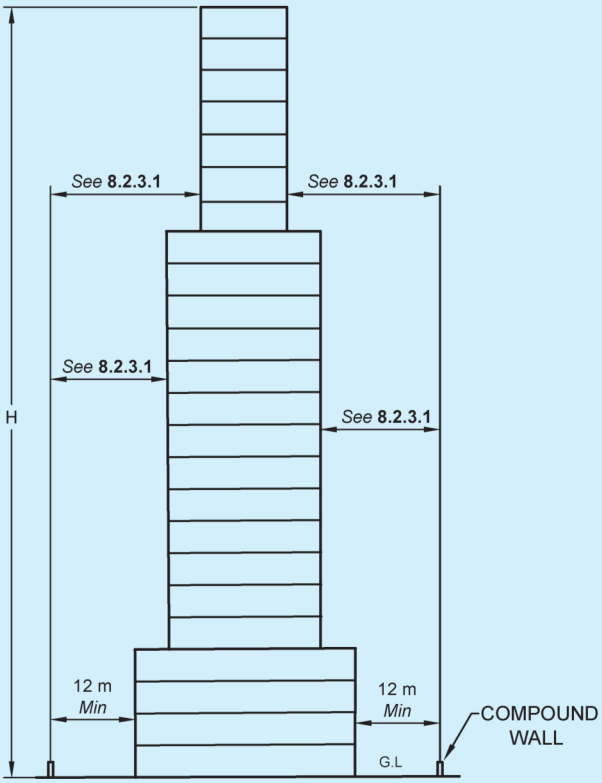
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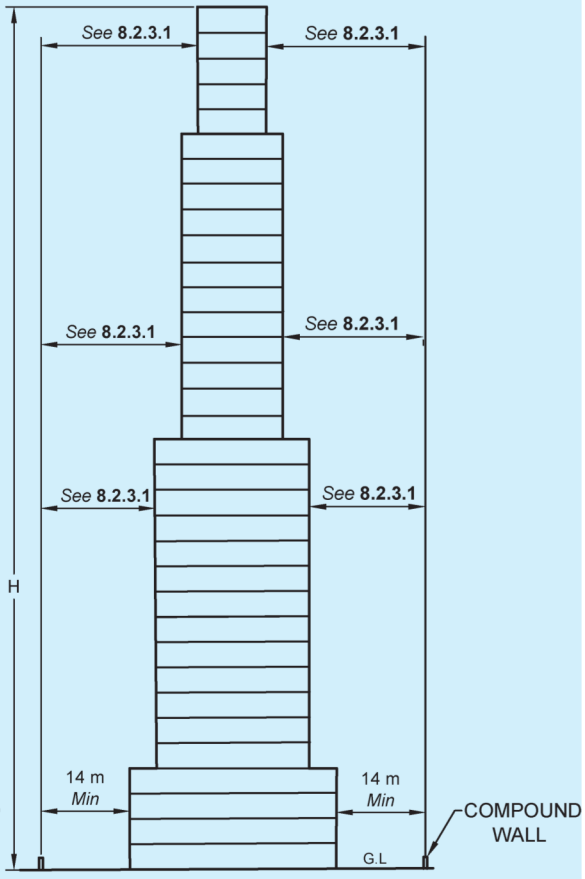
10A FOR BUILDINGS HEIGHT (H) UP TO 24 m



10B FOR BUILDINGS HEIGHT (H) BETWEEN 24 m AND 37.5 m



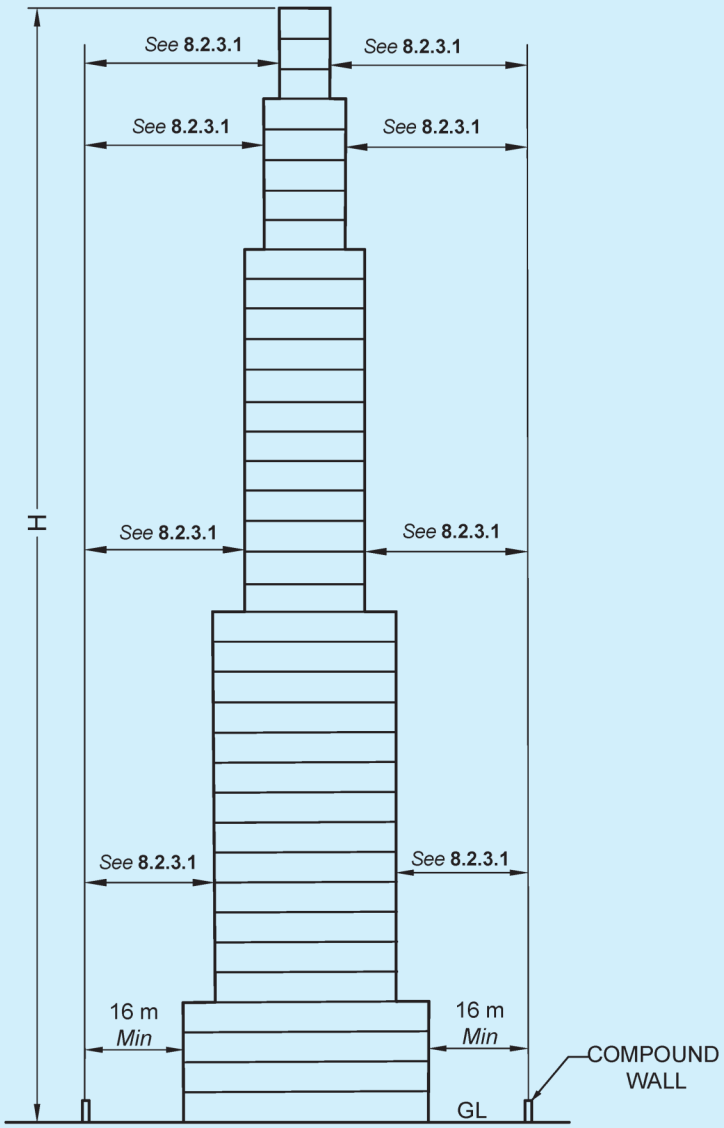
10C FOR BUILDINGS HEIGHT (H) BETWEEN 37.5 m AND 70 m



10D FOR BUILDINGS HEIGHT (H) BETWEEN 70 m AND 120 m

FIG. 10 — (*Continued*)

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10E FOR BUILDINGS HEIGHT (H) ABOVE 120 m

FIG. 10 OPEN SPACES AROUND TOWER-LIKE STRUCTURES

8.2.6.2 If such interior or exterior open air space is jointly owned by more than one person, its width shall also be as specified in **8.2**, provided every such person agrees in writing to allow his portion of such joint open air space to be used for the benefit of every building abutting on such joint open air space and provided he sends such written consent to the Authority for record. Such common open air space shall thenceforth be treated as a permanently open air space required for the purposes of the Code. No boundary wall between such joint open air space shall be erected or raised to a height of more than 2.0 m.

8.3 Other Occupancies

8.3.1 Open spaces for other occupancies shall be as given below:

a) *Educational buildings* — Except for nursery schools, the open spaces around the building shall be not less than 6 m.

b) *Institutional buildings* — The open spaces around the building shall be not less than 6 m.

c) *Assembly buildings* — The open space at front shall be not less than 12 m and the other open spaces around the building shall be not less than 6 m.

NOTE — However, if assembly buildings are permitted in purely residential zones, the open spaces around the building shall be not less than 12 m.

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d) *Business, mercantile and storage buildings* — The open spaces around the building shall be not less than 4.5 m for heights up to 16 m, with an increase of the open spaces of 0.25 m for every increase of 1 m or fraction thereof in height above 16 m. Where these occur in a purely residential zone or in a residential with incidental shops line zone the open spaces may be relaxed.

e) *Industrial buildings* — The open spaces around the building shall be not less than 4.5 m for heights up to 16 m, with an increase of the open spaces of 0.25 m for every increase of 1 m or fraction thereof in height above 16 m.

NOTE — Special rules for narrow industrial plots in the city, namely plots less than 15 m in width, and with appropriate set-backs from certain streets and highways, shall be applicable.

f) *Hazardous occupancies* — The open spaces around the building shall be as specified for industrial buildings [*see* **8.3.1**(e)].

8.4 Exemption to Open Spaces

8.4.1 *Projections into Open Spaces*

Every open space provided either interior or exterior shall be kept free from any erection thereon and shall be open to the sky, except as given below:

a) Cornice, roof or weather shade not more than 0.75 m wide;

b) Sunshades over windows/ventilators or other openings not more than 0.75 m wide;

c) Canopy not to be used as a sit out with clearance of 1.5 m between the plot boundary and the canopy;

d) Projected balcony at higher floors of width not more than 1.2 m; and

e) Projecting rooms/balconies [*see* **8.4.1**(d)] at alternate floors such that rooms of the lower two floors get light and air and the projection being not more than the height of the storey immediately below.

However, these projections into open spaces shall not reduce the minimum required open spaces.

8.4.1.1 *Accessory building*

The following accessory buildings may be permitted in the open spaces:

a) In an existing building, sanitary block of 2.4 m in height subject to a maximum of 4 m2 in the rear open space at a distance of 1.5 m from the rear boundary may be permitted, where facilities are not adequate.

b) Parking lock up garages not exceeding 2.4 m in height shall be permitted in the side or rear open spaces at a distance of 7.5 m from any road line or the front boundary of the plot; and

c) Suction tank and pump room each up to 2.5 m^2 in area.

8.4.2 *Projection into Street*

8.4.2.1 In existing built-up or congested areas, no projection of any sort whatsoever, except sunshades (*see* **8.4.2.3**) extending more than 230 mm below a height of 4.3 m, shall project over the road or over any drain or over any portion outside the boundaries of the site, provided the projection arising out of the vertical part of the rain-water spouts projecting at the road level or the water pipe may be permitted in accordance with the drainage plan.

8.4.2.2 *Porticos in existing developed area*

Porticos in bazaar areas of existing developed areas may be permitted to project on road land subject to the following limitations:

a) Porticos may be allowed on such roads leaving a minimum clear space of 18 m between kerbs;

b) The porticos shall not be less than 3 m wide;

c) Nothing shall be allowed to be constructed on the portico which shall be used as an open terrace;

d) Nothing shall be allowed to project beyond the line of arcades; and

e) The space under the portico shall be paved and channeled according to the directions of the Authority.

8.4.2.3 *Sunshades over windows and ventilators*

Projections of sunshades over windows or ventilators in existing built-up or congested areas when permitted by the Authority shall fulfill the following conditions:

a) No sunshade shall be permitted over the road or over any drain or over any portion outside the boundaries of the site below a height of 2.8 m from the road level;

b) Sunshades provided above a height of 2.8 m from the ground level shall be permitted to project up to a maximum width of 60 cm, if the road over which they project exceeds 9 m in width; and

c) No sunshade shall be permitted on roads less than 9 m in width or on roads having no footpaths.

8.5 Limitations to Open Spaces

8.5.1 *Safeguard Against Reduction of Open Space*

No construction work on a building shall be allowed if

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such work operates to reduce an open air space of any other adjoining building, belonging to the same owner to an extent less than what is prescribed at the time of the proposed work or to reduce further such open space if it is already less than that prescribed.

8.5.2 *Additions or Extensions to a Building*

Additions or extensions to a building shall be allowed, provided the open spaces for the additions/extensions satisfy **8.2** after such additions/extensions are made.

8.6 In case of buildings on podium, the requirements for spaces shall also comply with **4.6.1.3** [*see also* Fig. 8(a)].

9 AREA AND HEIGHT LIMITATIONS

9.1 General

The limitation of area and height of buildings of different occupancy classes and types of construction shall be achieved by specifying it in terms of FAR, which shall take into account the various aspects that govern in specifying FAR as given below:

a) Occupancy class;
b) Types of construction;
c) Width of street fronting the building and the traffic load;
d) Locality where the building is proposed and the density;
e) Parking facilities;
f) Local fire fighting facilities; and
g) Water supply, drainage and sanitation facilities.

9.2 The comparative FARs for different occupancies and types of construction are as given in Table 5 and the Authority shall select a basic FAR for one occupancy and a type of construction and arrive at the FAR values for other combinations taking into account the other local factors (*see* **9.1**).

9.2.1 *Unlimited Areas*

The minimum fire separation on all sides of buildings of unlimited areas (*see* Table 5) and of Type 1 construction shall be 9 m.

9.3 Street Width

The area limits shall apply to all buildings fronting on a street or public space not less than 9 m in width accessible to a public street.

9.4 Height Limit

The height and number of storeys shall be related to FAR and the provisions of **8**.

9.4.1 Where a building height is not covered by Table 5, the maximum height shall be limited according to the width of the street as follows:

a) The maximum height of building shall not exceed 1.5 times the width of road abutting plus the front open space, subject to the requirement of front open space of a maximum of 16 m;
b) If a building abuts on two or more streets of different widths, the building shall be deemed to face upon the street that has the greater width and the height of the building shall be regulated by the width of that street and may be continued to this height to a depth of 24 m along the narrower street subject to conformity of **8**; and
c) For buildings in vicinity of aerodromes, provisions of **9.5** shall apply.

9.4.2 *Height Exceptions*

9.4.2.1 *Roof structures*

The following appurtenant structures shall not be included in the height of the building unless the aggregate area of such structures, including pent-houses, exceeds one-third of the area of the roof of building upon which they are erected:

a) Roof tanks and their supports (with support height not exceeding 1 m);
b) Ventilating, air conditioning, lift rooms and similar service equipment;
c) Stair cover (*Mumty*) not exceeding 3 m in height; and
d) Chimneys, parapet walls and architectural features not exceeding 1.2 m in height.

9.4.2.2 The building height for different occupancy types shall not exceed the maximum height prescribed in Part 4 'Fire and Life Safety' of the Code.

9.5 Restrictions in the Vicinity of Aerodromes

9.5.1 For buildings in the vicinity of aerodromes, the maximum height of such buildings shall be decided in consultation with the Airports Authority of India who shall be responsible for issuing the no objection certificate. This shall be in accordance with the concerned notification of the Ministry of Civil Aviation, Govt of India.

9.5.1.1 For the purpose of **9.5.1,** new buildings and structures coming up in the vicinity of an aerodrome shall be subjected to height restrictions in accordance with the subject notification.

No building or structure higher than the height specified in the subject notification shall be constructed or erected and no tree which is likely to grow or ordinarily grows

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Table 5 Comparative Floor Area Ratios for Occupancies Facing One Public Street of at least 9 m Width

(*Foreword*, *Clauses* 2.26, 9.2 *and* 9.2.1)

Sl No.	Occupancy Classification	Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Residential	UL	2.0	1.4	1.0
ii)	Educational	UL	2.0	1.4	1.0
iii)	Institutional	UL	1.5	1.0	0.8
iv)	Assembly	UL	1.0	0.7	0.5
v)	Business	UL	2.9	2.3	1.6
vi)	Mercantile	8.0	1.8	1.4	1.0
vii)	Industrial	7.5	1.9	1.6	1.3
viii)	Storage (*see* Note 4)	6.0	1.5	1.3	1.0
ix)	Hazardous (*see* Note 4)	2.8	1.1	0.9	NP

UL – Unlimited.

NP – Not Permitted.

NOTES

1 This table has been prepared, taking into account the combustible content in the different occupancies as well as the fire resistance offered by the type of construction (*see* Part 4 'Fire and Life Safety' of the Code).

2 This table shall be modified by the Authority, taking into account the other aspects as given below (*see* **9.1**):

a) Density in terms of dwelling units/hectare;
b) Traffic considerations;
c) Parking spaces;
d) Local fire fighting facilities; and
e) Water supply, drainage and sanitation requirements.

3 The FAR specified may be increased by 20 percent for the following:

a) A basement or cellar and space under a building constructed on stilts and used as a parking space, and air conditioning plant room used as accessory to the principal use;
b) Electric cabin or substation watchman's booth of maximum size of 1.6 m^2 with minimum width or diameter of 1.2 m, pump house, garbage shaft, space required for location of fire hydrants, electric fittings and water tank;
c) Projections and accessory buildings as specifically exempted (*see* **8.4.1**); and
d) Staircase room and lift rooms above the topmost storey, architectural features; and chimneys and elevated tanks of dimensions as permissible under the Code; the area of the lift shaft shall be taken only on one floor.

4 In so far as single storey storage and hazardous occupancies are concerned, they would be further governed by volume to plot area ratio (VPR), to be decided by the Authority.

higher than the height specified in the subject notification shall be planted on any land within the specified radius from the aerodrome reference point, as given in the notification.

9.5.1.2 In the case of buildings or structures to be erected in the vicinity of defence aerodromes, the maximum height of such buildings shall be decided by the Defence Authority.

9.5.2 The location of slaughter house/butcher house and other areas for activities like depositing of garbage dumps which would attract high flying birds like eagles/ hawks, etc, shall not be permitted within a radius of 10 km from aerodrome reference point.

9.6 Group Housing

9.6.1 Group housing development may be in low rise house clusters or high rise multi-storeyed apartments for high density development.

9.6.2 No limit to floors and height shall be applicable, but the coverage and floor area ratio for various densities may be as given in Table 6 unless provided otherwise in the Master Plan and local development control rules.

9.6.3 The minimum size of the site for group housing multi-storeyed apartment shall be 3 000 m^2.

9.6.3.1 The number of dwelling units are calculated on the basis of the density pattern given in the Development Plan taking into consideration a population of 4.5 persons per dwelling unit.

9.6.3.2 The basement may vary between 33.33 and 50 percent of the plot area and is to be used for parking, servicing and for essential household storage without counting in FAR.

9.6.3.3 Parking space shall be provided in accordance with **10**. Designated accessible parking spaces shall be provided in accordance with **B-3**.

9.6.4 With a view to providing adequate parking for occupancies and the vehicular load, appropriate off-street parking provisions have to be made in the

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Table 6 Floor Area Ratio and Coverage for Group Housing

(*Clause* 9.6.2)

Sl No.	Net Residential Density Dwelling Units/Hectare	Maximum Coverage Percent	Floor Area Ratio
(1)	(2)	(3)	(4)
i)	25	25	0.50
ii)	50	30	0.75
iii)	75	33	0.90
iv)	100	35	1.00
v)	125	35	1.25
vi)	150	35	1.50
vii)	175	35	1.75
viii)	200	35	2.00
ix)	225	35	2.25
x)	250	35	2.50
xi)	275	35	2.75
xii)	300	35	3.00
xiii)	325	35	3.25
xiv)	350	35	3.50
xv)	375	35	3.75
xvi)	400	35	4.00

NOTE — The coverage shall be calculated on the basis of the whole area reserved for group housing.

building/on-site. This can also be permitted in basement areas (*see* **12.9**) and in podium (*see* **4.6.1**) and the footprint for the basement parking may exceed the ground coverage of the building subject to no basement building construction to cross the building line and all other safety features for structural, fire, health and public safety being ensured (*see also* **12.9.2.2** and Fig. 11).

10 OFF-STREET PARKING SPACES

10.1 The off-street parking (on-site parking) spaces in a plot to be provided shall be in accordance with Annex A. The spaces given in Annex A shall be considered by the Authority in conjunction with the Development Rules, in force, if any.

10.2 The spaces to be left out for off-street parking as given in **10.3** to **10.6** shall be in addition to the open spaces left out for lighting and ventilation purposes as given in **20**.

10.2.1 Further 50 percent of the open spaces required around buildings under **8** may be allowed to be utilized for parking or loading or unloading spaces, provided a minimum distance of 3.6 m around the building is kept free from any parking, loading or unloading spaces subject to the provisions of Part 4 'Fire and Life Safety' of the Code.

10.3 Each off-street parking space provided for vehicles shall be as follows:

a) For car, the minimum parking space to be 3 m × 6 m when individual parking space is required and 2.75 m × 5 m when common parking space is required.

b) Space for scooter/two wheeler and bicycle to be not less than 1.25 m^2 and 1.00 m^2, respectively.

c) Area for each equivalent car space inclusive of circulation area is 23 m^2 for open parking, 28 m^2 for ground floor covered parking and 32 m^2 for basement.

10.4 For buildings of different occupancies, off-street parking space for vehicles shall be provided as stipulated below:

a) *Motor vehicles* — Space shall be provided as specified in Annex A for parking motor vehicles (cars).

b) *Other types of vehicles* — For non-residential building, in addition to the parking areas provided in (a) above, 25 to 50 percent additional parking space shall be provided for parking other types of vehicles and the additional spaces required for other vehicles shall be as decided by the Authority, keeping in view the nature of traffic generated in the city.

For residential occupancy, space for motorcycle/scooter/cycle/two-wheeler shall be provided at the rate of one for each tenement.

10.5 Off-street parking space shall be provided with adequate vehicular access to a street; and the area of drives, aisles and such other provisions required for adequate manoeuvering of vehicle shall be exclusive of the parking space stipulated in these provisions.

10.6 If the total parking space required by these provisions is provided by a group of property owners for their mutual benefits, such use of this space may be construed as meeting the off-street parking requirements under these provisions, subject to the approval of the Authority.

10.7 In buildings of mercantile (commercial), industrial and storage type, in addition to the parking spaces provided, a space at the rate of 3.5 m × 7.5 m, shall be provided for loading and unloading activities, for each 1 000 m^2 of floor area or fraction thereof.

10.8 Parking spaces shall be paved and clearly marked for different types of vehicles.

10.9 Apart from parking at ground level, provision of underground or multi-storeyed parking or podium parking may be permitted. The parking of vehicles at different level may also be mechanized. In the case of parking spaces provided in basement(s), at least two ramps of width and slope as per **4.6.1.3** shall be

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provided, located preferably at opposite ends. In case of underground/multi-storeyed parking, special measures with regard to fire safety shall be taken (*see* Part 4 'Fire and Life Safety' of the Code).

10.10 Designated accessible parking spaces shall be provided in accordance with **B-3** for the occupancies specified in **13**.

11 GREENBELTS, LANDSCAPING AND WATER CONSERVATION

11.1 General

Greenbelts and landscaping including plantation of shrubs and trees help to certain extent in enhancing the environmental quality.

11.1.1 Planting of trees in streets and in open spaces should be done carefully to take advantage of both shades and sunshine without obstructing the flow of wind circulation and sight. Their advantage for abating glare and for providing cool and/or warm pockets in developed areas should also be taken.

11.2 Norms for Planting of Shrubs and Trees

11.2.1 Suitable provisions may be made for greeneries including plantation of shrubs and trees as a part of environmental protection in general. This aspect shall be taken care of from the initial stage of town and country planning, zoning and planning of development of particular area and group housing. Finally, this aspect shall also be taken into account in planning individual building of different occupancies.

11.2.2 The types of plants, the distance between trees/ plants from the building and the distance between plants shall be carefully worked out keeping in view the structural safety and aesthetic requirements of buildings.

11.3 Trees shall be numbered area-wise, plot-wise and road-wise by the concerned authority and they shall be checked periodically.

11.4 Cutting and pruning of trees in public as well as private areas shall be suitably regulated. Trees shall be cut only after obtaining the permission of the Authority designated for this purpose.

11.5 The landscape planning and design shall be done in accordance with Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 1 Landscape Planning, Design and Development' of the Code.

11.6 Water Conservation and Augmentation

In view of critical shortage of water, conservation of water by rain water harvesting and by use of recycled water to the maximum extent possible is required. In this regard the provisions given in **11.6.1** to **11.6.5** may be adopted.

11.6.1 The local authority preparing a town-planning scheme or a development plan should see that the local water bodies are preserved, and if dry, are activated by directing water-courses appropriately. If required, the same should be enlarged, deepened, etc.

11.6.2 The water body should be protected by ensuring that no permanent/temporary construction/development takes place around it up to a distance of 50 m from the edge of the water body and the same shall be suitably landscaped. Further, the public shall have easy access to the water body.

11.6.3 The rain water run off shall be suitably directed to recharging wells in plots belonging to the local authority and of appropriate design. The local authority should encourage for collection of rain-water from roofs and terraces and direct the same either to a storage tank or to a recharging well. These shall be done in accordance with Part 9 'Plumbing Services (including Solid Waste Management), Section 2 Drainage and Sanitation' of the Code.

11.6.4 Buildings having central air conditioning plants requiring water for cooling purposes may not be allowed to use fresh water for the purpose.

11.6.5 Commercial or residential multi-storeyed complexes may use recycled water for flushing of toilets, horticulture and fire fighting purposes. Separate storage tanks and separate distribution pipes shall be provided for the purpose.

12 REQUIREMENTS OF PARTS OF BUILDINGS

The requirements for various parts of buildings shall be in accordance with **12.1** to **12.9**. The requirements as given in **13**, for public buildings and sites as accessible and barrier free for elders and persons with disabilities, shall also be complied with.

12.1 Plinth

12.1.1 *Main Buildings*

The plinth or any part of a building or outhouse shall be so located with respect to the surrounding ground level that adequate drainage of the site is assured. The height of the plinth shall be not less than 450 mm from the surrounding ground level.

12.1.2 *Interior Courtyards and Covered Parking*

Every interior courtyard shall be raised at least 150 mm above the determining ground level and shall be satisfactorily drained.

12.2 Habitable Rooms

12.2.1 *Height*

The height of all rooms for human habitation shall not be less than 2.75 m measured from the surface of

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the floor to the lowest point of the ceiling (bottom of slab). In the case of pitched roof, the average height of rooms shall not be less than 2.75 m. The minimum clear head room under a beam, folded plates or eaves shall be 2.4 m. In the case of air conditioned rooms, a height of not less than 2.4 m measured from the surface of the floor to the lowest point of air conditioning duct or the false ceiling shall be provided.

12.2.1.1 The requirements of **12.2.1** apply to residential, business and mercantile buildings. For educational and industrial buildings, the following minimum requirements apply :

a) Educational buildings : Ceiling height 3.6 m for all regions; in cold regions, 3 m

b) Industrial buildings : Ceiling height 3.6 m, conditioned, 3 m (*Factory Act*, 1948 and rules therein shall govern such heights, where applicable)

12.2.2 *Size*

The area of habitable room shall not be less than 9.5 m^2, where there is only one room with a minimum width of 2.4 m. Where there are two rooms, one of these shall not be less than 9.5 m^2 and the other not less than 7.5 m^2, with a minimum width of 2.1 m.

12.3 Kitchen

12.3.1 *Height*

The height of a kitchen measured from the surface of the floor to the lowest point in the ceiling (bottom slab) shall not be less than 2.75 m, except for the portion to accommodate floor trap of the upper floor.

12.3.2 *Size*

The area of a kitchen where separate dining area is provided, shall be not less than 5.0 m^2 with a minimum width of 1.8 m. Where there is a separate store, the area of the kitchen may be reduced to 4.5 m^2. A kitchen, which is intended for use as a dining area also, shall have a floor area of not less than 7.5 m^2 with a minimum width of 2.1 m.

12.3.3 *Other Requirements*

Every room to be used as kitchen shall have,

a) unless separately provided in a pantry, means for the washing of kitchen utensils which shall lead directly or through a sink to a grated and trapped connection to the waste pipe;

b) an impermeable floor;

c) a flue, if found necessary; and

d) a window or ventilator or opening of size not less than as specified in **20.1.1** subject to increase in area of opening in accordance with **20.1.2** (Note 3).

12.4 Bathrooms and Water-Closets

12.4.1 *Height*

The height of a bathroom or water-closet measured from the surface of the floor to the lowest point in the ceiling (bottom of slab) shall not be less than 2.1 m.

12.4.2 *Size*

The area of a bathroom shall not be less than 1.8 m^2 with a minimum width of 1.2 m. The floor area of water-closet shall be 1.1 m^2 with a minimum width of 0.9 m. If bath and water-closet are combined, its floor area shall not be less than 2.8 m^2 with a minimum width of 1.2 m.

12.4.3 *Other Requirements*

Every bathroom or water-closet shall,

a) be so situated that at least one of its walls shall open to external air;

b) not be directly over or under any room other than another water-closet, washing place, bath or terrace, unless it has a water-tight floor;

c) have the platform or seat made of water-tight non-absorbent material;

d) be enclosed by walls or partitions and the surface of every such wall or partition shall be finished with a smooth impervious material to a height of not less than 1 m above the floor of such a room;

e) be provided with an impervious floor covering, sloping towards the drain with a suitable grade and not towards *Verandah* or any other room; and

f) have a window or ventilator, opening to a shaft or open space, of area not less than 0.3 m^2 with side not less than 0.3 m.

12.4.4 No room containing water-closets shall be used for any purpose except as a lavatory and no such room shall open directly into any kitchen or cooking space by a door, window or other opening. Every room containing water-closet shall have a door completely closing the entrance to it.

12.5 Ledge or Tand/Loft

12.5.1 *Height*

The minimum head-room of ledge or *Tand*/loft shall be 2.2 m. The maximum height of loft shall be 1.5 m.

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12.5.2 *Size*

A ledge or *TAND*/loft in a habitable room shall not cover more than 25 percent of the area of the floor on which it is constructed and shall not interfere with the ventilation of the room under any circumstances.

12.6 Mezzanine Floor

12.6.1 *Height*

It shall have a minimum height of 2.2 m.

12.6.2 *Size*

The minimum size of the mezzanine floor, if it is to be used as a living room, shall not be less than 9.5 m^2. The aggregate area of such mezzanine floor in a building shall in no case exceed one-third the plinth area of the building.

12.6.3 *Other Requirements*

A mezzanine floor may be permitted over a room or a compartment, provided,

a) it conform to the standard of living rooms as regards lighting and ventilation in case the size of mezzanine floor is 9.5 m^2 or more (*see* **20.1.2**);
b) it is so constructed as not to interfere under any circumstances with the ventilation of the space over and under it;
c) such mezzanine floor is not subdivided into smaller compartments;
d) such mezzanine floor or any part of it shall not be used as a kitchen; and
e) in no case shall a mezzanine floor be closed so as to make it liable to be converted into unventilated compartments.

12.7 Store Room

12.7.1 *Height*

The height of a store room shall be not less than 2.2 m.

12.7.2 *Size*

The size of a store room, where provided in a residential building, shall be not less than 3 m^2.

12.8 Garage

12.8.1 *Height*

The height of a garage shall be not less than 2.4 m.

12.8.2 *Size*

The size of garages shall be as below:

a) *Private garage* — 3.0 m × 6.0 m, minimum; and
b) *Public garage* — Based on the number of vehicles parked, etc (*see* **10**).

12.9 Basement

12.9.1 The basement shall not be used for residential purposes.

12.9.2 The construction of the basement shall be allowed by the Authority in accordance with the land use and other provisions specified under the Development Control Rules.

12.9.2.1 The following uses shall be permitted in the basements:

a) Storage of household or other goods of ordinarily non-combustible material;
b) Strong rooms, bank cellars, etc;
c) Air conditioning equipment and other machines used for services and utilities of the building; and
d) Parking spaces.

The Authority may also consider permitting mercantile occupancy as well as institutional occupancy for medical, health care services involving radiation facilities in the first basement subject to compliance of all requirements for fire safety in accordance with Part 4 'Fire and Life Safety' of the Code and necessary measures for required lighting, ventilation and water supply, drainage and sanitation.

12.9.2.2 The basements can be permitted below the ground and beyond the building lines at ground level subject to a clear minimum front margin of 4.5 m and side and rear margins of 3 m, and further subject to non-habitable uses and provision for mechanical ventilation and all safety provisions and drainage (*see* Fig. 11). However, it is essential that the basement top slab below the external circulation at ground level should be designed for fire fighting vehicular loads as given in **4.6**.

12.9.3 The basement shall have the following requirements:

a) Every basement shall be in every part at least 2.4 m in height from the floor to the underside of the roof slab or ceiling;
b) Adequate ventilation shall be provided for the basement. The ventilation requirements shall be the same as required by the particular occupancy according to byelaws. Any deficiency may be met by providing adequate mechanical ventilation in the form of blowers, exhaust fans, air conditioning systems, etc;
c) The height of the ceiling of any basement shall be minimum 0.9 m and the maximum, 1.2 m above the average surrounding ground level. However, in case of parking, mercantile or business occupancy at ground floor, minimum height of the ceiling of the basement may

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be 0.3 m above the average surrounding ground level subject to mechanical ventilation being provided (*see* Fig. 11);

d) Adequate arrangements shall be made such that surface drainage does not enter the basement;

e) The walls and floors of the basement shall be watertight and be so designed that the effects of the surrounding soil and moisture, if any, are taken into account in design and adequate damp proofing treatment is given;

f) The access to the basement shall be separate from the main and alternative staircase providing access and exit from higher floors. Where the staircase is continuous in the case of buildings served by more than one staircase, the same shall be of enclosed type serving as a fire separation from the basement floor and higher floors. Open ramps shall be permitted if they are constructed within the building line subject to the provision of (d);

g) Access to basements through ramps shall be permitted subject to provision of (d). The requirements for the ramps shall be in accordance with **4.6.1.3** [*see also* Fig. 8 (b)];

h) For all public buildings and uses including group housing, having basement going up to more than one level, access to all levels shall also be provided through lift.

The exit requirements in basements shall comply with the provisions of Part 4 'Fire and Life Safety' of the Code.

12.10 Chimneys

The chimneys shall be built at least 0.9 m above flat roofs, provided the top of the chimneys is not below the top of the adjacent parapet wall. In the case of sloping roofs, the chimney top shall not be less than 0.6 m above the ridge of the roof in which the chimney penetrates.

12.11 Parapet

Parapet walls and handrails provided on the edges of roof terraces, balcony, *Verandah*, etc, shall not be less than 1.0 m and not more than 1.2 m in height from the finished floor level.

12.12 Cabin

The size of cabins shall not be less than 3.0 m^2 with a minimum width of 1.0 m. The clear passages within the divided space of any floor shall not be less than 0.75 m and the distance from the farthest space in a cabin to any exit shall not be more than 18.5 m. In case the subdivided cabin does not derive direct lighting and ventilation from any open spaces/ mechanical means, the maximum height of the cabin shall be 2.2 m.

12.13 Boundary Wall

The requirements of the boundary wall are given below:

a) Except with the special permission of the Authority, the maximum height of the compound wall shall be 1.5 m above the centre line of the front street. Compound wall up to 2.4 m height may be permitted if the top 0.9 m is of open type construction of a design to be approved by the Authority.

b) In the case of a corner plot, the height of the boundary wall shall be restricted to 0.75 m for a length of 10 m on the front and side of the intersections and the balance height of 0.75 m, if required in accordance with (a) may be made up of open type construction (through railings) and of design to be approved by the Authority.

c) However, the provisions of (a) and (b) are not applicable to boundary walls of jails. In industrial buildings, electric substations, transformer stations, institutional buildings like sanitoria, hospitals, industrial buildings like workshops, factories and educational buildings like schools, colleges, including hostels, and other uses of public utility undertakings and strategically sensitive buildings, a height up to 2.4 m may be permitted by the Authority.

12.14 Wells

Wells, intended to supply water for human consumption or domestic purposes, where provided, shall comply with the requirements of **12.14.1** and **12.14.2**.

12.14.1 *Location*

The well shall be located,

a) not less than 15 m from any ash pit, refuse pit, earth closet or privy and shall be located on a site upwards from the earth closet or privy;

b) not less than 18 m from any cess pit soakway or borehole latrine and shall be located on a site upwards from the earth closet or privy;

c) such that contamination by the movement of sub-soil or other water is unlikely; and

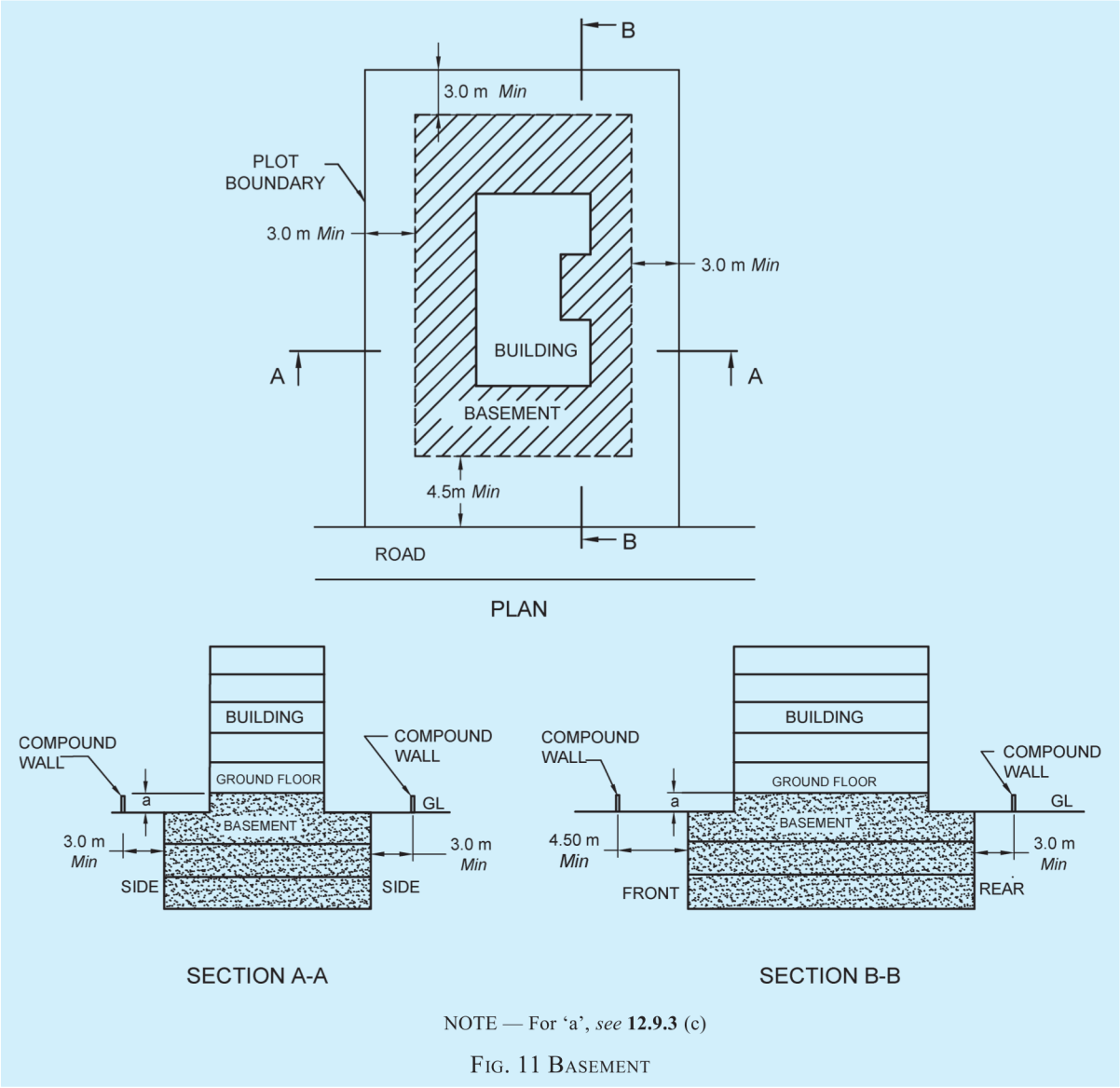
d) not under a tree or otherwise it should have a canopy over it, so that leaves and twigs may not fall into the well and rot.

12.14.2 *Requirements*

The well shall,

a) have a minimum internal diameter of not less than 1 m;

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NOTE — For 'a', *see* **12.9.3** (c)

FIG. 11 BASEMENT

b) be constructed to a height not less than 1 m above the surrounding ground level, to form a parapet or kerb and to prevent surface water from flowing into a well, and shall be surrounded with a paving constructed of impervious material which shall extend for a distance of not less than 1.8 m in every direction from the parapet from the kerb forming the well head and the upper surface of such a paving shall be sloped away from the well;

c) be of sound and permanent construction (*Pucca*) throughout. Temporary or exposed (*Kutcha*) wells shall be permitted only in fields or gardens for purposes of irrigation; and

d) have the interior surface of the lining or walls of the well be rendered impervious for a depth of not less than 1.8 m measured from the level of the ground immediately adjoining the well-head.

12.15 Septic Tanks

Where a septic tank is used for sewage disposal, the location, design and construction of the septic tank shall conform to requirements of **12.15.1** and **12.15.2** [*see also* Part 9 'Plumbing Services (including Solid Waste Management), Section 2 Drainage and Sanitation' of the Code].

12.15.1 *Location of the Septic Tanks and Subsurface Absorption Systems*

A subsoil dispersion system shall not be closer than 18 m from any source of drinking water, such as well, to mitigate the possibility of bacterial pollution of water supply. It shall also be as far removed from the nearest habitable building as economically feasible but not closer than 6 m, to avoid damage to the structures.

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12.15.2 *Requirements*

a) *Dimensions of septic tanks* — Septic tanks shall have a minimum width of 750 mm, a minimum depth of 1 m below the water level and a minimum liquid capacity of 1 m^3. The length of tanks shall be 2 to 4 times the width;

b) Septic tanks may be constructed of brickwork, stone masonry, concrete or other suitable materials as approved by the Authority;

c) Under no circumstances shall effluent from a septic tank be allowed into an open channel drain or body of water without adequate treatment;

d) The minimum nominal diameter of the pipe shall be 100 mm. Further, at junctions of pipes in manholes, direction of flow from a branch connection shall not make an angle exceeding 45° with the direction of flow in the main pipe;

e) The gradients of land drains, under-drainage as well as the bottom of dispersion trenches and soakways shall be between 1:300 and 1:400;

f) Every septic tank shall be provided with ventilating pipe of at least 50 mm diameter. The top of the pipe shall be provided with a suitable cage of mosquito-proof wire mesh.

The ventilating pipe shall extend to a height which would cause no smell nuisance to any building in the area. Generally, the ventilating pipe may extend to a height of about 2 m, when the septic tank is at least 15 m away from the nearest building and to a height of 2 m above the top of the building when it is located closer than 15 m;

g) When the disposal of septic tank effluent is to a seepage pit, the seepage pit may be of any suitable shape with the least cross-sectional dimension of 0.90 m and not less than 1.00 m in depth below the invert level of the inlet pipe. The pit may be lined with stone, brick or concrete blocks with dry open joints which should be backed with at least 75 mm of clean coarse aggregate. The lining above the inlet level should be finished with mortar. In the case of pits of large dimensions, the top portion may be narrowed to reduce the size of the RCC cover slabs. Where no lining is used, specially near trees, the entire pit should be filled with loose stones. A masonry ring may be constructed at the top of the pit to prevent damage by flooding of the pit by surface runoff. The inlet pipe may be taken down a depth of 0.90 m from the top as an anti-mosquito measure; and

h) When the disposal of the septic tank effluent is to a dispersion trench, the dispersion trench shall be 0.50 m to 1.00 m deep and 0.30 m to 1.00 m wide excavated to a slight gradient and shall be provided with 150 mm to 250 mm of washed gravel or crushed stones. Open jointed pipes placed inside the trench shall be made of unglazed earthenware clay or concrete and shall have a minimum internal diameter of 75 mm to 100 mm. Each dispersion trench shall not be longer than 30 m and trenches shall not be placed closer than 1.8 m.

12.16 Office-Cum-Letter Box Room

In the case of multi-storeyed multifamily dwelling apartments constructed by existing and proposed Cooperative Housing Societies or Apartment Owners Associations, limited companies and proposed societies, an office-cum-letter box room of dimension 3.6 m × 3 m shall be provided on the ground floor. In case the number of flats is more than 20, the maximum size of the office-cum-letter box room shall be 20 m^2.

12.16.1 *Business Buildings*

Provision shall be made for letter boxes on the entrance floor as per the requirements of the postal department.

12.17 Meter Rooms

For all buildings above 15 m in height and in special occupancies, like educational, assembly, institutional, industrial, storage, hazardous and mixed occupancies with any of the aforesaid occupancies having area more than 500 m^2 on each floor, provision shall be made for an independent and ventilated meter (service) room, as per requirements of electric (service) supply undertakings on the ground floor with direct access from outside for the purpose of termination of electric supply from the licensee's service and alternative supply cables. The door/doors provided for the service room shall have fire resistance of not less than two hours.

12.18 Staircase/Exit Requirements

12.18.1 The minimum width, minimum tread width and maximum riser of staircases for buildings shall be as given in **12.18.1.1** to **12.18.1.3** (*see also* Part 4 'Fire and Life Safety' of the Code).

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12.18.1.1 *Minimum clear width*

The following minimum width shall be provided for staircases for respective occupancies (*see* **7.1** and Part 4 'Fire and Life Safety' of the Code for classification of buildings based on occupancy):

a)	Residential (A-2) NOTE — For row housing with 2 storeys, the minimum width shall be 0.75 m.	: 1.00 m
b)	Residential (A-1, A-3 and A-4)	: 1.25 m
c)	Residential hotel (A-5 and A-6)	: 1.50 m
d)	Assembly NOTE — The width of stairs may be accepted to be 1.50 m in case of assembly occupancy having less than 150 persons	: 2.00 m
e)	Educational	: 1.50 m
f)	Institutional	: 2.00 m
g)	All other occupancies	: 1.50 m

12.18.1.2 *Minimum tread*

The minimum width of tread without nosing shall be 300 mm. However, for one or two family dwelling, it may be reduced to not less than 250 mm.

12.18.1.3 *Maximum riser*

The maximum height of riser shall be 150 mm. However, for one or two family dwelling, it may be increased to not more than 190 mm.The number of risers shall be limited to 12 per flight.

12.18.2 The minimum head-room in a passage under the landing of a staircase shall be 2.2 m. The minimum clear head-room in any staircase shall be 2.2 m.

12.18.3 *Exit Requirements*

All aspects of exit requirements for corridors, doors, staircases, ramps, etc, in respect of widths, travel distance shall be as per Part 4 'Fire and Life Safety' of the Code.

12.19 Roofs

12.19.1 The roof of a building shall be so designed and constructed as to effectively drain water by means of sufficient rain water pipes of adequate size, wherever required, so arranged, jointed and fixed as to ensure that the rain water is carried away from the building without causing dampness in any part of the walls, roof or foundations of the building or an adjacent building.

12.19.2 The Authority may require rain water pipes to be connected to a drain or sewer to a covered channel formed beneath the public footpath to connect the rain-water pipe to the road gutter or in any other approved manner.

12.19.3 Rain-water pipes shall be affixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external walls or in such other manner as may be approved by the Authority.

12.19.4 It is desirable to conserve rain water using suitable rain water harvesting techniques including by roof water collection. In this context, reference shall be made to Part 9 'Plumbing Services (including Solid Waste Management), Section 2 Drainage and Sanitation' of the Code.

13 REQUIREMENTS FOR ACCESSIBILITY IN BUILT ENVIRONMENT FOR ELDERS AND PERSONS WITH DISABILITIES

13.1 General

13.1.1 These requirements deal with barrier free access to, movement within and around buildings, by the elderly persons and persons with disabilities who may have non-ambulatory disabilities, ambulatory disabilities, sight disabilities, hearing disabilities, disabilities of inco-ordination, ageing, allergies, heart and lung diseases, epilepsy, haemophilia, incontinence, enterostomy, etc.

It is intended to make all buildings and facilities used by the public accessible to, and usable by all people including those living with disabilities and may include those with inability to walk or difficulty in walking, reliance on walking/mobility aids, blindness and visual impairments, speech and hearing impairments, in-coordination of motor movements, reaching and manipulation, lack of stamina, difficulty in interpretation and reacting to sensory information and extremes in physical sizes. It supplements the general requirements of this Part of the Code, and reflects greater concern for safety of life and limb of every resident irrespective of age, gender or abilities.

13.1.2 These requirements apply to all buildings and facilities open to and used by the public. These shall also apply to all forms of public housing by the government/civic bodies or private developers. It does not apply to private residences. For extent of application of requirements covered under **13** to different building occupancy types, reference shall be made to **13.5**.

13.1.3 The reference to the accessibility needs of persons with disabilities, made in this Part shall also mean a reference to such needs of the elderly persons, children and persons of too short stature in so far as the concerned provision is applicable to the type of disabilities that may be associated therewith.

13.2 For the purpose of this clause, the following definitions shall apply.

13.2.1 *Ability* — identifiable human attribute, including but not exclusively, to walk, to speak, to hear, to see, to feel by touch, to taste, to understand, and to recognize.

13.2.2 *Access Aisle* — An accessible pedestrian space between elements, such as parking spaces, seating and desks, that provides clearances appropriate for use of the elements

13.2.3 *Accessible Site, Building, Facility or Portions* — A site, building, facility, or portions thereof that complies with the requirements given in this clause to

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which people, regardless of their disability, age or gender are able to gain access to, in to them, to use them and exit from them with dignity.

NOTE — Accessibility includes ease of independent approach, entry, evacuation and/or use of a building and its services and facilities, by all of the building's potential users with an assurance of individual health, safety and welfare during the course of those activities.

13.2.4 *Accessible Route* — A continuous unobstructed path connecting all accessible elements and spaces in a building or facility that may be negotiated by a person with disabilitiy using a wheelchair and that is also safe for and usable by persons with other disabilities. Interior accessible routes may include corridors, ramps, elevators, lifts, and clear floor space at fixtures. Exterior accessible routes may include parking, access aisles, kerb ramps, walkways, pathways, footpaths/sidewalks, and ramps.

13.2.5 *Accessible Toilet* — A compartment having the basic requirements of minimum clear spaces, water-closet, washbasin and other essential washroom accessories as required by people with non-ambulatory disabilities. There are also toilets for ambulant disabled which provide accessibility for convenient use by persons with ambulatory disabilities.

13.2.6 *Ageing* — Those manifestations of the ageing processes that significantly reduce mobility, flexibility, coordination, and perceptiveness but are not accounted for in disability categories mentioned elsewhere in this Part.

13.2.7 *Area of Rescue Assistance* — Building space directly adjoining, and visible from, a main vertical evacuation route, robustly and reliably protected from heat, smoke and flame during and after a fire, where people can temporarily wait with confidence for further information, instructions, and/or rescue assistance, without obstructing or interfering with the evacuation travel of other building users

NOTE — 'Robust' means structurally hardened and resistant to mechanical damage during the fire and for a period of time afterwards, that is, the cooling phase.

13.2.8 *Assistive Product/Device* — Product/device especially produced or generally available, for preventing, compensating for, monitoring, relieving or neutralizing impairments, activity limitations and participation restrictions.

13.2.9 *Assisted Evacuation* — Strategy that exists during which a designated person or persons provide assistance, during an emergency, to another person to leave a building or a specific part of the built environment and to reach a final place of safety.

13.2.10 *Automatic Door* — A door equipped with a power operated mechanism and controls that open and close the door automatically upon receipt of a momentary signal. The switch that begins the automatic cycle may be photoelectrical device, floor mat, sensing device, or manual switch mounted on or near the door itself.

13.2.11 *Circulation Path* — An exterior or interior way of passage from one place to another for pedestrians, including walkways, pathways, hallways, courtyards, stairways and stair landings.

13.2.12 *Circulation Space* — Unobstructed space necessary for access to, into and within and egress from any part of the built environment.

13.2.13 *Clear* — Unobstructed.

13.2.14 *Colour Contrast* — The difference in colour that makes an object (or its representation in an image or display) distinguishable. It is determined by the difference in the colour of the object and other objects within the same field of view. Distinguishing one form/object from another by hue is the most basic and easily understood contrast.

NOTE — The basic guidelines for making effective colour choices are based on the hue value of the colours. The most commonly used methods of achieving colour contrast incorporate either harmonizing or contrasting colour combinations. Contrast of hue is what relates most directly to the colour wheel combinations. The further away from each other two colours are, the higher the contrast. This means that the complementary colour combination has the highest contrast, while the analogous combination has the lowest.

13.2.15 *Disability* — An umbrella term for impairments, activity limitations, and participation restrictions, denoting the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors(environmental and personal factors). Disability is neither simply a biological nor a social phenomenon but arises from the relationship between health condition and context.

13.2.16 *Grab Bars* — A bar used to give a steadying or stabilizing assistance to a person engaged in a particular function.

13.2.17 *Handrails* — A rail used in circulation areas such as corridors, passageways, ramps and stairways to assist in continuous movement.

13.2.18 *Hue* — Attribute of visual sensation which has given rise to colour names, such as, blue, green, yellow, red and purple.

NOTE — People with normal colour vision report that hues follow a natural sequence based on their similarity to one another. With most colour deficits, the ability to discriminate between colours on the basis of hue is diminished.

13.2.19 *Impairment* — Limitation in body function or structure such as a significant deviation or loss which can be temporary due, for example to injury, or permanent, slight or severe and can fluctuate over time, in particular, deterioration due to ageing.

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NOTE — Body function can be a physiological or psychological function of a body system; body structure refers to an anatomic part of the body such as organs, limbs and their components.

13.2.20 *International Symbol of Accessibility* — The symbol consisting of a square overlaid with a stylized image of a person using a wheelchair (*see* **B-24.2.16** and Fig. 105).

NOTE — The symbol is often provided where access has been improved, particularly for wheelchair users and other mobility impaired persons. The symbol denotes a barrier free environment, to help older people, parents with prams and travellers with luggage besides persons with disabilities. The wheelchair symbol is always facing to the right.

13.2.21 *Kerb* — A side barrier to a trafficable surface or the edge where a raised sidewalk/footpath, road median, or road shoulder meets an unraised street or other roadway.

13.2.22 *Kerb Ramp* — A short ramp cutting through a kerb or built up to it.

13.2.23 *Knurled Surface* — Roughened area, often in a crisscross pattern; used on grab bars to improve grasp and to prevent slipping.

13.2.24 *Landing* — A platform or part of a floor structure at the end of a flight of stairs or a ramp or at the entrance to a lift car.

13.2.25 *Light Reflectance Value (LRV)* — The total quantity of visible light reflected by a surface at all wavelengths and directions when illuminated by a light source.

13.2.26 *Manoeuvring Zone* — The minimum three dimensional space within which it is feasible to complete a manoeuvre needed to gain access to a specific facility, component or fitting, in particular while using a wheelchair or a walking aid.

13.2.27 *Ramp* — The construction, in the form of an inclined plane that is steeper than or equal to 1:20 (5 percent) from the horizontal, together with any intermediate landing, that makes it possible to pass from one level to another (*see* **B-6.2**).

13.2.28 *Operable Parts* — A part of a piece of equipment or appliance used to insert or withdraw objects, or to activate, deactivate, or adjust the equipment or appliance (for example coin slot, push button, handle, etc).

13.2.29 *Persons with Disabilities* — A person with any physical, mental, intellectual or sensory impairment which in interaction with various barriers may hinder full and effective participation in society on an equal basis with others.

13.2.30 *Space* — A definable area (for example toilet room, hall, assembly area, entrance, storage, room alcove, courtyard, or lobby).

13.2.31 *Tactile* — That relating to perception using the sense of touch.

NOTE — It relates to information and interpretations derived from the sense of touch. This involves sensory transfer through physical contact of the hands or feet with other surfaces, as well as sensory transfers received by contact with non-physical elements such as pressure, wind and temperature.

13.2.32 *Tactile Ground Surface Indicators* — Indicators profiled paving surface with visual contrast criteria to enable a person with impaired sight using a long cane, underfoot or visual identification to detect a specific route (guiding pattern) or the presence of a hazard (attention pattern). These are also called tactile tiles or tactile walking surface indicators.

NOTE — These indicators which provide a distinctive surface pattern of strips and truncated domes or cones (small domes or cones that have had their tops cut off, or truncated) are used to guide/alert persons with vision impairments of their approach to facilities, streets and hazardous drop-offs. People who are blind or visually impaired are alerted of impending danger from vehicle impact or a grade change.

13.2.33 *Tactile Guiding Blocks* — Tiles of size 300 mm × 300 mm that incorporate flat topped bars 5 mm (± 0.5 mm) high, 20 mm wide and spaced 50 mm from the centre of one bar to the centre of the next, and are easily detectable underfoot by persons with visual impairments. They are used externally to guide people with visual impairments along the circulation path. They may also be used internally in large busy areas such as railway stations and airports.

13.2.34 *Tactile Warning Blocks* — Tiles of size 300 mm × 300 mm that incorporate rows of 5 mm (± 0.5 mm) high flat topped blister like domes that are easily detectable underfoot by persons with visual impairments, recognized as a sign of approaching hazards. These are placed along the approach path to unavoidable obstacles and hazards to warn persons with visual impairments of the approaching danger or level change.

13.2.35 *Tactile Signs* — Tactile signage incorporates raised text or symbols to enable touch reading by people who are blind, and touch enhancement of visual perception for people who are vision impaired.

13.2.36 *Unobstructed Width* — Free unobstructed space necessary for passage through a doorway, along a passageway, or other route element (for example stairway).

13.2.37 *Unobstructed Width, Door* — Available width for passage through a door opening, clear of all obstructions, measured when the door is opened 90°, or when a sliding or folding door is opened to its fullest extent

13.2.38 *Unisex Accessible Toilet* — Accessible toilets that can be used by both sexes.

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NOTE — Unisex accessible toilets allow the greatest flexibility for people who require assistance.

13.2.39 *Universal Design* — The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.

13.2.40 *Visual Contrast* — Visual perception between one element of a building and another. This can be produced by a difference in light reflectance value (LRV) or luminance, also called luminance contrast.

NOTE — Light reflectance value is measured on a scale of 0 to 100 where 0 equals black meaning total light absorption and 100 equals white meaning total light reflection.

A simple formula for visual contrast is given below for guidance:

$$\text{Visual contrast} = [(B1 - B2)/B1] \times 100, \text{ in percent}$$

where

$B1$ = LRV of the lighter area; and

$B2$ = LRV of the darker area.

In most circumstances, a difference in these values of 30 percent is considered adequate. However, research suggests that signs are more legible for the visually impaired when characters contrast with their background by at least 70 percent.

13.2.41 *Walks (Walkways)* — A predetermined prepared surface, exterior pathway leading to or from a building or facility, or from one exterior area to another, placed on the existing ground level and not deviating from the level of the existing ground immediately adjacent.

13.2.42 *Way Finding* — Descriptive of a system whereby appropriate information is provided to assist a person to pass through the built environment towards a specific destination.

NOTE — Way finding includes orienting oneself, knowing one's destination, following the best route, recognizing one's destination and finding one's way back out. People who are blind or who have a vision impairment benefit from tactile information to facilitate way finding.

13.2.43 *Wheelchair User* — A person who relies on a wheelchair for mobility.

13.2.44 *Water-Closet Compartment/Toilet Cubicle* — A compartment having a water-closet with grab bars installed to assist persons with physical disabilities/ mobility impairments.

13.2.45 *White Cane* — A long rod-like device used by blind or visually impaired travellers to give them information about the environment they are travelling through.

13.3 General Design Considerations

13.3.1 These requirements relate to the principal human abilities that should be considered when designing, constructing and managing the built environment. Some of these abilities are described in **B-1** which gives an overview of concerned design considerations that should be taken into account.

13.3.2 *Design Aspects According to Human Abilities*

Understanding of the human abilities or limitation thereof as described below, and design aspects according to the same, when fully implemented, are expected to benefit all people:

a) *Non-ambulatory disabilities* — Impairments that, regardless of cause or manifestation, for all practical purposes, make an individual a wheelchair user for his mobility. The requirement of non-ambulatory disabilities relates primarily to the design of buildings, so as to meet their independent mobility needs while sitting in the wheelchair with or without assistance, minimum widths and heights, level changes and signage, etc.

b) *Ambulatory disabilities* — Impairments that cause individuals to walk with difficulty or insecurity of balance. Such persons are able to walk on level, either with or without personal assistance, and may depend on prostheses (artificial limbs), orthoses (calipers), sticks, crutches or walking aids or may negotiate suitably graded steps provided that convenient handrails are available. For example elders using walking sticks, ladies in advance stage of pregnancy, temporary disabilities, such as, fracture, individuals using braces or crutches, amputees, persons having arthritis, those with spasticity and those with pulmonary and cardiac ills, etc, may be ambulatory disabled.

c) *Sight disabilities* — Total blindness or impairments affecting sight to the extent that the individual may have to use his other sensory organs such as sense of touch and hearing, use assistive devices for orientation in the environment, such as white cane. Accordingly, building design needs to take in to account means, such as, tactile, Braille and audio-visual, and colour contrasting signage.

d) *Hearing disabilities* — Deafness or hearing impairment may affect an individual's verbal communication or ability to hear warning signals in the environment. The buildings needs to be designed to provide more visual signage, induction loops for hearing enhancement, emergency audio-visual sirens, etc.

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e) *Disabilities of incoordination* — Incoordination of motor movements due to cerebral palsy, spinal injury or peripheral nerve injury.

f) *People with allergies* — People with allergies may be sensitive to dust, mildew, pollen, animal hair, formalin, turpentine, etc. Some are sensitive to contact with substances and materials such as nickel, chromium and rubber.

g) *People with heart and lung diseases* — People with heart and lung diseases may only be able to walk short distances and may be unable to climb stairs. The requirements of these people are similar to those with impaired mobility.

h) *People with epilepsy, haemophilia, etc* — The requirements of those with epilepsy, heamophilia, etc, are related primarily to the design of buildings and the need to minimize the risk of injury caused by falling or encountering obstacles.

j) *People with incontinence, enterostomy operations, etc* — The requirements of people with incontinence, enterostomy operations, etc, (colostomies, ileostomies and urostomies) are mainly related to bathroom provision. In certain circumstances, for example in public water-closet compartments, it may be desirable to provide a special sink for emptying urine bags.

k) *People with hidden (such as strength, stamina, dexterity and allergy) impairments*, and

m) *People with diversities in age and stature* (including frail persons).

13.3.3 *Key Accessibility Issues*

Entering, using and evacuating buildings should be safe and easy for individuals, families and groups which include persons with disabilities. The main considerations are as follows:

1) Pedestrian access into site;
2) Designated vehicular parking near the main entrance;
3) Accessible path to the entrance;
4) Appropriate external lighting;
5) Accessible external furniture (seats, bins, etc);
6) Accessible information at the entrance to the site;
7) Suitable drop-off point near main entrance;
8) Reduced travelling distances;
9) Level entrances and exits;
10) Simple and logical layouts;
11) Unobstructed level circulation;
12) Easy access to information desks, lifts and toilet compartments for disabled persons;
13) Intuitive, obvious and accessible means of egress;
14) Spacious lifts;
15) Safe stairs that are easy to use, and facilitate safe assisted evacuation/rescue in emergencies;
16) Slip-resistant walking surfaces;
17) Wide door openings and easy door operation, sufficient space around doors that makes it possible to open and close them when seated in a wheelchair;
18) Adequate manoeuvring space;
19) Adequate height, location and easy operation of controls and switches;
20) Good lighting;
21) Good visual contrast of walls, floors, doors and signage;
22) Good signage;
23) Important information communicated *via* two senses or more (tactile, audible and visual);
24) Good acoustics;
25) Hearing enhancement systems; and
26) Management and maintenance of the built environment.

The key accessibility issues are highlighted in Table 7.

13.4 Various key accessibility issues shall be taken into account for ensuring accessibility in built environment in accordance with the provisions given in Annex B in regard to anthropometrics and specific requirements on site planning and development, designated accessible parking space, approach to the buildings, access at entrance and within the buildings, controls and operating mechanisms, seating spaces, other facilities, level changes, toilet and sanitary facilities, emergency evacuation in buildings, signages, etc. Requirements for accessibility in buildings and built environment as given in other Parts/Sections of the Code shall also be complied with.

13.5 Various accessibility requirements for persons with disabilities and the elderly shall be applied to different building occupancies in accordance with Table 8, unless mentioned otherwise specifically in Annex B. In addition, all building occupancy types shall comply with the following:

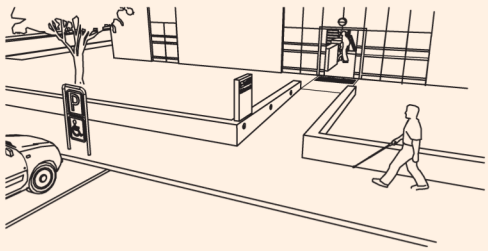
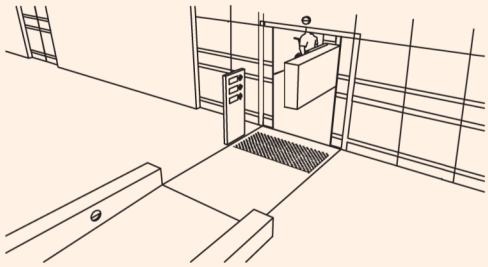
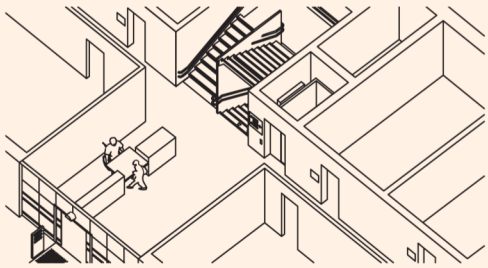
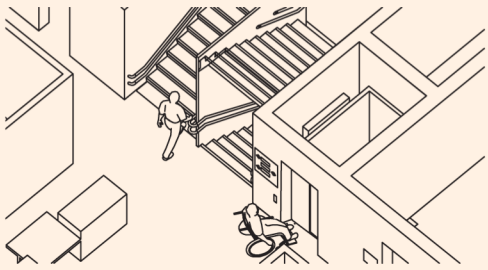
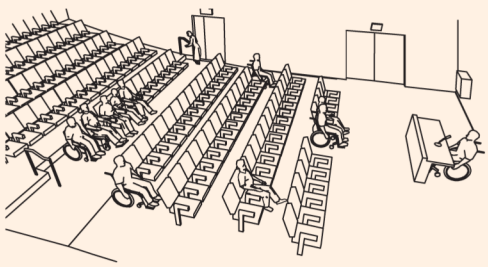
a) At least one entrance preferably the main entrance per building shall be accessible. All efforts should be made to make as many/all entrances accessible.

b) All common areas open to public and staff and all facilities provided in a building for

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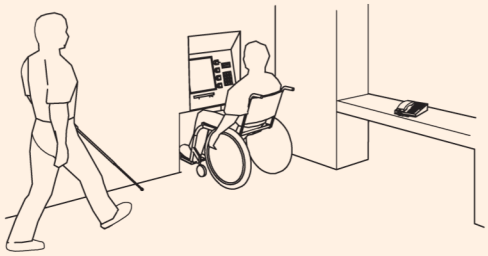
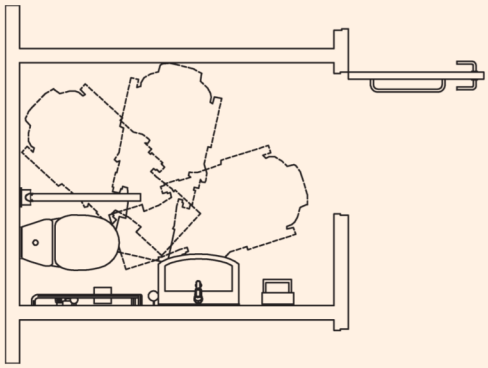
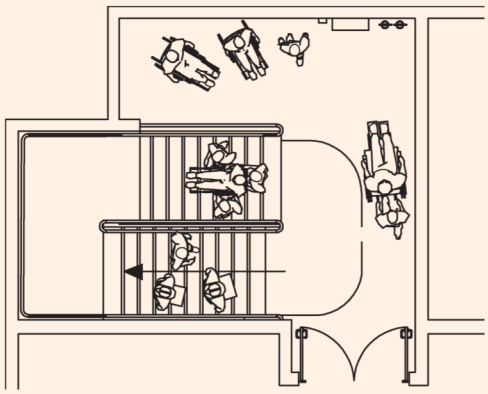
Table 7 Key Accessibility Issues

(*Clause* 13.3.3)

Sl No.	Key Accessibility Issues	Example
(1)	(2)	(3)
i)	Equitable approach to a building, for example designated parking, clear pedestrian routes separate from vehicles and cyclists, no steps or obstacles, short distances from parking and public transport, good signage, good lighting and good contrast	
ii)	Equitable entry *via* the same entrances, for example easy to locate main entrances, no steps or obstacles, wide openings, adequate manoeuvring space in front of the door, low operating forces, good signage, good lighting and good visual contrast	
iii)	Equitable use of the same paths in horizontal circulation, for example no steps or obstacles, adequate manoeuvring space, wide door openings, easy to operate doors, resting places, clear layout, good signage, good lighting and good visual contrast	
iv)	Equitable access to the same paths in vertical circulation, for example safe stairs, spacious lifts with easy operation, good signage, good lighting and good visual contrast	
v)	Equitable use of the same rooms, for example ample circulation space and different seating possibilities, good acoustics and hearing enhancement systems, good lighting and good visual contrast	

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Table 7 — (*Concluded*)

(1)	(2)	(3)
vi)	Equitable use of the same equipment and facilities, for example easy to understand and operate, adequate manoeuvring space and operating height, information *via* two senses	
vii)	Equitable use of toilet and sanitary facilities, for example good signage, adequate manoeuvring space, good transfer options, well-placed equipment, easy operation	
viii)	Equitable means of egress, concepts for emergency planning, for example no steps or obstacles, fire protected lifts, good signage, good lighting, good visual contrast, good fire safety, protection and evacuation, accessible means of egress	
ix)	Important information *via* two senses or more, for example visual, audible and tactile	

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Table 8 Minimum Accessibility Provisions in Different Building Occupancies

(*Clause* 13.5)

Sl No.	Category	Type of Built Environment Within the Category	Applicability
(1)	(2)	(3)	(4)
i)	Residential	Public housing including low income housing and housing developed by private developers	a) All common and communal areas, such as, approach, entrances/exits, lifts, stairs, lobbies, clubs, religious facilities, parking, sports facilities/parks and recreation areas, etc, and associated sanitary and other facilities therein. b) 5 percent houses to be accessible meeting accessibility requirements, preferably on ground floor. c) In all other 95 percent houses, minimum universal design features, such as, minimum clear door widths of: main entrance, rooms, kitchen and that of at least one toilet and sanitary room in each house. Such toilet and sanitary room in the house shall be the one having access from the living/drawing room and their size shall comply with those given in **B-9** to allow the occupants to adapt to their needs to facilitate ageing-in-place and disabled friendly environment. NOTE — The provisions given in (c) are minimum prescriptions with the objective to progressively move towards universal design of the buildings and the built environment, to be usable by all people, to the greatest extent possible irrespective of their age, situation, abilities, gender or any other diversity.
ii)	Hotels/hospitality centres	Hotels, dormitories, lodging and rooming houses, such as inns, clubs, motels and guest houses	Minimum five percent of the total rooms including their toilet room, shower room, balcony, etc, shall be accessible and preferably be provided on the ground floor for ease of evacuation in case of an emergency. All other rooms shall have universal design features (without specific adaptations like handrails/grab bars, etc). This would include minimum clear door widths of 900 mm of all entrances including those of sanitary rooms and balcony areas; and minimum passage width of 1 200 mm in the rooms and required turning radius. In accommodations having more than one toilet/sanitary room, one such facility shall be accessible. In case of accessible accommodations, a choice of right or left hand transfer to the toilet and shower shall be provided.
iii)	Educational buildings	Schools, colleges, classrooms, libraries, assembly points, halls, staff rooms, laboratories, play grounds	a) All teaching/administrative and common areas frequented by staff/students. b) In libraries all open book stacks. Few enclosed rooms in library for those with hearing and vision impairments who may need assistance while reading. c) In laboratories, equipment and facilities.
iv)	Hospitals/ health facilities	Hospitals/clinics/diagnostic centres/pharmacy, etc	All public areas to be accessible, including OPDs, IPDs, wards, toilets, changing rooms, sample collection rooms, x-ray rooms, patient examination rooms, medical distribution rooms/centres.
v)	Assembly buildings	Stadia, theatres, lecture halls, spectator seating in sports centres and all other type of assembly halls with fix seatings, by whatever name called	To all common areas/facilities open to public and staff. Number of designated seating areas to be as per **B-12.3**.
vi)	Public transit buildings	Bus terminus, airports, railway/metro stations, organized inter-change points/transit junctions, taxi stands	All public areas used by passengers and staff including but not limited to drop off areas, parking, boarding/transfer areas, waiting areas/lounges, custom areas, baggage halls, booking halls, inquiry offices, ticket counters, shops, banks, etc.
vii)	Heritage buildings/ sites	All heritage sites/buildings protected by concerned authorities and open to public, interpretation centres, ancillary services/ facilities	a) Reasonable access to all public areas without affecting the historical character of the building. b) Alternative solutions and innovative methods that do not conflict with conservation/preservation requirements should be explored.

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Table 8 — (*Concluded*)

(1)	(2)	(3)	(4)
viii)	Public toilets		To be provided in accordance with **B-9.15**.
ix)	Cafeterias and restaurants		To be provided in accordance with **B-15**.
x)	Sports buildings		a) Sports halls, administration and common areas. b) At least one changing room and shower room to be provided at every place where such facility is provided. c) Spectators seating areas for wheelchair users as per assembly buildings above.
xi)	Mercantile buildings	Shops, malls, large multi-storey department stores and super markets, etc	At least one trial room for each group of such facility. Where only one is provided, it shall be accessible.

public use, such as, waiting areas, seating spaces, coffee shops, display areas, merchandising departments, service areas, ticket counters and refreshment stands shall be accessible to all persons with disabilities. These shall also include facilities like, lobby toilets, lifts, saloons, bars, restaurants, eateries, clubs, swimming pool, parking, fitness centres/gymnasiums, religious facilities, sports facilities/parks and recreation areas, etc, within an occupancy.

c) In all buildings, accessible toilet and sanitary room(s) shall be provided in accordance with **B-9**. Such facility shall be provided in each toilet group in a building.

14 SPECIAL REQUIREMENTS OF LOW INCOME HOUSING IN URBAN AREAS

Special requirements of low income housing shall be as given in Annex C. For detailed information in this regard, reference may be made to the accepted standard [3(3)].

With the exception of requirements given in Annex C, requirements of building shall be governed by the provision of this Code.

15 SPECIAL REQUIREMENTS FOR CLUSTER PLANNING FOR HOUSING

Special requirements for cluster planning for housing shall be as given in Annex D. With the exception of requirements given in Annex D, requirements of building shall be governed by the provision of this Code.

16 SPECIAL REQUIREMENTS FOR LOW INCOME HABITAT PLANNING IN RURAL AREAS

Special requirements for low income habitat planning in rural areas shall be as given in Annex E. With the exception of requirements given in Annex E, requirements of building shall be governed by the provision of this Code.

17 SPECIAL REQUIREMENTS FOR DEVELOPMENT PLANNING IN HILLY AREAS

Special requirements for development planning in hilly areas is given in Annex F. With the exception of requirements given in Annex F, requirements of building shall be governed by the provision of this Code.

18 FIRE AND LIFE SAFETY

For requirements regarding fire and life safety for different occupancies, reference shall be made to Part 4 'Fire and Life Safety' of the Code.

19 DESIGN AND CONSTRUCTION

For requirements regarding structural design, reference shall be made to Part 6 'Structural Design' of the Code. For requirements regarding construction (including management and safety), reference shall be made to Part 7 'Construction Management, Practices and Safety' of the Code.

20 LIGHTING AND VENTILATION

20.1 For requirements regarding lighting and ventilation for different uses and occupancies, reference shall be made to Part 8 'Building Services', Section 1 'Lighting and Natural Ventilation' of the Code.

20.1.1 *Lighting and Ventilation of Rooms*

Rooms shall have, for the admission of light and air, one or more openings, such as windows and ventilators, opening directly to the external air or into an open *Verandah*.

20.1.2 Notwithstanding the area of openings obtained through **20.1**, the minimum aggregate area (*see* Notes 1 to 3) of such openings, excluding doors inclusive of frames, shall be not less than,

a) one-tenth of the floor area for hot-dry climate;

b) one-sixth of the floor area for warm-humid climate;

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c) one-eighth of the floor area for temperate and composite climate; and

d) one-twelfth of the floor area for cold climate.

NOTES

1 If a window is partly fixed, the openable area shall be counted.

2 No portion of a room shall be assumed to be lighted, if it is more than 7.5 m away from the opening assumed for lighting that portion.

3 The area of openings as given in (a) to (d) above shall be increased by 25 percent in the case of a kitchen [*see* **12.3.3**(d)].

21 ELECTRICAL AND ALLIED INSTALLATIONS (INCLUDING LIGHTNING PROTECTION OF BUILDINGS AND SOLAR ENERGY UTILIZATION)

21.1 For requirements regarding electrical installations in buildings including lightning protection of buildings, reference shall be made to Part 8 'Building Services Section 2 Electrical and Allied Installations' of the Code.

21.2 Solar Energy Utilization

The solar panels can be provided on roof tops and integrated photovoltaic panels on walls/windows as well as solar photovoltaic (PV) banks on open areas.

21.2.1 *Solar Photovoltaic Power Generation System*

All plots having size 500 m^2 and above shall install solar photovoltaic power generation system. This should also be encouraged for plots smaller than 500 m^2. The power generated may be used for in-house utilization or for transfer to the grid. The Authority shall have required provisions in the building bye-laws and mechanism for required clearances and approvals. The Authority shall also specify minimum generation requirement. The following may be used as a guide:

Sl No.	*Building Type*	*Plot Size*	*Generation Requirement*
(1)	(2)	(3)	(4)
i)	Residential (Plotted houses)	100 m^2 and above	1 kWp or 5 percent of connected load, whichever is higher
ii)	Residential (Group housing)	All sizes	Minimum 5 percent of connected load
iii)	Business, educational buildings having connected load of 30 kW and above	500 m^2 and above	5 kWp or 5 percent of connected load, whichever is higher
iv)	Mercantile, hotels, motels, assembly, industrial and institutional buildings	500 m^2 and above	for buildings having connected load of: a) *50-1 000 kW* — 10 kWp or 5 percent of connected load whichever is higher b) *Above 1 000 kW* — 50 kWp or 5 percent of connected load whichever is higher

21.2.2 *Solar Water Heating System*

The following building occupancy types shall install solar assisted water heating system for supplying hot water:

a) Residential buildings (except hostels of educational buildings and plotted houses) having plot area 4 000 m^2 and above;

b) Plotted houses having plot area of 250 m^2 and above;

c) Hostels for schools, colleges and training centres for more than 100 students;

d) Institutional buildings; and

e) Assembly buildings

The Authority shall have required provisions in the building bye-laws and mechanism for required clearances and approvals. The Authority, considering the availability of solar energy for harnessing, shall decide the minimum capacity be installed subject to a minimum of 25 litre per day hot water yield for each bathroom and kitchen.

For solar water heating system and their installation reference shall be made to accepted standards and good practice [3(4)].

22 AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION

For requirements regarding design, construction and installation of air conditioning, heating and mechanical ventilation systems, reference shall be made to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code.

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23 ACOUSTICS, SOUND INSULATION AND NOISE CONTROL

For requirements regarding the desired noise levels and sound insulation in different occupancies, reference shall be made to Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code.

24 HEAT INSULATION

For calculation of solar radiation on buildings and recommended limits of thermal transmittance of roofs and walls for different parts of the country and heat transmission losses due to different constructions, reference may be made to good practice [3(5)].

25 INSTALLATION OF LIFTS, ESCALATORS AND MOVING WALKS

Provision for lifts shall be made for buildings 15 m or more in height. For requirements regarding planning, designing and installation, etc, of lifts and escalators, reference shall be made to Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks' of the Code.

26 INFORMATION AND COMMUNICATION ENABLED INSTALLATIONS

For requirements regarding information and communication enabled installations in buildings, reference shall be made to Part 8 'Building Services, Section 6 Information and Communication Enabled Installations' of the Code.

27 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

For requirements regarding water supply, drainage and sanitation, solid waste management and gas supply, reference shall be made to Part 9 'Plumbing Services (including Solid Waste Management)' of the Code.

28 SUSTAINABILITY

For requirements regarding sustainable buildings and built environment, reference shall be made to Part 11 'Approach to Sustainability' of the Code.

29 ASSET AND FACILITY MANAGEMENT

For requirements regarding asset and facility management in respect of existing buildings and services thereof, reference shall be made to Part 12 'Asset and Facility Management' of the Code.

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ANNEX A

(*Clauses* 10.1 *and* 10.4)

OFF-STREET PARKING SPACES

A-1 The off-street parking spaces shall be as given in Table 9.

Table 9 Norms for Off-Street Parking Spaces

(*Clause* A-1)

Sl No.	Occupancy	One Car Parking Space for Every				
		Population Less than 50 000	Population Between 50 000 and 200 000	Population Between 200 000 and 1 000 000	Population Between 1 000 000 and 5 000 000	Population Above 5 000 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Residential a) Multi-family	—	—	a) 2 tenements having built-up area 101 to 200 m^2	1 tenement of 100 m^2 built-up area	a) 1 tenement of 75 m^2 built-up area
				b) 1 tenement of built-up area above 200 m^2		b) ½ tenement of built-up area above75 m^2
	b) Lodging establishments, tourist homes and hotels, with lodging accommodation	12 guest rooms	8 guest rooms	4 guest rooms	3 guest rooms	2 guest rooms
ii)	Educational (*see* Note 1)	—	—	70 m^2 area or fraction thereof of the administrative office area and public service areas	50 m^2 area or fraction thereof of the administrative office area and public service areas	35 m^2 area or fraction thereof of the administrative office area and public service areas
iii)	Institutional (Medical)	20 beds (Private) 30 beds (Public)	15 beds (Private) 25 beds (Public)	10 beds (Private) 15 beds (Public)	5 beds (Private) 10 beds (Public)	2 beds (Private) 5 beds (Public)
iv)	a) Assembly halls, cinema theatres	120 seats	80 seats	25 seats	15 seats	10 seats
	b) Restaurants	60 seats	40 seats	20 seats	10 seats	5 seats
	c) Marriage halls, community halls	600 m^2 plot area	400 m^2 plot area	200 m^2 plot area	50 m^2 plot area	25 m^2 plot area
	d) Stadia and exhibition centre	240 seats	160 seats	50 seats	30 seats	20 seats
	e) Sport complex (without stadium), parks and multipurpose open spaces	—	—	1 000 m^2 plot area	500 m^2 plot area	250 m^2 plot area
v)	a) Business offices and firms for private business	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof	25 m^2 area or fraction thereof
	b) Public or semi-public offices	500 m^2 area or fraction thereof	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof
vi)	Mercantile (*see* Note 2)	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof	25 m^2 area or fraction thereof
vii)	Industrial	400 m^2 area or fraction thereof	300 m^2 area or fraction thereof	200 m^2 area or fraction thereof	100 m^2 area or fraction thereof	50 m^2 area or fraction thereof
viii)	Storage	—	—	500 m^2 floor area or part thereof	250 m^2 area or fraction thereof	125 m^2 area or fraction thereof

NOTES

1 In the case of auditoria for educational buildings, parking space shall be provided as per Sl No. (iv).
2 For plots up to 50 m^2, as in the case of shops, parking spaces need not be insisted upon.
3 For other institutions, transport/communication centre, parking space requirement shall be assessed based on the proposed building.
4 In case of permitted mixed residential-commercial or mixed residential-industrial areas the parking requirements shall be double the number for residential use.
5 The requirements specified in this table shall not be applicable for buildings meant for parking alone, including the multi-level car parking buildings which shall be as decided by the Authority.
6 Designated accessible parking spaces shall be provided in accordance with **B-3** for the occupancies specified in **13**.

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ANNEX B

[*Clauses* 4.6.1.3(g), 13.3.1, 13.4 *and* 13.5]

ANTHROPOMETRICS AND REQUIREMENTS FOR ACCESSIBILITY IN BUILT-ENVIRONMENT FOR ELDERS AND PERSONS WITH DISABILITIES

B-1 ANTHROPOMETRICS

Adequate space should be allocated for persons using mobility devices, for example wheelchairs, crutches and walkers, white cane etc, as well as those walking with the assistance of others. The dimensions prescribed in **B-1.1** to **B-1.4** may be used for guidance while designing facilities and equipment to be used by persons with disabilities.

B-1.1 Mobility Devices and Space Allowance

B-1.1.1 *Wheelchair*

The basic elements of wheelchairs (manual, electric and any others) and terms and definitions for these elements are as defined in the accepted standard [3(6)]. Basic elements of a wheelchair (folding, adult size) are also shown in Fig. 12.

Wheelchair requirements are given in the accepted standards [3(7)].

B-1.1.1.1 Some of the dimensions of a standard wheelchair are extremely important and helps to arrive at requirements for space allowance, reach range, etc, of a wheelchair user. Electric wheelchair may be of a large dimension, much heavier and do not have the same manoeuvrability/capability as manual wheelchairs.

B-1.1.1.2 Manual wheelchair dimensions are as follows (*see* Fig. 12):

a) Overall length : 1 000 mm -1 100 mm
b) Overall width, open : 650 mm - 720 mm
c) Overall width, folded : 300 mm - 330 mm
d) Overall height : 910 mm - 950 mm
e) Seat height from floor at the front : 480 mm - 510 mm
f) Distance between seat and footrest : 400 mm - 450 mm
g) Arm rest height from seat : 220 mm - 230 mm
m) Seat depth : 420 mm - 440 mm
n) Clearance of foot-rest from floor : 90 mm - 200 mm
p) Clearance of frame from floor : 90 mm, *Min*
q) Wheelchair footrest : 350 mm (deep)
r) Wheelchair castor width : 12 mm
s) Weight of the wheelchair (basic model) : 25 kg, *Max*

The following form important considerations in deciding various space requirements to ensure functionality for wheelchair users:

1) Arm rest height from floor : 760 mm
2) Lap height : 675 mm

NOTE — The dimensions given above are from the point of view of better understanding and appreciation of various needs emanating therefrom. However, considering various aspects including diversity of population, stature, age, gender, etc, the

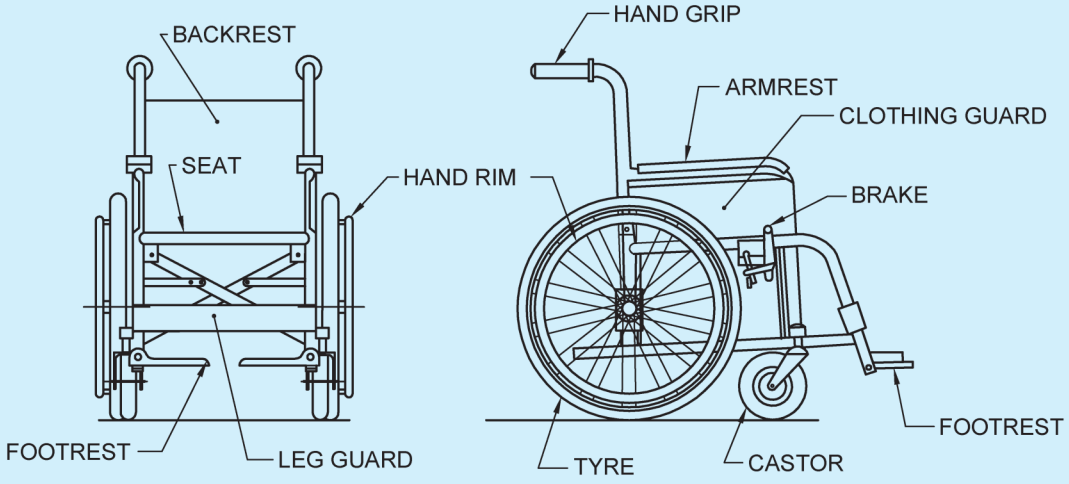


FIG. 12 NOMENCLATURE OF BASIC ELEMENTS OF WHEELCHAIR

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dimensions and ranges thereof as may be applicable have been prescribed in these provisions given hereinafter.

B-1.1.1.3 A wheelchair has a footplate and leg rest attached in front of the seat. The footplate extends about 350 mm in front of the knee. The footplate may prevent wheelchair users from getting close enough to an object/site. Hence, at least 350 mm deep and 700 mm high space under a counter, stand, etc, shall be provided (*see* Fig. 13).

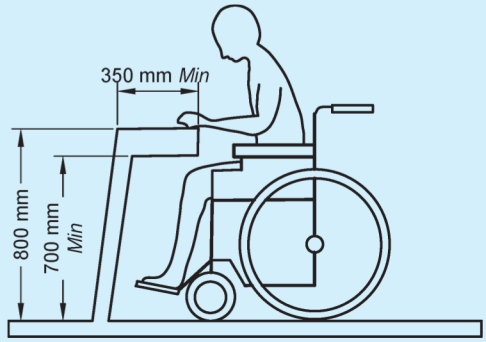


FIG. 13 NECESSARY SPACE UNDER COUNTER OR STAND FOR EASE OF WHEELCHAIR USERS

B-1.1.1.4 *Clear floor space for wheelchair user*

The minimum clear floor or ground area required for accommodating a single, stationary wheel chair and occupant is 900 mm × 1 200 mm (*see* Fig. 14). Where transfer from the wheelchair is involved, the clear space should preferably be 900 mm × 1 350 mm.

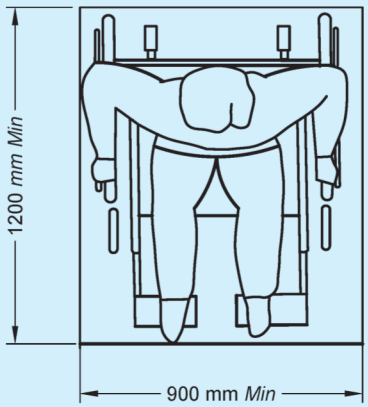


FIG. 14 CLEAR FLOOR SPACE

B-1.1.1.5 *Circulation dimensions*

The minimum clear floor ground area for a wheelchair to turn is 1 500 mm, whereas comfortable is 1 800 mm and it is ideal to provide 2 000 mm (*see* Fig. 15).

B-1.1.2 *Space Allowance for Crutch Users*

Although people who use walking aids can manoeuvre through door openings of 900 mm clear width, they need wider passageways for comfortable gaits as shown in Fig. 16. Crutch tips, often extend down out at a wide angle, and are hazardous in narrow passageways where they might not be seen by other pedestrians.

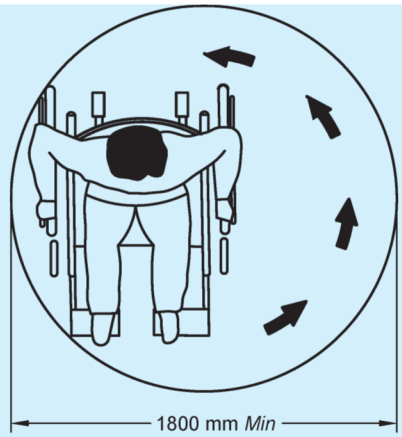


FIG. 15 PREFERRED COMFORTABLE TURNING RADIUS

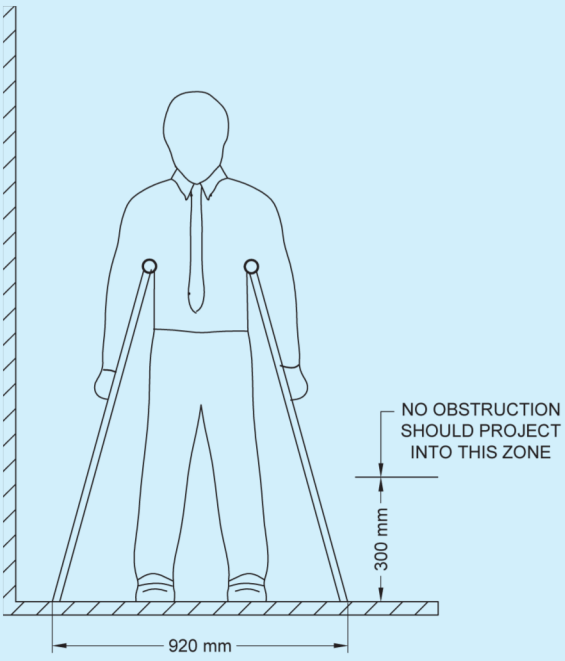


FIG. 16 PASSAGEWAY REQUIRED FOR PEOPLE WHO USES WALKING AIDS

B-1.1.3 *Space Allowance for White Cane Users*

Following shall be ensured for white cane users:

a) Protruding objects, such as directional signs, tree branches, wires, guy ropes, public telephone booths, benches and ornamental fixtures shall be installed with consideration of the range of the white cane of a person with vision impairment.

b) A barrier to warn blind or visually impaired person shall be provided under stairways or escalators so that they don't accidently enter

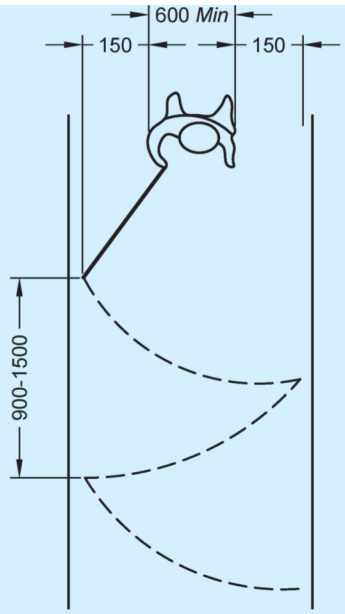
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in to them.

c) Walkways, halls, corridors, passage ways, aisles, or other circulations spaces shall have clear headroom to minimize the risk of accidents.

d) Adequate space allowance should be made considering that the radial range of white cane is a band of 900 mm wide (*see* Fig. 17).

e) Any obstacle above 300 mm cannot be detected by the white cane. If there are projections above this height then the same has to be treated in accordance with **B-2.6.2**.



All dimensions in millimetres.

FIG. 17 SPACE ALLOWANCE (RADIAL RANGE) FOR PEOPLE USING WHITE CANES

B-1.2 Reach Range

A wheelchair user's movement pivots around its shoulders (*see* Fig. 18). The range of reach (forward and side; with or without obstruction) of a wheelchair users, as given in **B-1.2.1** to **B-1.2.3** shall be taken in to consideration.

B-1.2.1 *Forward Reach*

The maximum forward reach without obstruction is 1 200 mm from the floor and the minimum forward reach without obstruction is 400 mm from the floor as shown in Fig. 19.

The maximum forward reach over an obstruction is 1 000 mm from the floor as shown in Fig. 20, which also indicates the touch reach and grasp reach.

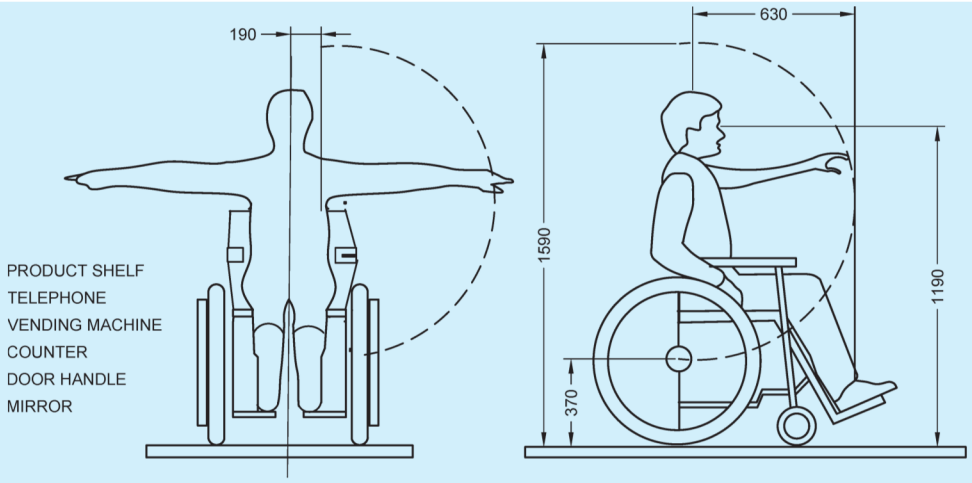
B-1.2.2 *Side Reach*

The maximum side reach without obstruction is 1 300 mm from the floor and the minimum side reach is 250 mm as shown in Fig. 21.

The maximum side reach over an obstruction of size 860 mm high × 500 mm deep is 1 200 mm from the floor as shown in Fig. 22, which also indicates the touch reach and grasp reach.

B-1.2.3 *Common Reach Zone*

As part of the common reach zone, the comfortable reach zone when seated on a wheelchair is between 900 mm and 1 200 mm and the maximum reach zone is between 1 200 mm and 1 400 mm (*see* Fig. 23).



All dimensions in millimetres.

FIG. 18 RANGE OF REACH OF WHEELCHAIR USER

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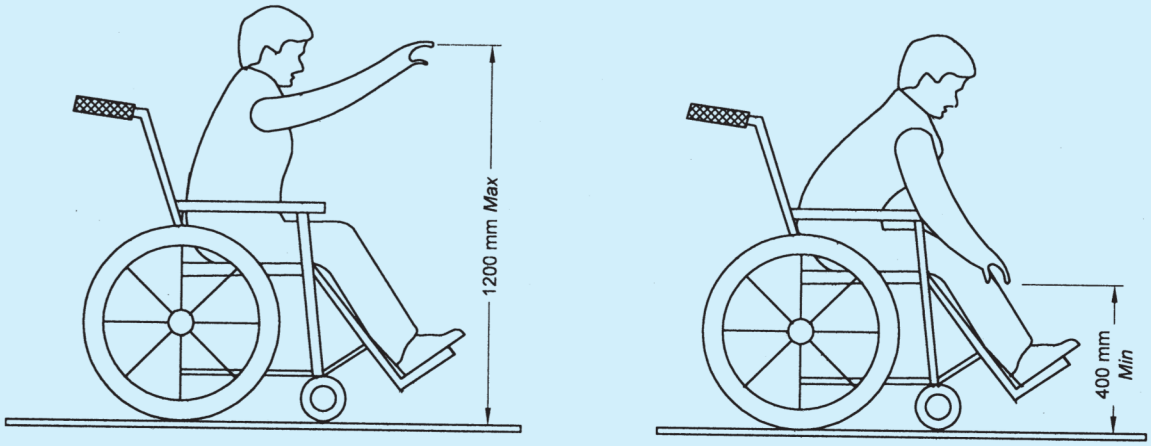


FIG. 19 FORWARD REACH WITHOUT OBSTRUCTION

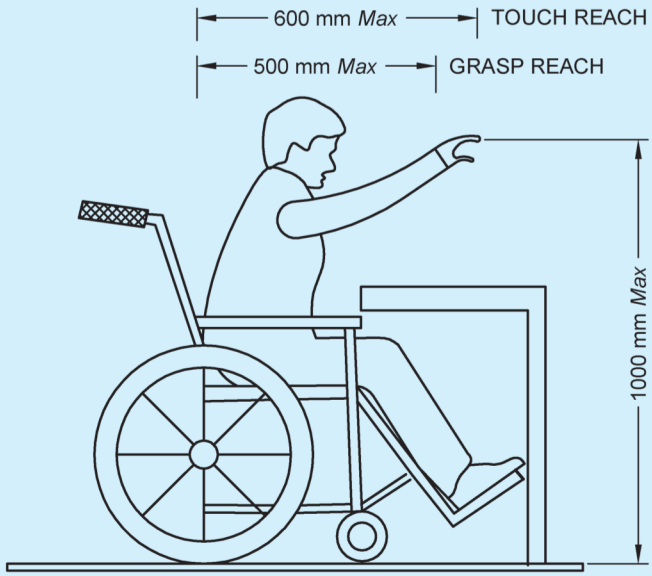


FIG. 20 FORWARD REACH OVER OBSTRUCTION

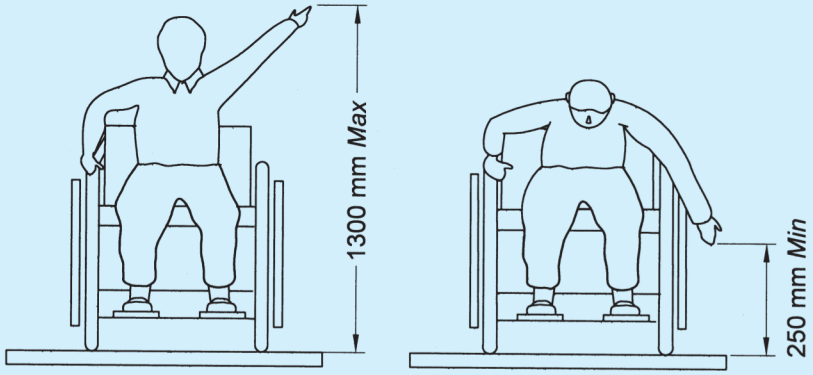
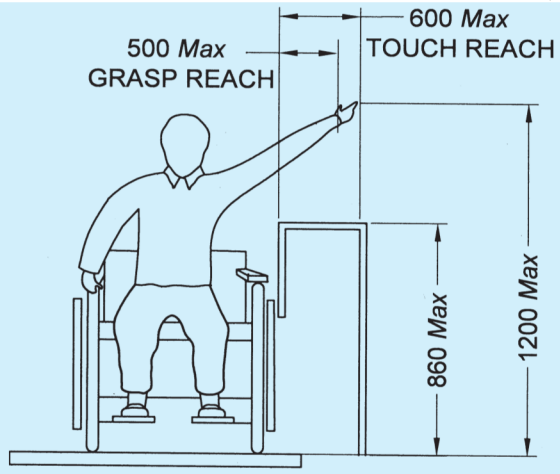


FIG. 21 SIDE REACH WITHOUT OBSTRUCTION

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All dimensions in millimetres.

FIG. 22 SIDE REACH OVER OBSTRUCTION

B-1.3 Vision Zone

Different fields of vision are given in Fig. 24. All signage should be designed based on these dimensions.

Map and information panels along pathways shall be placed at a height between 900 mm and 1 800 mm (*see* Fig. 25).The smallest letter shall not be less than 15 mm.

B-1.4 Heights and Widths

B-1.4.1 *Wheelchair Users*

The average height of a person seated on a wheelchair is generally less than 1 200 mm.

B-1.4.2 *Standing Person*

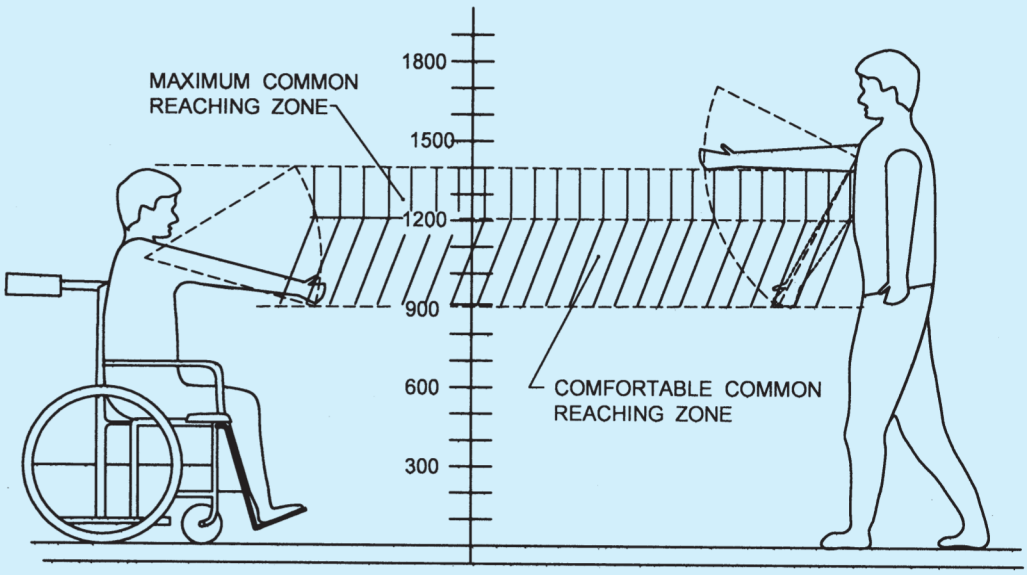
The average height of a standing person is generally less than 2 000 mm.

B-1.4.3 *Height of Controls*

a) Height of controls from floor level : 400 mm - 1 200 mm
b) Height for switches (power) : 400 mm - 500 mm
c) Height for switches (lights) : 800 mm - 1 200 mm
d) Height of door handles : 800 mm - 1 100 mm
e) Opening controls for windows : 800 mm - 1 100 mm
f) Space required under the counter for wheelchair footrest : 350 mm deep

B-1.4.4 *Entrance/Exit Door*

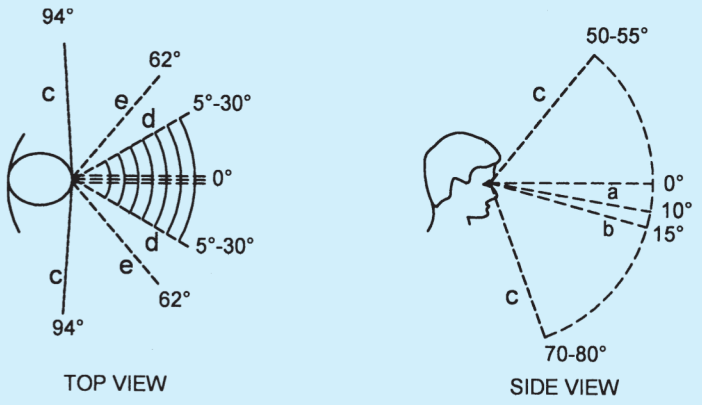
a) Minimum width of entrance/ exit door (*see* Fig. 43) : 900 mm
b) Minimum front approach doorways space (*see* Fig. 44 and Fig. 45) : 600 mm
c) Minimum latch side approach doorways space (*see* Fig. 44) : 1 250 mm



All dimensions in millimetres.

FIG. 23 COMMON REACHING ZONE

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Key

a Normal optical axis, standing person
b Normal optical axis, sitting person
c Limit of field of vision
d Normal angle of vision
e Maximum angle of vision

FIG. 24 FIELD OF VISION

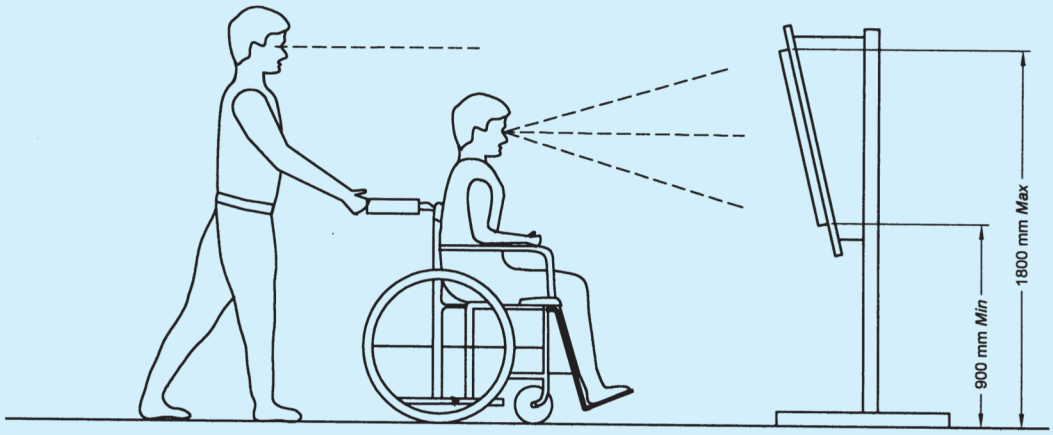


FIG. 25 VISION ZONE

B-2 SITE PLANNING AND DEVELOPMENT

B-2.1 General

Site development is the most effective means to resolve the problems created by topography, definitive architectural designs or concepts, water table, existing streets, and typical problems, singularly or collectively, so that ingress and egress to buildings by persons with disabilities can be facilitated while preserving the desired design and effect of the architecture. Each building and its site shall be planned and designed as an integral unit from the very beginning of the design process. Equipment and materials causing allergic reactions shall as far as possible be avoided in dwellings and buildings.

The provisions of accessibility in outdoor built environment covered herein pertain to the immediate outdoor environment of a building or of a building complex. However, these may be considered by the Authorities and concerned parties for suitably applying the same at township/city level.

B-2.2 Walkways and Pathways

B-2.2.1 *General*

Walkways and pathways (used here interchangeably) shall meet the following general requirements:

a) Walkways shall be smooth, hard and have levelled surface suitable for walking and wheeling. Irregular surfaces as cobble stones, coarsely exposed aggregate concrete, bricks, etc, often cause bumpy rides and shall be avoided.

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b) Minimum walkway width shall be provided as per **B-2.2.2**. The width of footpath shall be in accordance with **4.3.2.1.1**.

c) The walkway shall not have a gradient exceeding 1:20. If the slope or any part of a walkway on an accessible route to a building exceeds 1:20, it shall be designed and constructed as a ramp in accordance with **B-6.2**.

d) Where pathway meets the road, a kerb shall be provided; which shall be designed in accordance with **B-2.3.**

e) The cross-fall gradient across an accessible route shall not exceed 1:50 (20 mm/m), except when associated with a dropped kerb.

f) The requirements for drainage of pathways shall be as per **B-2.2.5**.

g) When walkways exceed 60 m in length, it is desirable to provide rest area adjacent to the walk at convenient intervals of 30 m in the form of benches/resting seats. For comfort, seat height shall be between 450 mm and 500 mm, and the seating shall have a back rest and arm rests at 700 mm height. One side of seating may be without arm rest to address the transfer needs of persons with disabilities. A colour contrast should be provided around the seating area for ease of identification by persons with low vision.

h) Texture change in walkways adjacent to seating shall be provided for persons with vision impairment by means of warning blocks (*see* **B-2.5**).

j) Gratings and manholes should be avoided in walks.

k) Walks or driveways shall have a non-slip surface. Care shall be taken to ensure that adjacent surface materials do not display different slip resistance characteristics, particularly at the edges of changes of level or gradients.

m) Such walks shall be of a continuing common surface not interrupted by steps or abrupt changes in level.

n) Wherever walks cross other walks, driveways, or parking lots, they shall blend to a common level.

p) Obstacles, such as objects or signs mounted on walls, columns or free-standing supports along the walking path shall be avoided. These shall however be regulated in accordance with **B-2.6.1**. Bollards along or on the walking pathway shall also be regulated in accordance with **B-2.6.1**. Any protruding object projecting into a walkway shall be treated in accordance with **B-2.6.2**.

B-2.2.2 Width of the Walkway/Pathway

B-2.2.2.1 The unobstructed width of the pathway shall be,

a) not less than 1 800 mm for two-way traffic (*see* key 1 of Fig. 26); which may be reduced to a minimum of 1 500 mm, provided that a passing and turning space of at least 1 800 mm × 2 000 mm should be provided for every 25 m (*see* keys 2 and 5 of Fig. 26); and

b) not less than 1 200 mm for one-way traffic (*see* key 3 of Fig. 26); which may be reduced to a minimum of 1 000 mm, provided that a passing and turning space of at least 1 800 mm × 2 000 mm should be provided for every 25 m (*see* keys 4 and 5 of Fig. 26).

B-2.2.2.1.1 The width of footpath shall be in accordance with **4.3.2.1.1**.

B-2.2.2.2 *Passing space for wheelchair users*

A path whose surface width is less than 1 800 mm (*see* **B-2.2.2.1**) and whose overall length is more than 50 m, shall be provided with a passing place or places. Passing places should be a maximum of 25 m apart. This does not apply to a landing forming part of a sloped path, a ramp, steps or a stair.

Passing place for two people using wheelchairs shall be a minimum width of 1 800 mm for a minimum length of 2 000 mm (*see* examples in Fig. 27).

NOTE — Passage widening can be associated with intersections, turns and doorways so as to appear as integrated design features or enhancements.

B-2.2.2.3 For wheelchair manoeuvrability at turnings, minimum turning radius shall be required in accordance with **B-5.2.3** and **B-5.2.4**.

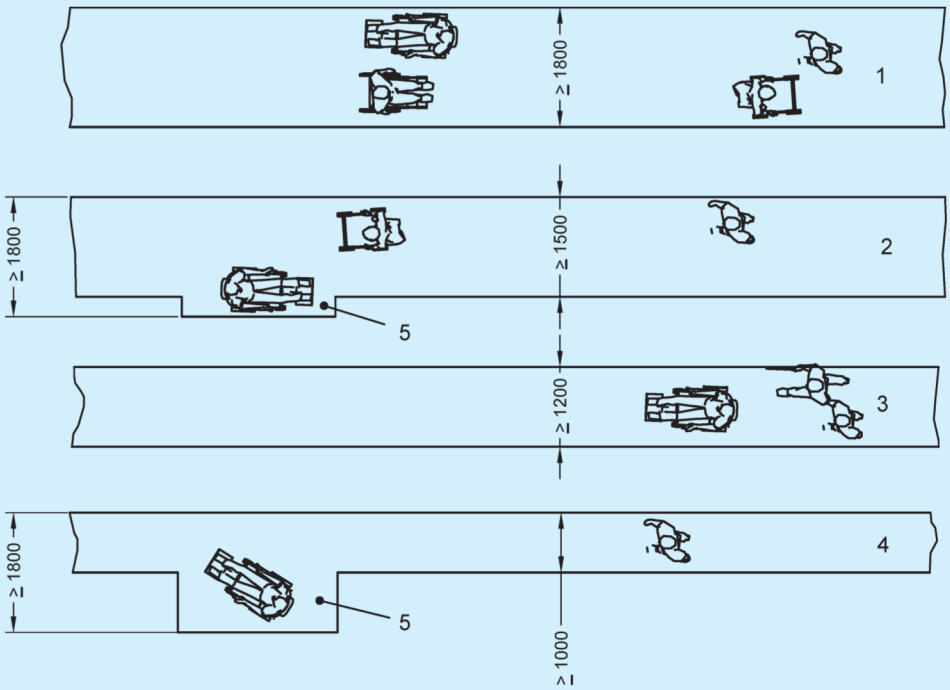
B-2.2.3 *Stepped Path and Stair*

For ambulant people, a stepped path can provide a safer and more assuring means of access than a sloped path or a ramp. Wherever the rise of a ramp exceeds 300 mm, an additional flight of steps shall also be provided. An isolated single step is not acceptable. Where required on a continuous accessible path of travel, tactile warning indicators shall be located at both the top and bottom of stairways. The surface width of a stepped path and stair shall be not less than 1 200 mm and it shall meet the other requirements of **B-6.3**.

B-2.2.4 *Support and Guidance by a Handrail on Paths*

Support and guidance by a handrail shall be provided on stepped paths. A handrail shall be provided on each

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Key

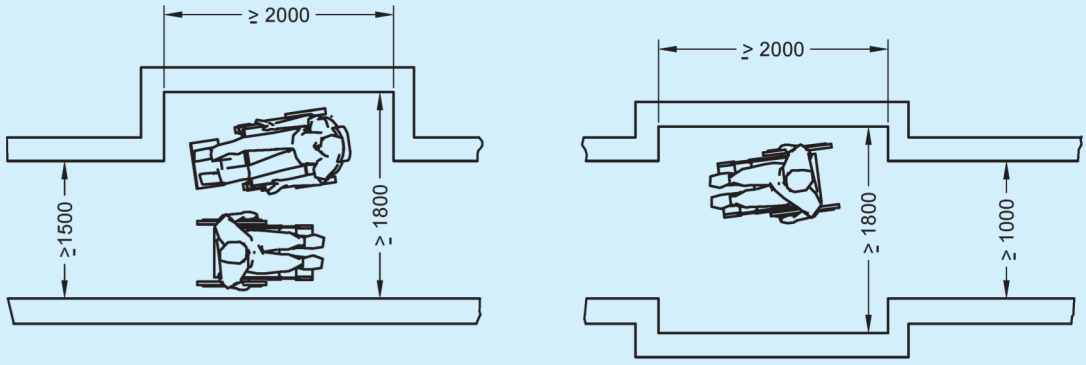
1 and 2 For two-way traffic

3 and 4 For one-way traffic

5 Passing and turning space every 25 m (only acceptable for wheelchair users under exceptional circumstances)

All dimensions in millimetres.

FIG. 26 DIFFERENT SURFACE WIDTHS OF THE PATH DEPENDING ON TRAFFIC



All dimensions in millimetres.

FIG. 27 EXAMPLES FOR PASSING PLACES FOR WHEELCHAIR USERS

side of a flight of steps consisting of two or more risers and each riser shall be not more than 150 mm high. A handrail shall be provided on both sides of a channel that can subdivide a flight of steps. For requirements of handrails, reference shall be made to **B-5.5.2**.

B-2.2.5 *Drainage of Path/Access Routes*

The cross-fall of a level or sloped path, a stepped path, a ramp, or a landing, that is provided to permit drainage of surface water, shall be in accordance with **B-2.2.1**(e).

The top, bottom and landings of steps and ramps shall be properly drained in order to avoid water flowing down steps and ramps.

A dished channel should not be constructed within the boundaries of a path or ramp. Dished channels shall have a maximum width of 150 mm and a maximum drop into gulley of 5 mm.

A drainage grating that is within the boundaries of a path or a ramp shall be set flush with the surface (*see* **B-2.4**).

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B-2.2.6 *Guarding along Paths and Ramps*

Providing protection at the side of the path protects people who use wheelchairs and ambulant people from injuring themselves as the result of a fall. Examples of protection against falling are shown in Fig. 28.

a) If a level or sloped path is bounded on one or both sides by terrain that slopes downwards by up to 30° from the horizontal, a firm and level margin of at least 600 mm shall be provided at the relevant side or sides.

b) If a sloped path or ramp is bounded on one or both sides by terrain that slopes downwards by more than 30°, an upstand of minimum height of 150 mm shall be provided at the relevant side or sides. Upstands shall have a minimum difference in LRV of 30 points in relation to the ramp.

c) If a path, or a sloping path, stepped path, ramp, terrace or other unfenced platform rises more than 600 mm above the adjacent ground, it shall be provided with guarding. If the adjacent ground is firm and level with the path for 600 mm, no guard is needed.

Guarding shall be designed to discourage a user, particularly a child, from climbing on it.

B-2.3 Kerb Ramp/Dropped Kerb

B-2.3.1 *General*

It is a ramp built on a footpath or pavement to accommodate the change in level towards vehicular areas to allow easy and continuous access. Kerb ramps shall be provided at pedestrian crossings and at each end of the footpath of a private street or access road.

Kerb ramps shall be provided where the vertical rise is less than 150 mm. They shall meet the following requirements:

a) They shall have a slip-resistant surface.

b) They shall avoid raised traction strips in order to reduce the hazard to everyone.

c) They shall be designed not to allow water accumulating on the walking surface.

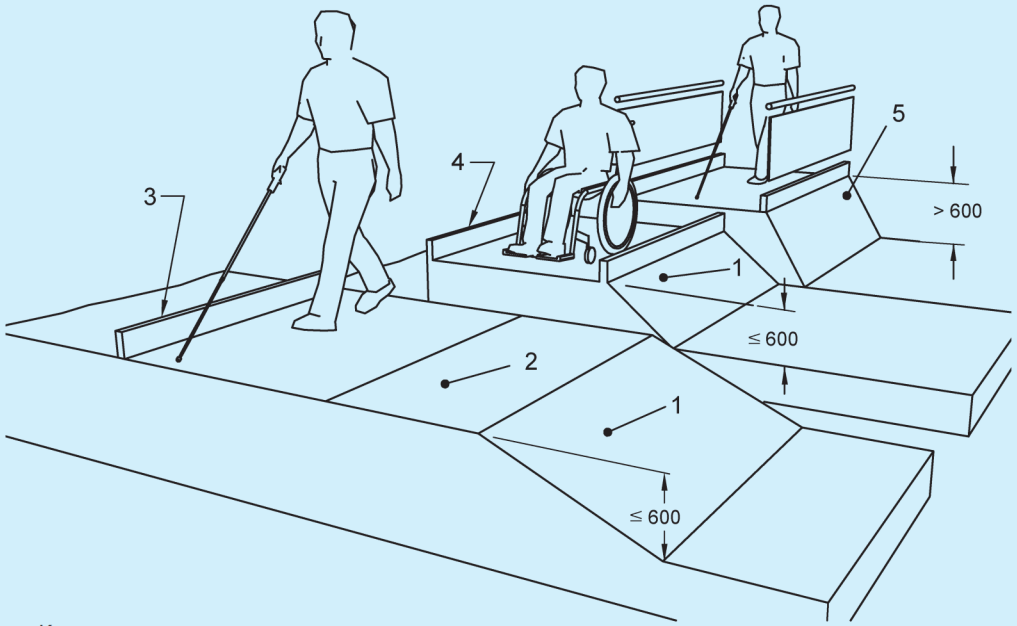
d) Handrails may not be provided with kerb ramps.

e) They shall not project into the road surface.

f) They shall be so located and also protected to prevent obstruction by parked vehicles.

g) They shall be free from any obstruction such as signposts, traffic lights, etc.

h) They shall not encroach into a roadway, as it is dangerous for users and obstructive for vehicles.



Key

1 Downward slope less than 30°
2 Level margin minimum 600 mm wide
3 Upstand where the difference in level is 600 mm or less
4 Upstand with a minimum difference in LRV of 30 points in relation to the path or ramp
5 Upstand with guarding where the difference in level is greater than 600 mm

All dimensions in millimetres.

FIG. 28 EXAMPLES OF PROTECTION AGAINST FALLING

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j) They shall be so located to enable users to have an unobstructed view of traffic approaching from any direction.

k) They shall be provided with adequate visual and tactile warning.

m) TGSI (warning type) shall be provided to notify the presence of traffic and shall have a minimum luminous contrast of 70 percent with the adjoining surfaces for the elderly and persons with visual impairment.

Typical kerb ramp requirements and kerb extension at street intersections are shown in Fig. 29 and Fig. 30.

B-2.3.2 *Gradient*

The gradient of a kerb ramp shall not be steeper than 1:12.

B-2.3.3 *Width*

The kerb ramp shall not be less than 1 200 mm in width. It shall provide a clearance of at least 800 mm at the back of the kerb ramp on the footpath (*see* Fig. 29).

B-2.3.4 *Flared Sides*

Kerb ramps shall have flared sides where pedestrians are likely to walk across them as shown in Fig. 29 and the gradient of the flared side shall not be steeper than 1:10.

B-2.4 Levels, Grooves, Gratings and Manholes

B-2.4.1 *Passing over Different Levels and Grooves*

Vertical level changes up to 6 mm may not need edge treatment. Changes in level between 6 mm and 12 mm shall be levelled off with a slope no greater than 1:2. The edge shall be rounded off or bevelled.

B-2.4.2 *Gratings and Manholes*

Gratings and manholes should be avoided on walkways/ pathways. If unavoidable, gratings shall have spaces not greater than 12 mm wide in one direction to prevent a wheelchair from getting its casters caught in a drainage ditch or grating cover. Also, the grating bars shall be perpendicular to the travel path in such a way that its longer dimension is perpendicular to the dominant direction of movement. Grating shall be flushed with finished ground level and shall be treated with a non-slip finish (*see* Fig. 30).

B-2.5 Tactile Ground Surface Indicators (TGSI) — Tactile Guiding and Warning Blocks

Tactile ground surface indicators or tactile guiding and warning tiles/blocks aid blind and vision impaired pedestrians negotiate the built environment, and shall be of the dimensions as given in Fig. 31.

NOTE — Alternatively, other internationally accepted tactile pattern may be accepted by the Authority.

B-2.5.1 Tactile guiding blocks indicate a correct path/ route to follow for a person with visual impairment. It is recommended to install one/two rows of tactile guiding blocks along the entire length of the proposed accessible route. Care shall be taken to ensure that there are no obstacles, such as trees, poles or uneven surfaces, along the route traversed by the guiding blocks. Also, there shall be clear headroom of at least 2 100 mm height above the tactile guiding blocks, free of protruding objects such as overhanging tree branches and signage, along the entire length of the walk.

B-2.5.2 Tactile warning blocks indicate an

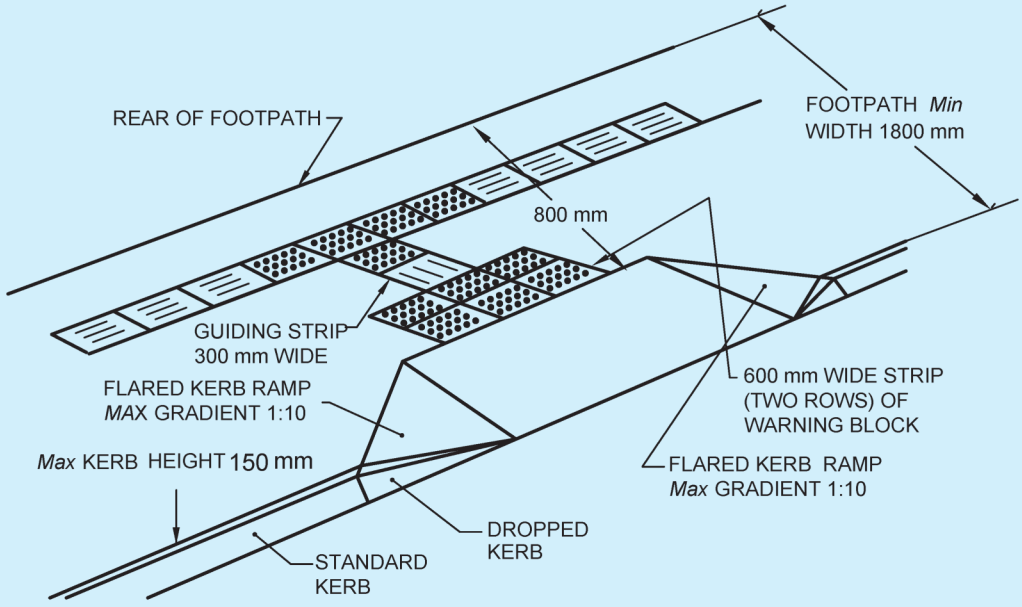


FIG. 29 KERB EXTENSION AT STREET INTERSECTION

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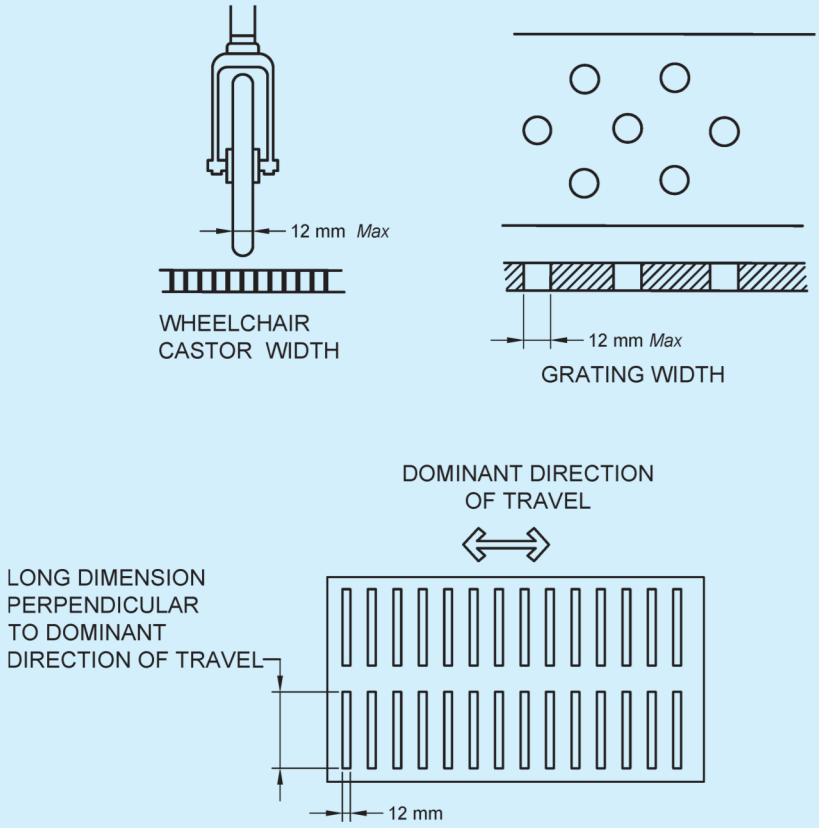
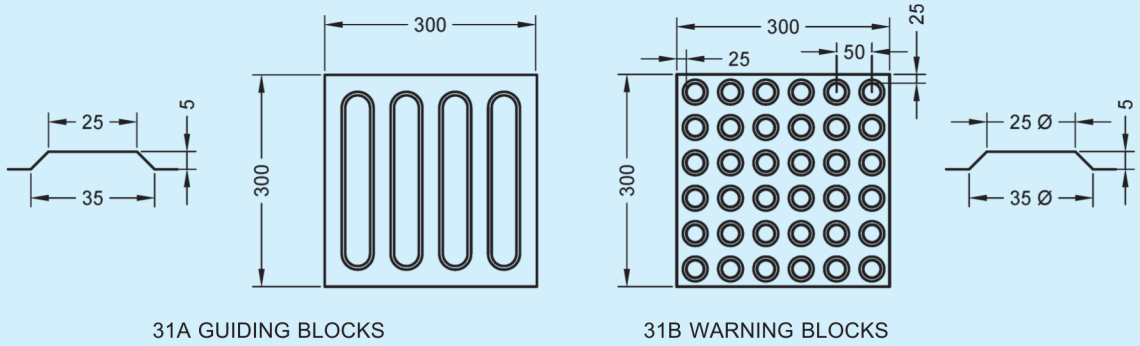


FIG. 30 INSTALLATION OF GRATING



All dimensions in millimetres.

FIG. 31 TACTILE GROUND SURFACE INDICATORS (TGSI)

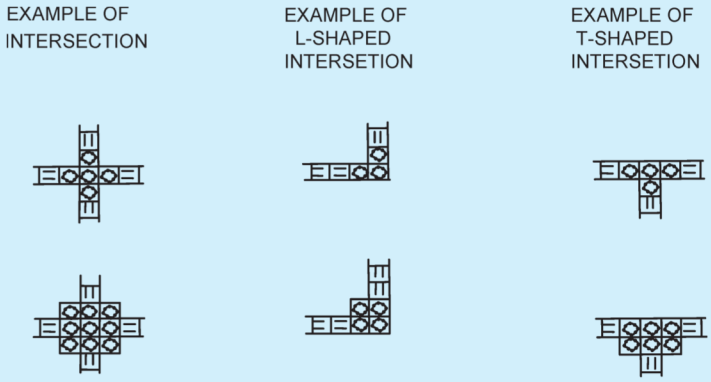
approaching potential hazard or a change in direction of the walkway, and serve as a warning of the approaching danger to persons with visual impairments, preparing them to tread cautiously and expect obstacles along the travel path, traffic intersections, doorways, etc. They are used to screen off obstacles, drop-offs or other hazards, to discourage movement in an incorrect direction, and to warn of a corner or junction. Two rows of tactile warning tiles shall be installed across the entire width of the designated accessible pathway, before intersections, building entrances, level changes, obstacles such as trees, and each time the walkway changes direction. Warning blocks shall be placed 300 mm from the beginning and end of the ramps and stairs, at landings and entrance to any door.

B-2.5.3 *Places to Install TGSI* (*see* Fig. 32 *and* Fig. 33)

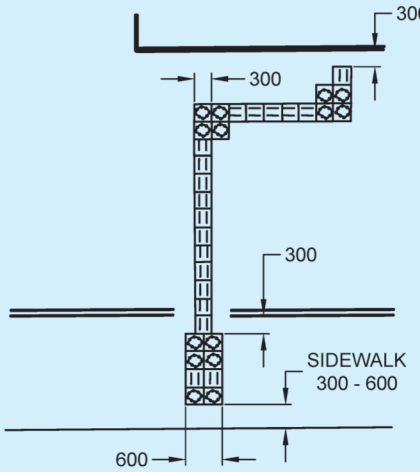
TGSI shall be installed at following places:

a) In open space to orient persons with vision impairment;
b) In front of an area where traffic is present;
c) In front of an entrance/exit to and from a ramp, staircase or multi-level crossing facility;
d) Entrances/exits at public transport terminals

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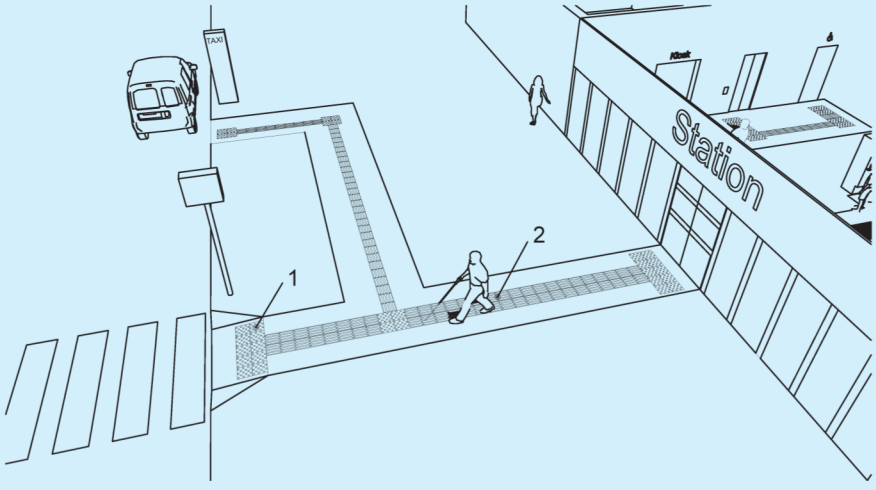
32A ARRANGEMENT OF GUIDING BLOCKS FOR PERSONS WITH VISUAL IMPAIRMENT



All dimensions in millimetres.

32B GUIDING PATH AND APPROACHING SIDEWALK TO THE BUILDING

FIG. 32 INSTALLATION OF TGSI



Key

1 Tactile ground surface indicator as attention pattern for decision points or hazards

2 Tactile ground surface indicator as guiding pattern

FIG. 33 EXAMPLE OF TACTILE GROUND SURFACE INDICATORS USED IN OPEN AREAS

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or boarding areas;

e) Sidewalk/footpath section of an approach road to a building; and

f) From a public facility to the nearest public transport station.

B-2.6 Barriers and Hazards

B-2.6.1 Obstacles, such as objects or signs mounted on walls, columns or free-standing supports along the walking path shall be avoided. Unavoidable free standing posts or columns within access routes on pathways shall leave at least unobstructed walking width of 1 000 mm and be clearly marked with visual indicators. Visual indicators at least 75 mm in height with a minimum visual contrast of 30 points difference in the LRV value of the colours to the background shall be placed; one at a height between 800 mm and 1 000 mm above floor level, and the other between 1 400 mm and 1 600 mm above floor level.

Bollards, short vertical posts generally arranged in a line to guide traffic and protect from vehicle intrusions, shall have a maximum height of 1 000 mm. Bollards, where installed within the access route shall have a minimum clear spacing between them of 1 000 mm so as to provide clear passage width for movement of wheelchairs.

B-2.6.2 *Protruding Objects*

Unavoidable protruding objects shall not reduce the minimum clear width of an accessible route or manoeuvring space. Protruding objects in the access route shall contrast visually with the background environment.

Objects with a height lower than 1 000 mm can create a hazard for blind or partially sighted people. Permanent equipment that cannot be located outside the boundaries of a path shall be,

a) designed to be easily seen with a minimum difference in LRVs of 30 points to the background;

b) shielded to protect against impact; and

c) accompanied by a feature that warns of the presence of a potential hazard and is detectable for a person using a white cane or stick (*see* Fig. 34).

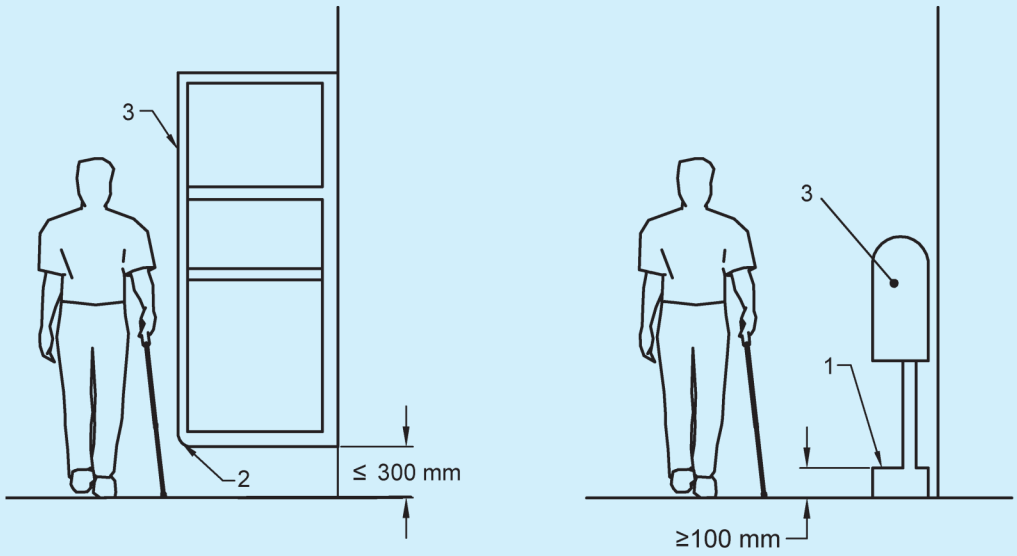
The headroom along a path shall be maintained at a height of not less than 2 100 mm above the surface of the path.

Any objects projecting more than 100 mm between 300 mm and 2 100 mm above ground level into an access route shall be clearly visible and detectable with a cane (*see* Fig. 34).

When a projecting obstacle exists, a protective guard shall be provided at ground level, under the projecting object, such as, a kerb or fixed element at a height of 100 mm-300 mm as cane detection. Cane detection shall not be set back more than 100 mm from the face of the projecting object. Wing walls, side partitions, alcoves or recesses are solutions for projecting elements where free space under the object is needed. Winged protection shall extend continuously between 300 mm and 1 000 mm above the floor and shall contrast visually with the background.

B-2.6.3 *Headroom*

Where headroom is less than 2 100 mm from the



Key

1 Base plinth detectable with cane if a projecting object is more than 100 mm above floor level

2 Winged protection between 300 mm and 1 000 mm above floor level, contrasting visually with the background and detectable with a cane

3 Difference in light reflectance value to background – minimum 30 points

FIG. 34 SOLITARY OBSTACLES

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finished floor level, a warning guardrail or other suitable barrier shall be provided for detection, having its leading edge at or below 680 mm above the finished floor level, such as to enable easy detection with a white cane (*see* Fig. 35).

B-2.6.4 *Identification*

Appropriate identification of specific facilities within a building used by the public is particularly essential to the persons with visual impairments. Raised letters or numbers shall be used to identify rooms or offices. Such identification shall be placed on the wall, to the left of the door, preferably at a height of 1 500 mm from the floor and comply with the requirements given in **B-24**.

B-2.6.5 *Warning Signals*

Following requirements with respect to warning signals near barriers shall be complied with:

a) Audible warning signals shall be accompanied by simultaneous visual signals for the benefit of those with hearing disabilities.

b) Visual signals shall be accompanied by simultaneous audible signals for the benefit of the blind and visually impaired people. To assist blind people, lettering and symbols on signs should be raised for tactile reading.

c) Information based on colour codes only should be avoided; colour blind people may find them difficult to understand.

d) Signs should be designed, located and illuminated as per **B-24**.

B-2.6.6 *Hazards*

B-2.6.6.1 Where hazards on the direct line of pedestrian travel such as stairs, escalators and moving walks or ramps with a slope of more than 1:16 cannot be avoided, tactile warning indicators and visual markings shall be provided. Every effort shall be exercized to obviate hazards to persons with disabilities.

B-2.6.6.2 Access panels in walls or manholes in walks, may be extremely hazardous, particularly when in use/ open, and shall be avoided. When manholes or access panels are open and in use, or when an open excavation exists on a site, particularly when it is in proximity of normal pedestrian traffic, barricades shall be placed on all open sides, and warning devices shall be installed.

B-2.7 Lighting for Walkways

Lighting for walkways shall be as given below:

a) Lighting should illuminate the walkway; lighting fixtures not exceeding a height of 4 m from ground level should be provided.

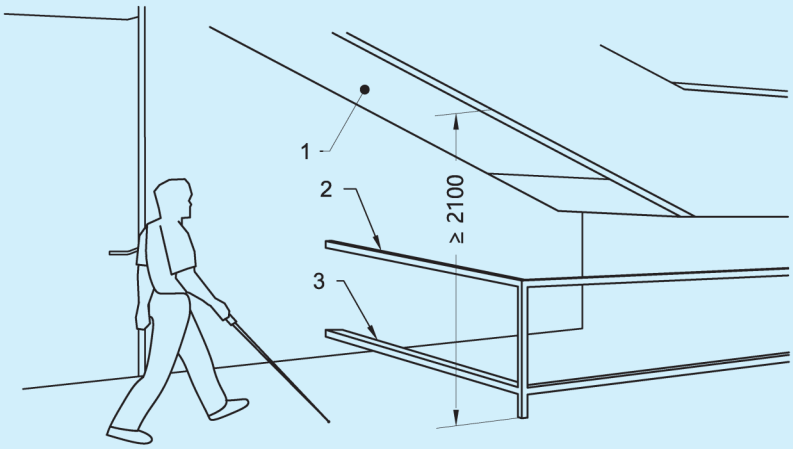
b) Lighting shall be provided every 20 m to 30m, focusing light not on the car lanes, but on the walkways.

c) A white light source, for example high-pressure sodium, is preferable in city and town centres for the aesthetic effect and for better colour definition, which benefits those with poor sight.

d) White lighting at average 35 to 40 lux is recommended to ensure colour contrast of tactile blocks and to ensure visibility at night to persons with low vision.

e) Light pole may preferably be located within the tree-planting zone.

f) Lower level light poles are preferred to avoid shadow where there are high trees.



Key
1 Minimum 2100 mm clear height
2 Guardrail against impact, at a height 680 - 700 mm above floor
3 Guardrail detectable with cane, at a maximum height 300 mm above floor

All dimensions in millimetres.

FIG. 35 WARNING GUARDRAIL IN CASE OF INSUFFICIENT HEADROOM

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B-3 DESIGNATED ACCESSIBLE PARKING SPACE

B-3.1 Location of Parking

The designated accessible parking spaces that serve a building shall be located as near as possible to the main entrance, and the distance from the accessible parking space to the main entrance shall not be more than 30 m. In case the access is through lift, the parking shall be located within 30 m of the lift lobby. Kerb ramp from parking space to an adjacent higher pedestrian path shall be provided in accordance with **B-3.6**.

Where indoor parking is provided, a suitable passenger lift or separated pedestrian ramp shall be installed to provide access from the parked vehicle to the principal entrance of the building or buildings served by the car parking.

B-3.2 Number of Designated Accessible Parking Spaces

The following minimum requirements concerning the number of parking places shall apply:

a) A minimum of one accessible designated parking space shall be provided in every parking area;
b) For up to 10 parking spaces, one designated accessible parking space shall be provided;
c) For up to 25 parking spaces, two designated accessible parking space shall be provided;
d) For up to 50 parking spaces, three designated accessible parking spaces shall be provided;
e) For up to 100 parking spaces, four designated accessible parking spaces shall be provided;
f) For up to 200 parking spaces, six designated accessible parking spaces shall be provided; and
g) For over 200 parking spaces, six designated accessible parking spaces for 200 parking spaces and one for each additional 100 parking spaces shall be provided.

In specialized facilities such as health care facilities, shopping areas and recreational facilities, a greater number of designated accessible parking spaces should be considered.

B-3.3 Signage for Parking

Signage for designated accessible parking spaces shall meet the following requirements:

a) International symbol of accessibility shall be displayed at approaches and entrances to car parking to indicate the provision of accessible parking lot for persons with disabilities within the vicinity.
b) Directional signs consisting of arrows combined with the international symbol of accessibility shall be placed along the route leading to the accessible parking lot (*see* Fig. 36).



FIG. 36 DIRECTIONAL SIGNAGE LEADING TO DESIGNATED ACCESSIBLE PARKING SPACES

c) Directional signs shall also be displayed to direct persons with disabilities to the accessible parking lot at points where there is a change of direction, or where the location of the accessible parking lot is not obvious or is distant from the approach viewpoints.
d) Accessible parking lot shall be identifiable by the International Symbol of Accessibility placed vertically. The signs shall not be obscured by a vehicle parked in the designated lot.
e) A vertical sign shall be provided, and to make it easily visible, the sign shall be at a minimum height of 2 100 mm. This height is to ensure that the sign does not get hidden behind large vehicles in the parking (*see* Fig. 37).

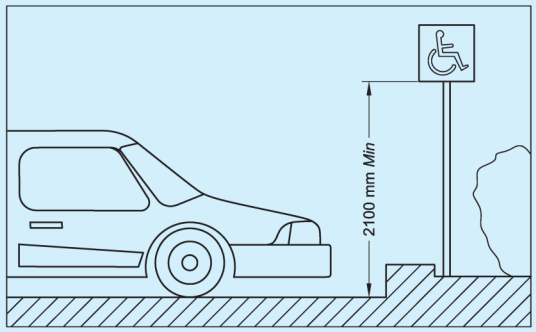


FIG. 37 VERTICAL SIGN AT DESIGNATED ACCESSIBLE PARKING SPACES

f) International symbol of accessibility shall be clearly marked/painted on the floor surface of the designated accessible parking lot for

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drivers/riders with disabilities only. The symbol painted on the designated lot shall comply the following:

1) A square with dimensions of at least 1 000 mm but not exceeding 1 500 mm in length;
2) Located at the centre of the parking lot; and
3) Colour of the symbol shall be in contrasting colour scheme of blue and white (*see* **B-24.2.16** and Fig. 105).

B-3.4 Car Park Entrance and Parking Controls

The car park entrance shall have a height clearance of at least 2 600 mm.

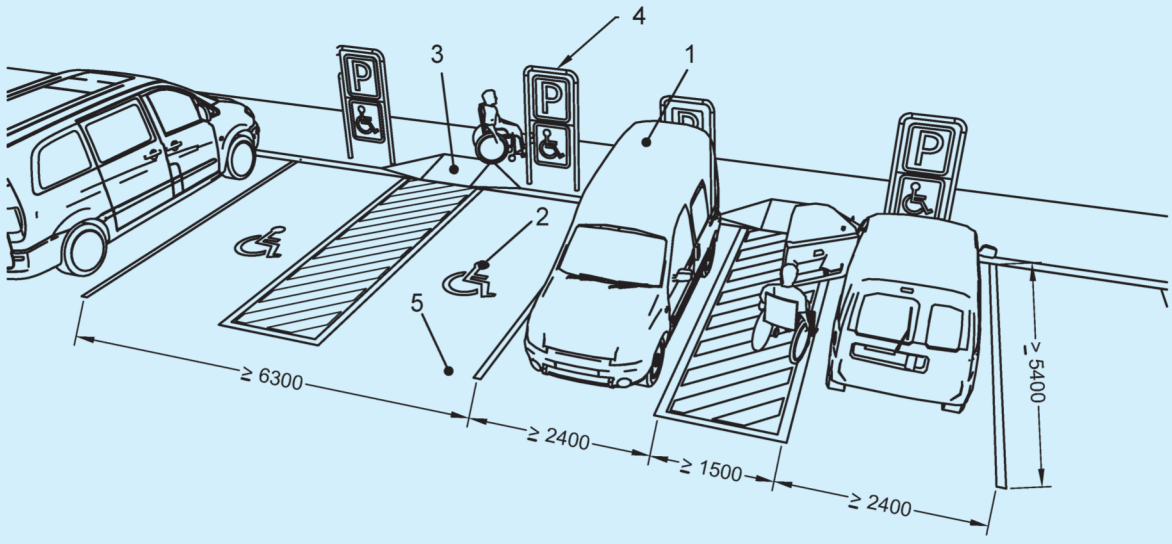
If payment machine is provided, it shall provide all control at the height between 800 mm and 1 000 mm (*see* **B-7**).

Access to the machine shall be level along an accessible route and easy to operate. The machine shall be located so that it does not create a hazard or barrier for persons with disabilities.

B-3.5 Accessible Car Parking Space Dimensions and Surface Requirements

The accessible car parking space shall meet the following requirements:

a) The minimum width of the parking space for a car shall be 3 900 mm and the minimum length shall be 5 400 mm. This minimum width includes the transfer area beside the car with a minimum of 1 500 mm.
b) Two accessible parking spaces with one shared transfer area are widely used and shall have a minimum width of 6 300 mm (*see* Fig. 38).
c) It shall have a firm, level surface without aeration slabs.
d) Wherever possible, it shall be sheltered.
e) The transfer zones, both on the side and the rear should have yellow or white cross-hatch road markings (*see also* Fig. 38).
f) The designated accessible parking spaces shall be located on a gradient not greater than 1:50, throughout its length and its width.
g) The accessible route of 1 200 mm width shall be provided for wheelchair users to pass behind vehicle that may be backing out (*see* Fig. 39).
h) *Parking space along the footpath/sidewalk* — For road side parking of an accessible van, the minimum dimensions shall be 9 000 mm × 2 400 mm with a kerb to access the nearest footpath/sidewalk (*see* Fig. 40).
j) *Van parking with auxiliary movable ramps* — The size and design of accessible vehicles may



Key
1 Minimum unobstructed height for vans 2 600 mm
2 Symbol of accessibility
3 Kerb ramp
4 Signage, including symbol of accessibility
5 Firm ground

All dimensions in millimetres.

FIG. 38 ACCESSIBLE PARKING SPACES ACCESSIBLE PARKING SPACES WITH ONE SHARED TRANSFER AREA

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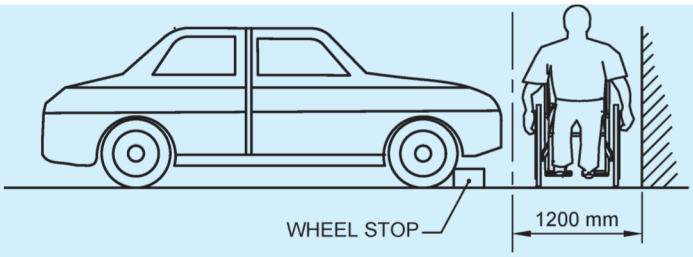
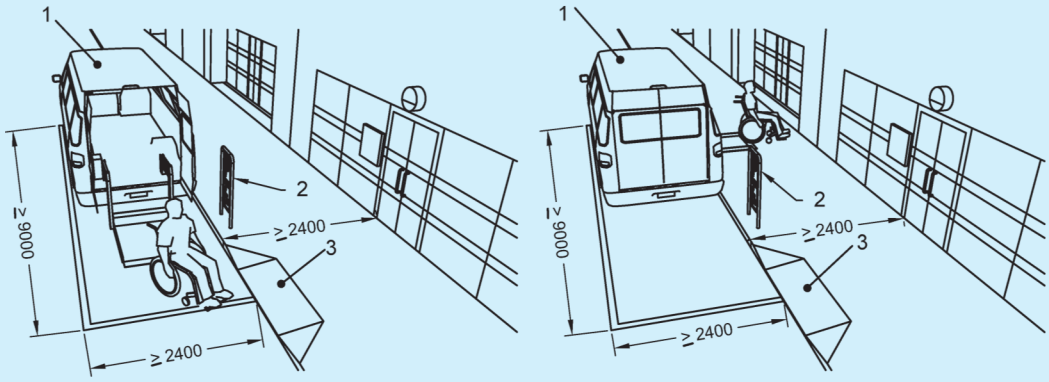


FIG. 39 ACCESSIBLE ROUTE WIDTH FOR WHEELCHAIR USERS TO PASS BEHIND A PARKED VEHICLE



Key

1 Minimum unobstructed height — 2 600 mm
2 Signage, including symbol of accessibility
3 Kerb ramp

All dimensions in millimetres.

FIG. 40 PARKING SPACE ALONG A FOOTPATH/SIDEWALK

vary as some are fitted with ramps or hoists at the side or at the rear. The minimum width of the accessible parking space for a van shall have at least the same dimensions as for car parking spaces (*see* Fig. 37). Transfer areas between spaces may be shared.

For multi-purpose vehicles with hoists or lifts, more space is needed; at least an additional 2 400 mm area beside the van and/or at the rear of the van may be required. The dedicated parking space in this case shall be 4 800 mm wide and 9 000 mm long (*see* Fig. 38 and Fig. 40 for different types of designated parking spaces).

As an alternative, a parking space of 2 400 mm wide × 9 000 mm in length along a footpath may be used, provided the footpath is at least 2 400 mm wide as shown in Fig. 39.

B-3.6 Kerb Ramp from Parking Space to an Adjacent Higher Pedestrian Path

The kerb ramp should be located in close proximity to the designated accessible parking area connecting the accessible path of travel to the main entrance. The kerb ramp width should be a minimum of 1 000 mm. The gradient of the kerb ramp should consider the requirements in **B-2.3**. Kerb ramps shall have a slip-resistant surface. The accessible path to the kerb ramp can be marked with hatching painted on the road surface to prevent people from parking in this area (*see* Fig. 38).

B-4 APPROACH TO THE BUILDING

The entry to the building shall be facilitated by the following:

a) Space should be provided for passenger drop-off points for taxis, public transport and also for large vehicles such as vans, etc, as near as possible to the main accessible entrance. Vehicle drop-off areas should be a minimum of 9 000 mm in length, have a minimum width of 3 600 mm and be served by a kerb ramp.

b) At least one accessible route leading to an accessible entrance of the building shall be provided from the alighting and boarding point of taxi stands and car park lots (*see* **B-3**) for people with disabilities.

c) If there is a difference in level between the carriageway and the footpath, a kerb ramp conforming to **B-2.3** shall be provided to facilitate the setting-down of people close to

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the main entrance of a building. This benefits people who need to transfer to and from a wheelchair and others.

An appropriate tactile ground surface indicator (TGSI) should be provided to lead vision impaired persons to the main entrance where no other clues indicate the path to the building.

d) Building shall have all accessible entrance doors complying with **B-5.3**.

e) The accessible entrance, if different from the main entrance, shall be located adjacent to the main entrance and not at the rear of the building. The accessible entrance shall be clearly signed and easy to locate.

f) Symbol shall be displayed at all other non-accessible entrances to direct persons with disabilities to the accessible entrance.

B-5 ACCESS AT ENTRANCE AND WITHIN THE BUILDING

B-5.1 General Requirements

a) Access to the building entrance shall be in accordance with **B-4**.

b) A clear, firm and level landing of at least 1 800 mm × 1 800 mm shall be provided on either side of the entrance door.

c) The width of the accessible entrance door shall not be less than 900 mm and the width of the corridors or passageways leading to and from such access door shall not be less than 1 200 mm.

d) In multi-storey buildings, the accessible entrance shall have an accessible route leading to the lifts.

e) Internal floor surfaces shall be of materials that do not impede the movement of wheelchairs. If mat is provided it shall be in level with the floor finish.

f) Persons with visual impairments find it easier to locate doors if there is a texture difference in the floor around the doorway from the rest of the flooring. It is generally good practice to recess foot mats in the floor on either side of the door but care shall be taken to ensure that the top end of the mats are flush with the rest of the flooring.

g) In addition to the tactile pavers (TGSI) leading to the main entrances, beepers may be put at all main entrances to enable people with visual impairments to locate them.

h) Tactile layout plan of the building should be provided at the entrance for people with visual impairments.

j) Glazed entrance doors shall have manifestations on the glass as per **B-5.3.13**.

B-5.2 Internal Corridors and Accessible Routes

B-5.2.1 *General*

The main horizontal circulation design shall be level on each floor in order to ensure that the building is accessible to all people. Horizontal circulation shall be without steps. Where differences in level cannot be avoided, ramps or lifts shall be provided in accordance with **B-6**.

Buildings should be designed, constructed and managed so that the internal layout is accessible and easily understood. All aspects of horizontal circulation, including corridors, should be designed to facilitate ease of movement for all people.

In order to avoid a tripping hazard (especially during a fire evacuation), where a raised threshold is necessary at a door opening, its maximum height shall be 12 mm, and those exceeding 5 mm shall be bevelled, and shall have a minimum difference in LRV of 30 points compared to the floor.

Routes should preferably intersect at right angles to each other and be easy to follow. To facilitate people with visual impairments, routes should have detectable cues and different visual contrast from the surroundings. For orientation and wayfinding in very complex buildings and across large areas, guidance may be provided by tactile ground surface indicators and visual, audible and tactile information, including egress and evacuation.

NOTE — Handrails can provide support for people with impaired mobility, guidance for people who are blind or have impaired vision, and can also support Braille information or tactile information.

B-5.2.2 *Internal Passages*

Intensity in use of the corridor shall be a criterion when establishing the minimum width and length of the corridor (*see* Fig. 41). The minimum unobstructed width of corridors shall be 1 500 mm, with a preference for a width of 1 800 mm.

Where less than 1 800 mm wide, a corridor shall be provided with passing places, 1 800 mm wide and at least 1 800 mm in length at reasonable intervals. These dimensions shall be exclusive of handrails and any other projections, for example portable fire extinguishers, notice boards, etc.

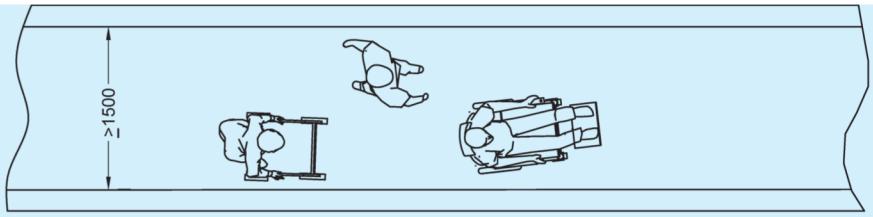
Adequate circulation space, where a doorway exists, shall be provided (*see* **B-5.3**).

Changes of direction within a corridor shall have a turning circle with a diameter of 1 500 mm or more, clear of any obstructions (*see* Fig. 42).

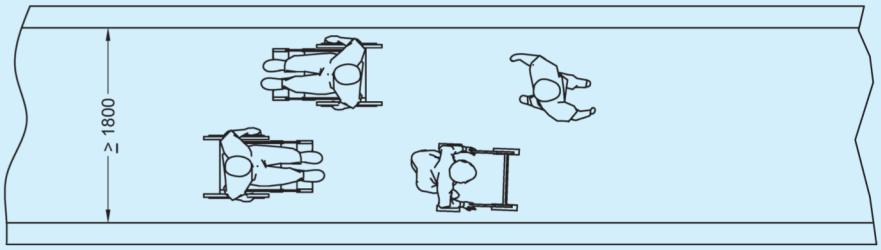
The minimum clear height of corridors shall be 2 100 mm.

Hanging objects on walls should be avoided, except when they comply with **B-2.6.2**. The minimum unobstructed width shall remain 900 mm.

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41A MINIMUM UNOBSTRUCTED WIDTH OF CORRIDOR



41B PREFERRED CORRIDOR WIDTH

All dimensions in millimetres.

FIG. 41 DIFFERENT CORRIDOR WIDTHS DETERMINED BY THE INTENSITY OF USE

B-5.2.3 *Turning Space for 90° Turn of a Wheelchair in Corridors*

The manoeuvring zone required for a wheelchair to make a 90° turn shall be designed according to Fig. 42.

It shall have no gradient, and it shall not be less than 1 500 mm wide and 1 500 mm long in the direction of travel.

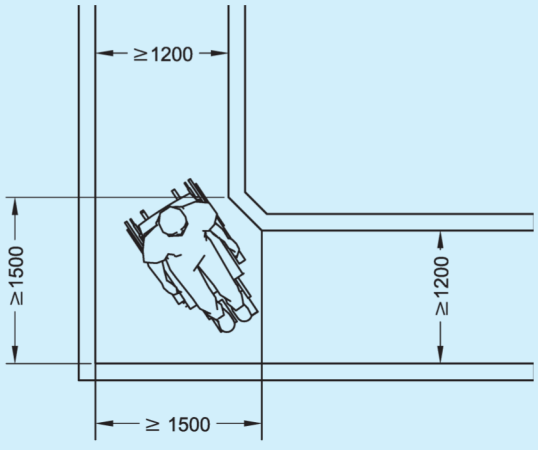
B-5.2.4 *Circulation Space for 180° Wheelchair Turn*

The space required for a wheelchair to make a 180° turn shall be not less than 2 000 mm in the direction of travel and not less than 1 800 mm wide.

For landing dimensions, *see* **B-6.2.6**.

B-5.2.5 *Resting Benches/Seats*

In long paths of travel resting areas shall be provided at frequent intervals not exceeding 30 m complying with **B-2.2.1** (g).



All dimensions in millimetres.

FIG. 42 SPACE REQUIRED FOR 90° TURN

B-5.2.6 *Protruding Object*

Obstacles, projections or other protrusions shall be avoided in corridors, passageways or aisles. Long paths of travel shall be avoided and resting areas shall be provided at frequent intervals not exceeding 30 m. For provision of unavoidable obstacles and protruding objects and protection therefrom, requirements given in **B-2.6** shall be followed.

B-5.2.7 *Floors in Corridors*

B-5.2.7.1 Floor surface shall be stable, firm, level and slip-resistant, preferably of matt finish and shall not have any projections, drops, or unexpected variation in level that may impede the easy access by persons with disabilities. Following requirements shall also be complied with:

a) Complex patterns shall be avoided.

b) Floor patterns that could be mistaken for steps, for examples stripes, shall not be used for floors in corridors.

c) Floors shall be levelled. If this is unavoidable, the slope of floors shall be no greater than 1:20. If greater slope is adopted, floor shall be designed as ramp.

B-5.2.7.2 For people with low vision, lines of brightly coloured fluorescent tape may be placed on the floor surface to assist mobility in poor lighted areas.

B-5.2.7.3 Carpeting should be avoided in circulation areas/accessible routes. In case, Where, carpets are used in circulations areas, they shall,

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a) not be deeper than 12 mm;
b) shall be securely fixed;
c) have firm cushion, pad or backing; and
d) exposed edges of carpets be fastened to floor surface and trimmed along the entire length of the exposed edge.

B-5.2.8 *Lighting in Corridors and Manoeuvring Zone*

Lighting in the corridor and manoeuvring zone shall be even, diffused and without glare, reflections or shadows. Minimum illumination level at the corridor and manoeuvring zone shall be 100 lux.

B-5.2.9 *Doors Leading into Corridors*

Doors shall conform to **B-5.3** and shall not open outwards from rooms directly into a frequently used corridor, with the exception of doors to accessible toilets and service ducts. Where a door opens into an infrequently used corridor such as emergency exit, the corridor width shall allow a clear space of 900 mm within the corridor when the door is open. Such doors shall be located clear of any sloping floor surfaces in the corridor. Any door that opens towards a frequently used corridor should be located in a recess at least as deep as the width of the door leaf.

B-5.3 Doors

B-5.3.1 *General*

The doors shall meet the following general requirements:

a) Doorways shall be levelled.
b) Doorways shall be easy for people with vision impairment to locate and identify.
c) Wherever revolving doors or turnstiles are installed, they shall be supplemented with an alternate side-hung (swing type) door with 900 mm minimum clear opening width.
d) Bathroom (toilets/washroom) doors should swing out/should be two way opening type so that the person inside does not fall against the door and block it. In case there is not much space available, consideration should be given to the use of sliding or folding doors, which are easier to operate and require less wheelchair manoeuvring space.
e) Door should not be too heavy to operate and shall not require a force of more than 22 N to operate.
f) Automatic doors shall have a push button system to open them.
g) All external doors shall have warning blocks installed 300 m before the entrances for aid of visually impaired users.
h) The leading edge of any door that is likely to be held open, especially those which are opening into corridors or circulation areas, shall contrast visually with the remaining surfaces of the door and its surroundings on its both sides by a 25 mm wide high-contrast manifestation, to help identification by visually impaired people. The architrave/door frame shall also contrast visually with the wall surfaces surrounding the doorway.
j) Low-hanging door closers that remain within the opening of a doorway, when the door is open or that protrude hazardously into regular corridors or traffic ways when the door is closed, shall be avoided.
k) All glazed doors shall have a highly visible contrasting frame with manifestations in a contrasting colour complying with the requirements given in **B-5.3.13**. Colour should contrast with the background visible through the door, whether on the inside looking out or on the outside looking in.
m) Tactile warning should be provided at approach to automatic doors complying with **B-2.5**.
n) Automatic doors, where provided should have guard rails, power floor mats, push or kick plate, horizontal or vertical sensing device and the doors should remain fully open until area is cleared by user. Sliding automatic doors are safer than swinging automatic doors.
p) Doors which remain ajar are extremely hazardous for vision impaired people. Doors are best fully open or completely closed; therefore, where appropriate, automatic door closure devices should be considered.
q) Entrance shall be well illuminated with even lighting between entrance and reception area.
r) Door hardware shall comply with the requirements in **B-5.3.6**.

B-5.3.2 *Clear Width*

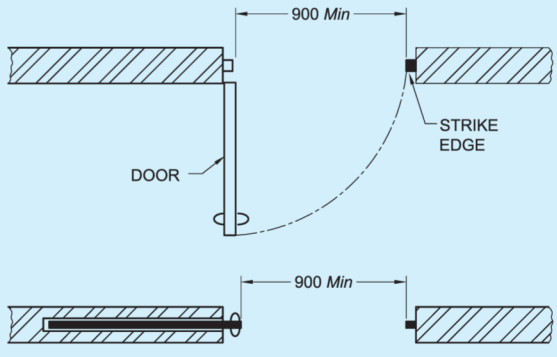
B-5.3.2.1 The minimum clear opening of doorways shall be 900 mm, measured between the face of the door and the face of the door stop with the door open at 90° as illustrated in Fig. 43.

B-5.3.2.2 In case, the door has two independently operated door leaves, at least one active leaf shall comply with **B-5.3.2.1**.

B-5.3.3 *Thresholds*

There shall be no thresholds (doorsills). If thresholds are unavoidable, they shall not exceed 12 mm and those exceeding 5 mm shall be bevelled and contrast visually

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All dimensions in millimetres.

FIG. 43 MINIMUM CLEAR OPENING OF DOORWAYS

with the adjacent floor. A minimum difference in LRV of 30 points compared to the floor shall be provided.

B-5.3.4 *Manoeuvring Space at Doors*

To enable wheelchair users to approach doors, manoeuvring space as given below shall be provided. In narrow spaces, sliding doors may be preferable.

A minimum distance of 600 mm shall be provided beyond the leading edge of door to enable a wheelchair user to manoeuvre and to reach the handle.

Wheelchair manoeuvring spaces shall be free of any obstructions and be provided on the side of the door handle in the following manner (*see also* Figs. 44 and 45):

a) On the pull side, a minimum space of 600 mm;

b) On the push side, a minimum space of 300 mm; and

c) For two-way swing door, a minimum space of 300 mm.

B-5.3.5 *Two Doors in Series*

The minimum space between two hinged or pivoted doors in series, shall be 1 500 mm plus the width of the door swinging into that space, as shown in Fig. 46.

B-5.3.6 *Door Hardware*

Operable devices such as handles, pulls, latches and locks shall meet the following requirements:

a) They shall be operable by one hand.

b) They shall not require fine finger control, tight grasping, pinching or twisting to operate.

c) They shall be mounted at a height of 850 mm to 1 100 mm from the floor (*see* Fig. 47).

d) For easy identification by persons with visual impairment, all door furniture shall contrast visually with the surface of the door;

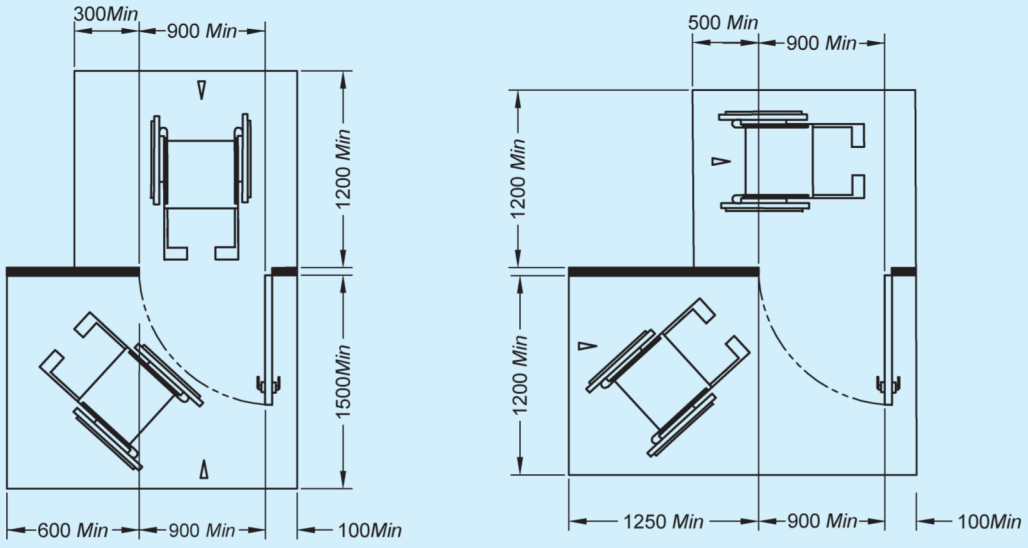
e) The location and design of latch and push/pull handles shall be consistent throughout a building.

f) To facilitate the closing of a door by wheelchair users (for example a water-closet compartment, that does not have a self-closing mechanism), the door shall have a horizontal handle, provided on the closing face of the door, approximately 760 mm from the floor.

B-5.3.7 *Door Handles*

The door handles shall conform to **B-7**. The following are recommended for door handles:

a) Push-pull mechanisms that require no grasping;



44A FRONT APPROACH

44B LATCH SIDE APPROACH

All dimensions in millimetres.

FIG. 44 MANOEUVRING SPACE NEEDED BY WHEELCHAIR USERS TO APPROACH DOORS

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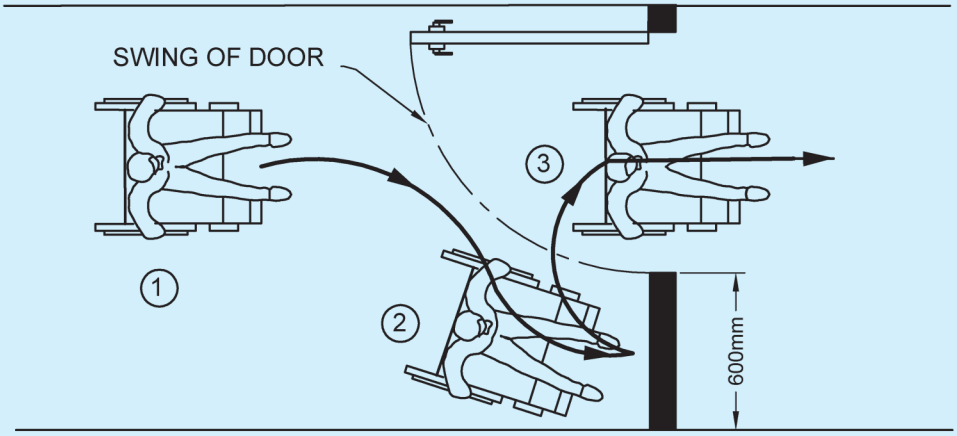
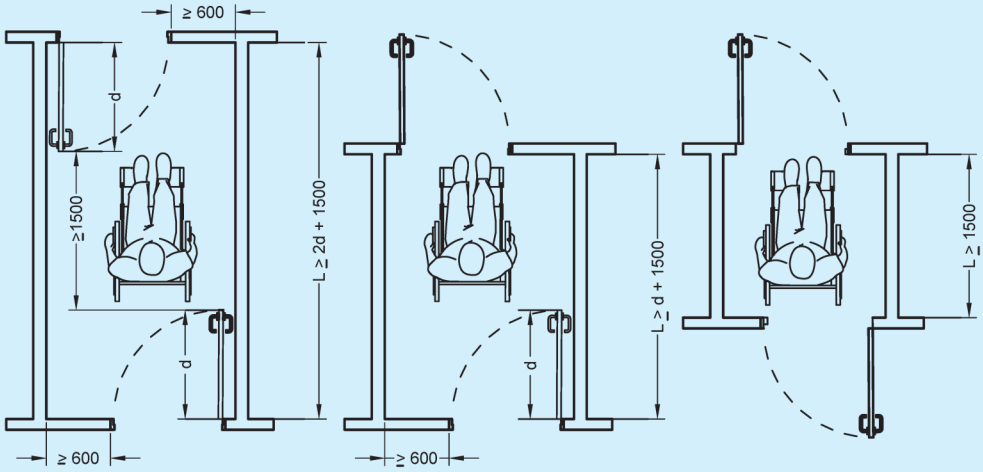
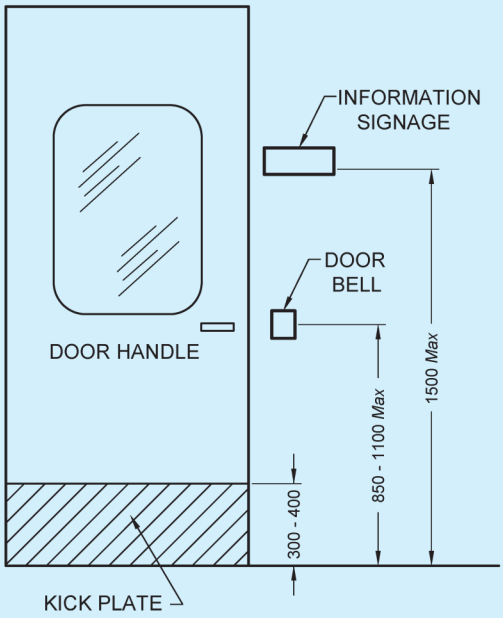


FIG. 45 POSITION TAKEN BY A WHEELCHAIR USER WHEN NEGOTIATING DOOR IN PASSAGE WAY



All dimensions in millimetres.

FIG.46 SPACE BETWEEN TWO HINGED OR PIVOTED DOORS IN SERIES



All dimensions in millimetres.

FIG. 47 DOOR HARDWARE LOCATION

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b) Lever handles to be preferred on latched doors;

c) It is safer to use D-shaped handles as they reduce the risk of catching on clothing, or injuring from the exposed lever end; and

d) Doorknob is not recommended, as it does not provide adequate grip for persons with impaired hand functions.

B-5.3.8 *Sliding/Folding Doors*

Operating hardware should be exposed and usable from both the sides when the door is fully open.

B-5.3.9 *Door Closure*

The sweep period of the door should be adjusted, so that from an open position of 90°, the door does not take less than 3 s to move to a semi-closed position.

B-5.3.10 *Vision Panel*

All two-way swing doors or doors in general circulation areas shall be provided with vision panels giving a visibility from a height of 800 mm to 1 500 mm (*see* Fig. 48). This will enable both the wheelchair user and the ambulatory disabled to be noticed by a person on the opposite side in order to prevent him/her from being accidentally struck by the door.

B-5.3.11 *Kick-Plate*

Kick-plates of not less than 300-400 mm height are recommended for doors in high-use in order to protect the push side of doors from damage (*see* Fig. 47 and Fig. 48).

B-5.3.12 *Door Identification*

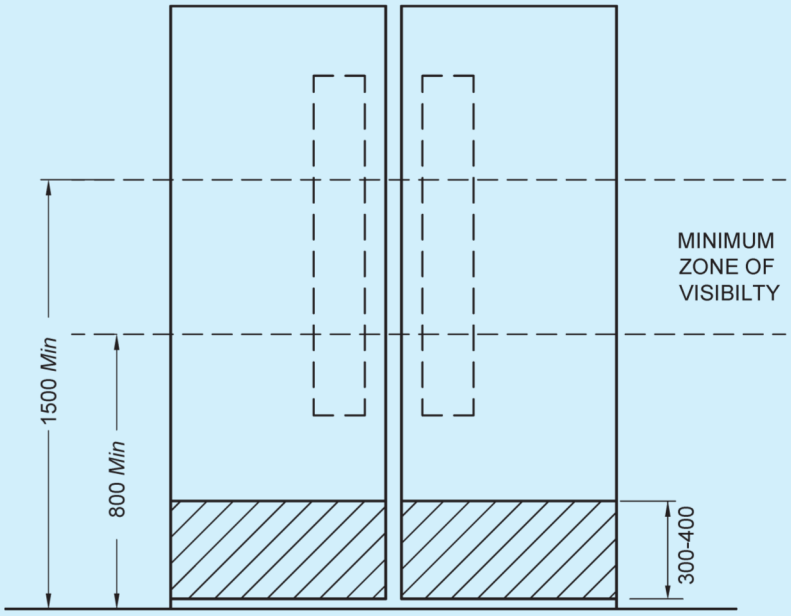
To help people with impaired sight to see doors, the door and frame should be in a colour which contrasts with the adjoining wall. The door shall not be of a highly polished/reflective material such as stainless steel.

B-5.3.13 *Glass Doors*

The presence of a glass door shall be made apparent, with permanent uninterrupted visual manifestation at two levels (hand and eye level), within 800 mm to 1 000 mm from the floor and within 1 400 mm to 1 600 mm from the floor, contrasting visually with the immediate background with a difference in LRV of 30 points seen through the glass in all light conditions (*see* Fig. 49). The width of the manifestation shall be minimum 75 mm. The edges of a glass door shall also be apparent when the door is open. An additional visual manifestation placed at a height of 100 mm to 300 mm is recommended (*see* Fig. 49). Visual manifestation consisting of two separate colours with a minimum difference in LRV of 60 points are recommended to enable lighting conditions and backgrounds to be taken into account.

If a glass door is adjacent to, or is incorporated within, a fully glazed wall, the door and wall shall be clearly differentiated from one another, with the door more prominent. To achieve this, the door may be framed on both sides and also on the top by an opaque high-contrast strip at least 25 mm wide.

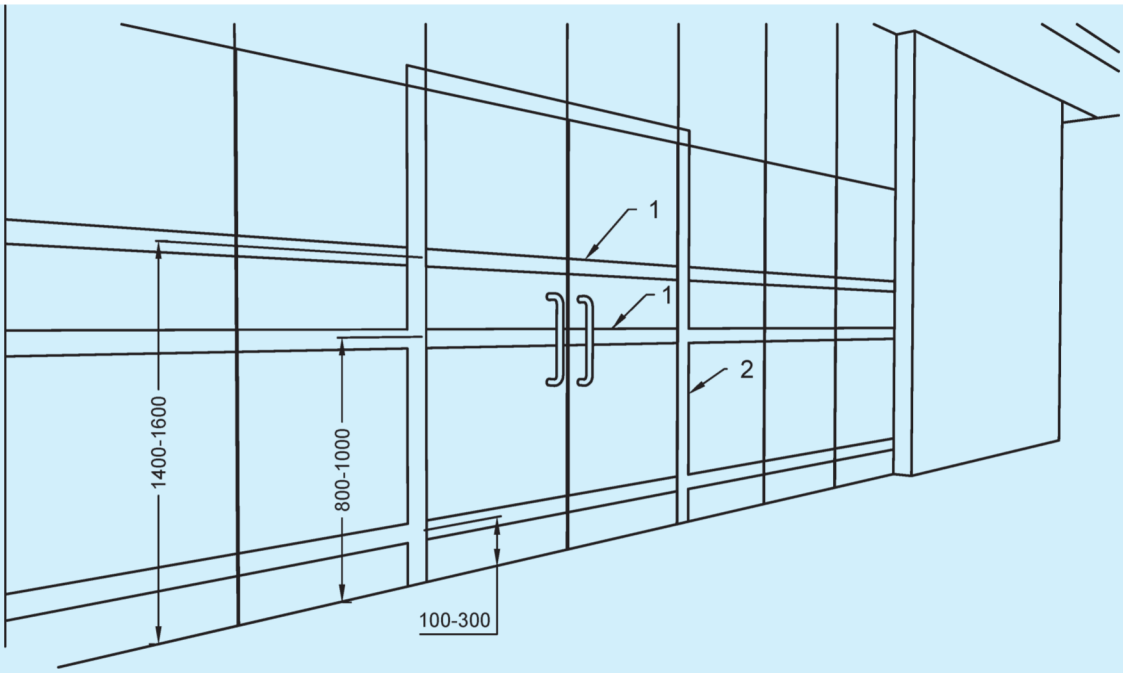
Glass that is silvered or highly reflective should be avoided and any free-standing edges of glazed screens should have a strip contrasting visually with the surroundings against which they are seen.



All dimensions in millimetres.

FIG. 48 VISION PANEL

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Key

1 Visual marking (manifestations), minimum width 75 mm, two separate colours with a minimum difference in LRV of 30 points

2 Visual marking on door frame, minimum width 50 mm

All dimensions in millimetres.

FIG. 49 PERMANENT MANIFESTATION ON GLASS DOOR

B-5.4 Windows

The windows shall meet the following general requirements (*see* Fig. 50):

a) Windows shall have handles/controls in accordance with **B-7** and **B-5.3.7**.

b) They shall provide an unobstructed viewing zone for wheelchair users between 600 mm and 1 400 mm.

c) Curtain or venetian blind controls/ropes shall be at 800-1 000 mm height from the finished floor level for wheelchair users/short stature persons.

B-5.5 Handrails and Grab Bars

B-5.5.1 *General*

Handrails/grab bars are extremely important features and shall be designed to be easy to grasp and to provide a firm and comfortable grip so that the hand can slide along the rail without obstruction. Many persons with disabilities rely upon handrails/grab bars to maintain balance or to prevent serious falls. Handrails are used as a locational and mobility aid by persons with visual impairments and as a support for persons with mobility impairments. The handrail/grab bars shall be securely fixed to the wall. To aid identification, the colour of the handrail/grab bar shall contrast with the wall behind.

B-5.5.2 *Specific Requirements for Handrail*

B-5.5.2.1 Handrails shall (*see also* Fig. 51),

a) be securely fixed and rigid; the fastenings and the materials shall be able to withstand a minimum point load, both vertical and horizontal of 1.7 kN;

b) be slip-resistant with round ends;

c) have a circular section of 38-45 mm in diameter;

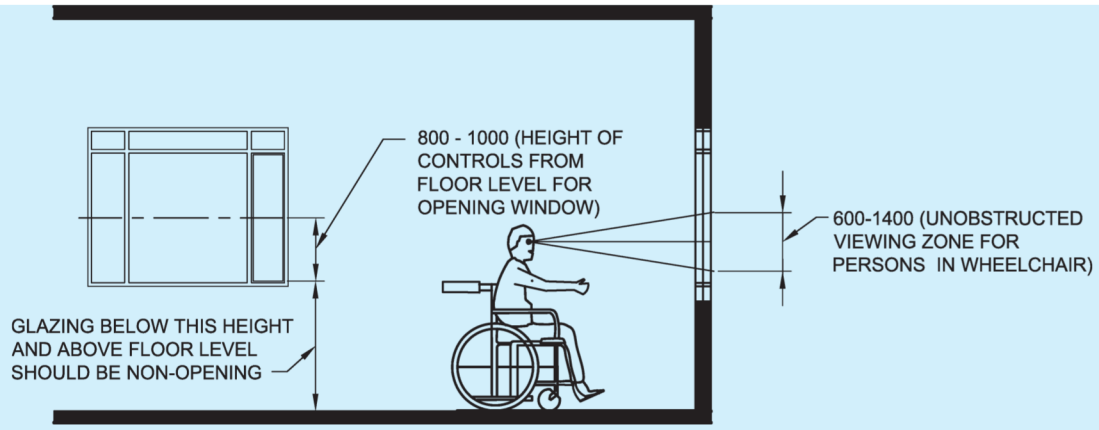
d) be free of any sharp or abrasive elements;

e) have continuous gripping surfaces, without interruptions or obstructions that may break a hand hold;

f) contrast with the wall behind; and

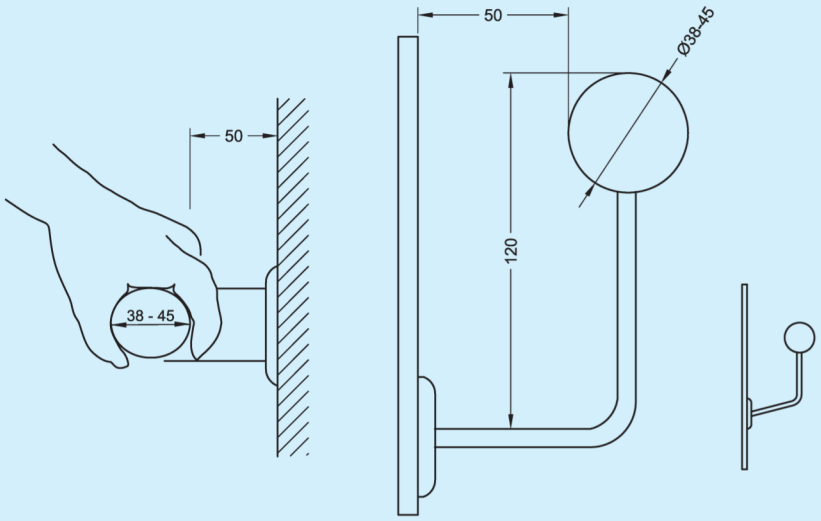
g) may be provided with Braille/tactile markings at the beginning and at the end to give information to people with visual impairment.

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All dimensions in millimetres.

FIG. 50 REQUIREMENTS FOR WINDOWS



All dimensions in millimetres.

FIG. 51 HANDRAILS

B-5.5.2.2 For stepped path, stairs and ramps, handrails shall meet the following requirements (*see* Figs. 52, 53 and 54):

a) They shall be provided on both the sides;
b) They shall be continuous, even at the landings;
c) They shall extend at least 300 mm beyond the first and last nosing. A handrail shall not project into a transverse circulation path unless it is continuous and intended to form part of the guidance along that path. The end of the horizontal extension should be turned towards the wall on the closed side of the ramp or stairs, or be turned down and terminate at the floor or ground level.
d) They shall have a minimum clear space of 50 mm from the walls; and
e) The height to the top of a handrail shall be between 850 mm and 950 mm above the surface of a ramp, the pitch line of a stair, and the surface of a landing. A second handrail, with a lower profile than the first one, shall be provided. The height to the top of the second handrail should be between 650 mm and 750 mm above the surface of a ramp, the pitch line of a stair, and the surface of a landing. There shall be sufficient distance between the two handrails (say, 200 mm).
f) In case the handrail is enclosed in a recess, the recess shall extend at least 450 mm above the top of the rail.

B-5.5.3 *Grab Bars*

Grab bars shall,

a) be securely fixed and rigid;
b) be slip-resistant with round ends;
c) Preferably have knurled surfaces;
d) have a circular section of 38-45 mm in diameter;

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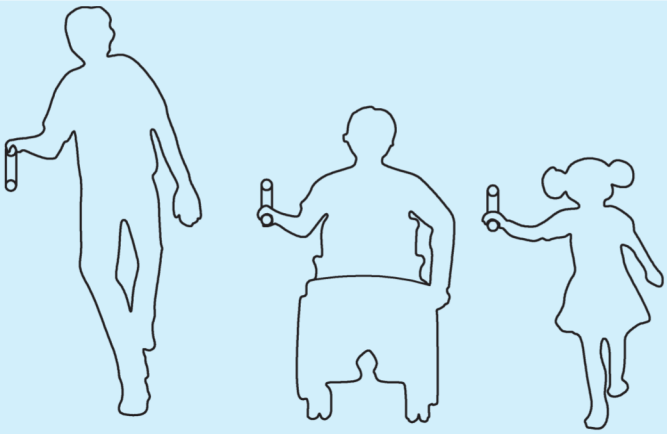
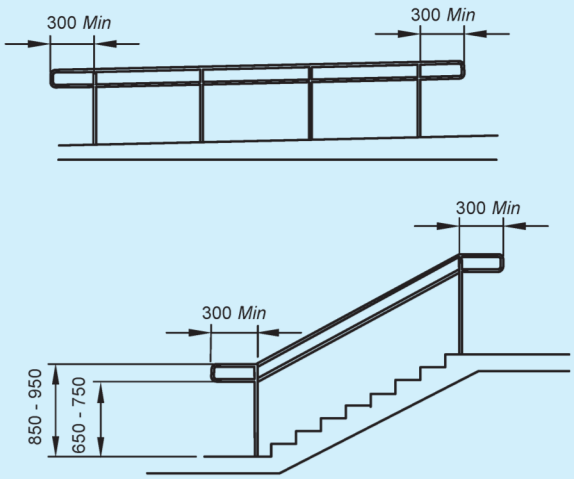
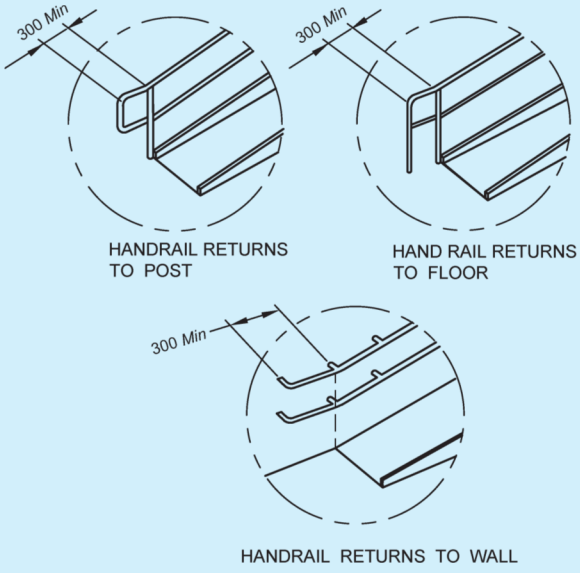


FIG. 52 HANDRAILS AT TWO LEVELS TO HELP CHILDREN AND PEOPLE WITH SHORT STATURE



All dimensions in millimetres.

FIG. 53 HANDRAILS FOR STEPS AND STAIRS



All dimensions in millimetres.

FIG. 54 TYPICAL HANDRAIL EXTENSIONS

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e) be free of any sharp or abrasive elements;
f) have a minimum clear space of 50 mm to 65 mm from the wall;
g) be installed at a height of 700 mm to 900 mm;
h) be able to bear a weight of 1.7 kN; and
j) contrast with the wall/surface behind.

B-6 LEVEL CHANGES

B-6.1 General

Vertical circulation and level changes shall be designed, constructed and managed so that they can easily be understood and used by all people. Vertical circulation includes the provision of ramps, stairs and lifts, as well as escalators, moving walks and lifting platforms.

B-6.2 Ramps

A ramp is a sloping pathway leading from one level to another. Ramps of an appropriate design shall be provided at all changes in level other than those served by an accessible lift or accessible lifting mechanism accommodating the specific requirements of persons with disabilities.

B-6.2.1 *General*

Ramps allow persons with reduced mobility to move from one level to another. However, many ambulant persons with disabilities negotiate steps more easily and safely. Hence it is preferable to provide accessibility by both steps and ramps.

Ramps shall meet the following general requirements:

a) Wherever the rise of a ramp exceeds 300 mm, an additional flight of steps shall also be provided as described in **B-6.3**, shall be provided for ambulant persons. An isolated single step is not acceptable hence; a ramp is preferred to a single step.
b) Where there is a large change in elevation that requires multiple ramps and landing combination, other solutions such as lifts should be considered.
c) Ramps should not ideally connect straight to doors as wheelchair users need a levelled platform at the end of the ramp to manoeuvre and negotiate opening the door.
d) A curved ramp is not a preferred design solution. Similarly, a cross fall may put a wheelchair user at risk and may adversely affect steering, particularly on manually propelled chair.
e) Shiny, polished surface materials that cause glare shall not be used for ramps.
f) Single row of tactile warning blocks (TGSI) shall be placed as per **B-2.5** at the beginning and end of each ramp. This shall be placed 300 mm before the beginning and end of each ramp run to indicate the level change to visually impaired persons.

B-6.2.2 *Gradient*

The gradient shall be constant between landings. The minimum specifications for ramp gradients addressing different level differences are given in Table 10 (*see also* Fig. 55).

B-6.2.3 *Width*

The minimum clear width of a ramp (exclusive of handrails) shall be 1 200 mm and shall increase correspondingly as the level difference addressed by the ramp increases as per Table 10.

B-6.2.4 *Surface*

Ramps and landing surfaces shall be non-glary, smooth, level, even and slip resistant even when wet. Outdoor ramps and their surface shall be designed to prevent water from accumulating on the walking surfaces. The surface finish shall be hard and suitable for the volume of traffic that the ramp is likely to experience.

B-6.2.5 Internal ramps should, if possible, be avoided. Where required, internal ramps shall be designed in accordance with the following additional criteria:

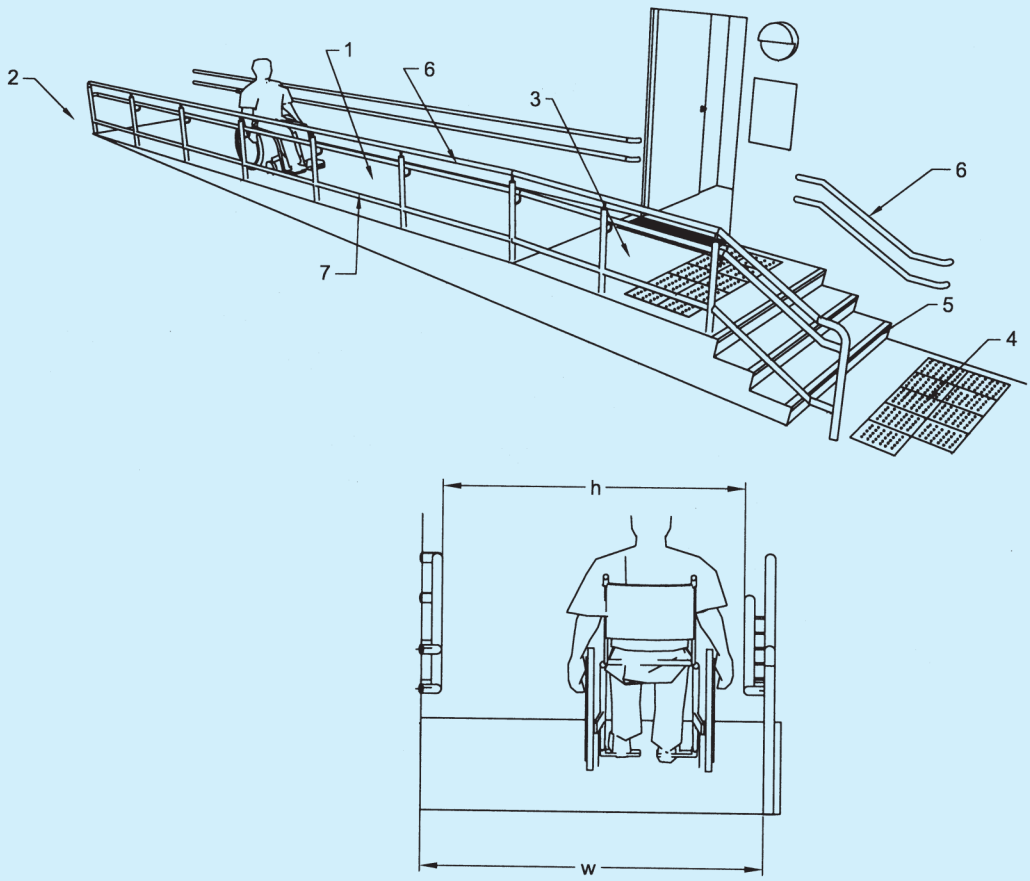
a) No series of ramps should rise more than 2 000 mm in total. If this is the case, an alternative should be provided, for example a lift.

Table 10 Requirements for Ramp

(*Clause* B-6.2.2)

Sl No.	Level Difference	Maximum Gradient of Ramp	Ramp Width mm	Handrail on Both Sides	Other Requirements
(1)	(2)	(3)	(4)	(5)	(6)
i)	150 mm to 300 mm	1:12	1 200	√	—
ii)	301 mm to 750 mm	1:12	1 500	√	Landings after every 5 m of ramp run
iii)	751 mm to 3 000mm	1:15	1 800	√	Landings after every 9 m of ramp run
iv)	More than 3 000 mm	1:20	1 800	√	Landings after every 9 m of ramp run

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Key
1 Ramp surface (*see* Table 10 for maximum slope and length)
2 Horizontal landing
3 Horizontal landing
4 Tactile ground surface indicator in front of stairs
5 Complementary stairs with markings
6 Handrails on both sides of ramp and stairs
7 Upstand, *Min* 150 mm
h Width between handrails
w Width of ramp surface

FIG. 55 EXAMPLES OF RAMP WITH SLOPE 1:20 AND HORIZONTAL LANDINGS AT BEGINNING AND END

b) An internal ramp should have the lowest practical gradient. In order to avoid trips and falls during a fire evacuation, a gradient of 1:15 should be the maximum permissible gradient within a building.

c) The minimum illumination at the top and bottom of the ramp should be 200 lux and 150 lux in between the bottom and top.

B-6.2.6 *Landings*

An end landing shall be provided at the bottom and the top of a sloped path, a stepped path, or a ramp and also where the run changes direction. The area of the end landing may be a part of the continuing path (*see* Fig. 56). The length of an end landing and an intermediate landing shall be not less than 1 500 mm. Where the ramp run changes direction, the minimum landing dimensions shall be 1 500 mm × 1 500 mm. The area of a landing shall be clear of any obstruction including the path of swing of a door or a gate.

Landings shall also be provided at regular intervals of not more than 9 000 mm of every horizontal run. It shall conform to other provisions of this annex if served by a doorway. If the end landing follows or precedes a turn for a pathway or an entrance, the minimum dimension of the landing shall be minimum 1 500 mm × 1 500 mm.

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The width of ramp and consequently the dimension of landing in the direction perpendicular to the direction of ramp shall also be governed by the provisions of Table 10.

B-6.2.7 *Handrails for Ramps*

A ramp run with a vertical rise greater than 150 mm shall have handrails that are on both the sides and comply with **B-5.5.2**.

B-6.2.8 *Edge Protection/Guarding Along Ramps*

Ramps and landings not adjacent to a wall should have an edge protection in form of a 75 mm kerb. Guarding along ramps in pathway shall also meet the requirements in **B-2.2.6**.

B-6.3 Stairs

B-6.3.1 *General*

Steps and staircases are intended as an alternative to lift access in buildings and shall be of adequate design to allow all persons, with or without a disability, to travel safely and independently.

Stairs shall not be the only means of moving between floors. They shall be supplemented by lifts (*see* **B-6.4**) and/or ramps (*see* **B-6.2**). Staircases shall comply with the following general requirements:

a) The materials selected for the surface finish of the stairs shall be firm and slip resistant, especially if surfaces are likely to become wet due to location or use, or if spillage occurs. Slippery surfaces like granite, glazed tiles shall be avoided.

b) Shiny, polished surface materials that cause glare shall not be used for stairs or ramps.

c) Risers, treads, maximum number of risers per flight and minimum width of stairs shall be in accordance with **12.18**.

d) The riser of a step shall not be open.

e) The stairs landing shall be minimum 1 500 mm deep (*see also* **B-6.2.6)**. In case of one or two family dwelling units, it may be reduced to 1 200 mm.

f) Steps shall be of a consistent height and depth throughout the staircase.

g) Projecting nosing and open stairs shall not be provided to minimize the risk of stumbling.

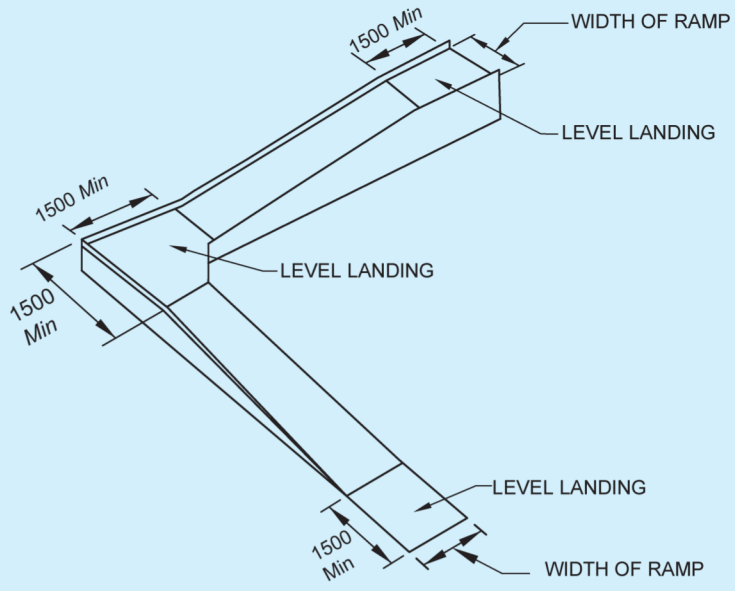
h) Spiral stairs shall be avoided.

j) Stairs shall have handrails comply with the requirements given in **B-5.5.2**.

B-6.3.2 *Tactile Warning Blocks (TGSI) for Stairs*

Tactile ground surface indicators (warning type) shall be installed 300 mm before the beginning and 300 mm after the end of each flight of steps to aid people with visual impairments. It shall be in accordance with **B-2.5**.

Tactile warning strips shall also be provided at landings. For landings leading to a floor or those enclosed by wall, railing or balustrade, tactile warning strips of 300 mm in width shall be provided; for those leading to an open space or the entrance/exit of a building, the tactile warning strips shall be 600 mm in width. In this case, Braille and tactile information signs shall be provided on the adjacent wall to indicate the presence



All dimensions in millimetres.

FIG. 56 LANDING DETAILS FOR RAMPS

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of an opening. For a staircase with intermediate steps between two flights, the provision of tactile warning strips shall follow the same arrangement.

B-6.3.3 *Avoidance of Projection in the Stairs*

No appliances, fixtures or fittings shall project beyond 90 mm from the surface of any wall in a staircase below a level of 2 000 mm, measured above the treads of the staircase. If such a projection is unavoidable, the same shall also be extended downwards to the level of the treads. However, in no case the width of the staircase shall be less than that prescribed in **12.18**.

B-6.3.4 *Colour Contrasting and Illumination*

There shall be colour contrast between landings, and the steps. Step edges shall contrast in colour to the risers and the treads. Contrast colour bands 50 mm wide shall be provided on edge of the tread. Illumination level of minimum 150 lux shall be maintained on the stairs.

B-6.3.5 *Soffit*

Soffit of the stairs, shall be cordoned off either by building a wall in front of it or by putting handrails to guide persons around the space. It shall comply with the requirements of **B-2.6.3** related to headroom in circulations spaces (*see also* Fig. 35).

B-6.4 Lifts

B-6.4.1 *General*

It is recommended that in multi-storeyed buildings there be at least one lift accessible to transport persons with disabilities at all usable levels. Such lifts shall meet the following general requirements:

a) Lift shall be located on accessible routes.

b) Accessible landings at lift entrance shall be provided on each eligible floors.

c) Lifts shall be marked with the international symbol of accessibility.

d) Directional signs indicating the location of an accessible lift shall be provided at a location that is clearly visible from the accessible building entrance. The directional signs shall incorporate a representation of the International symbol of accessibility (*see* Fig. 57).

e) A sign indicating the number of the floor arrived shall be provided on each lift landing on the wall opposite the lift in big fonts with good colour contrast.

f) It is recommended to install a floor directory of the main facilities and services available on the lift landing, along with an accessible emergency egress route that clearly indicates the location of the nearest refuge area for persons with disabilities.

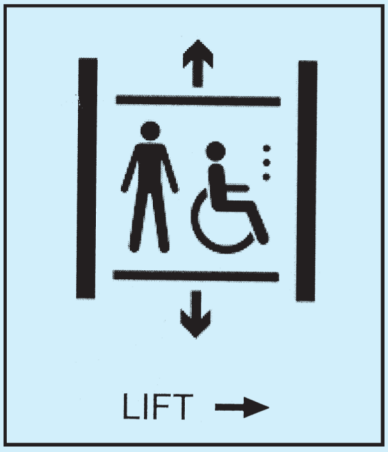


FIG. 57 WAY FINDING SIGNAGE FOR LIFT LOCATION

B-6.4.2 *Lift Size*

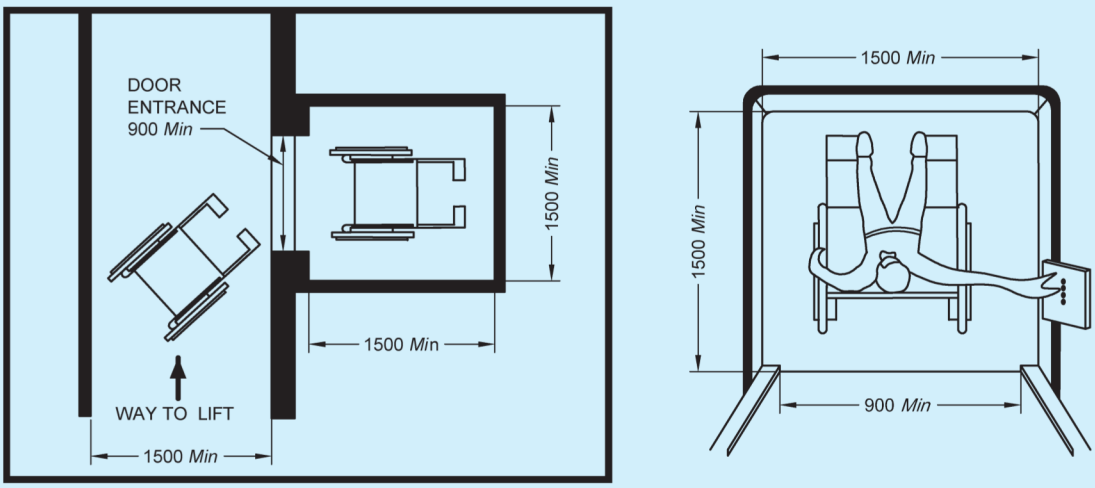
The minimum size of the lift shall be 1 500 mm wide by 1 500 mm deep, that allows easy manoeuvrability of wheelchair users (*see* Fig. 58).

B-6.4.3 *Lift Door*

The clear opening of entrance to the lift car shall be at least 900 mm. The doors shall be constructed as automatic horizontal sliding doors. The lift door shall be contrasting in colour from the adjoining wall. There shall be no difference in level between the lift door and the floor surface at each level. The gap between the lift door and building floor shall not be more than 12 mm.

A non-contact sensor device shall be provided in the door opening to detect an entering or exiting passenger or an assistive device and prevent the risk of the passenger or assistive device from being hit by the leading door panel(s). The sensor device shall cover at least 2/3 of the door height measured from a distance of 25 mm above the door sill. Time of closing of an automatic door shall be more than 5 s and the closing speed shall not exceed 0.25 m/s. The door opening time shall be adjustable to suit the conditions where the lift is installed. A mechanism to increase this time shall be installed to be customized by a user with mobility impairments (for example by means of a button outside the car to call the lift to the floor for it to arrive with extended door opening time, and a button marked with a wheelchair symbol inside the car with the same purpose). Under normal operation the levelling accuracy of the lift car shall be ±12 mm.

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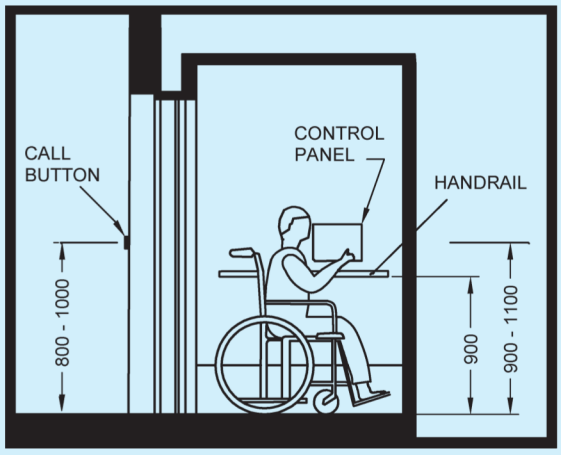


All dimensions in millimetres.

FIG. 58 LIFT SIZE

B-6.4.4 *Call Button*

The call button located outside the lift shall have a clear floor space of at least 900 mm × 1 200 mm with no obstruction placed to prevent a wheelchair user from reaching the call button and shall be installed at a height between 800 mm and 1 000 mm (*see* Fig. 59).



All dimensions in millimetres.

FIG. 59 PLACEMENT OF LIFT ACCESSORIES

B-6.4.5 *Control Panel*

Touch control panels shall not be used in any case as they are not accessible to visually impaired persons. The control panel inside the lift shall meet the following requirements (*see* Fig. 59):

a) It shall be placed at a height of between 900 mm and 1 100 mm from the floor level.

b) The control buttons may be placed either horizontally or vertically within this space.

c) It shall have buttons with Braille/raised letters and in sharp contrast from the background to aid people with visual impairments.

B-6.4.6 *Handrails*

Handrails shall comply with **B-5.5.2** and shall be placed at a height of 900 mm from the floor level. These shall be fixed on both sides and at the rear of the lift.

B-6.4.7 *Audio and Visual Indicators*

The lift shall have a voice announcement system along with a visual display to indicate the floor level and also the information that the door of the cage is open or closed for entrance or exit. The announcement system shall be clearly audible, that is, the announcement shall be of the order of 50 dB.

B-6.4.8 *Other Requirements*

In addition to the requirements given in **B-6.4.1** to **B-6.4.7**, following requirements shall also be complied with:

a) Internal walls shall have a non-reflective matte finish in a colour and tone contrasting with the floor.

b) The floor of the lift car shall be rigid and have a non-reflective matte finish and shall be slip resistant having similar frictional qualities to the floor of the lift landing to decrease the risk of stumbling.

NOTE — A lift floor with a high LVR reassures blind and partially sighted people that they are not stepping in to an open lift shaft.

c) The provision of a mirror on the wall of the lift car opposite the lift door is a positive aid to navigation for wheelchair users. It allows

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the wheelchair user to see if anyone is behind them and also to see the floor indicator panel. The mirror should not extend below 900 mm from the lift floor to avoid confusing people with impaired sight.

d) Internal car lighting should provide minimum level of illumination of 100 lux at floor level, uniformly distributed, and avoiding the spotlights.

e) *Emergency warning* — The car shall have an alarm device (two-way communication system) permanently connected to a manned security point according to the following:

1) The device shall ensure voice communication in both directions with an organization in charge of passenger rescue or with the person in charge of the safety of the building.

2) The operating force for alarm button shall be minimum 2.5 N and maximum 5 N.

3) The device shall provide visual and audible information feedback for passengers confirming that, the alarm has been sent, using a yellow enlightened bell-shaped symbol; and the alarm has been received, voice communication established, using the green enlightened symbol consisting of two heads.

For other requirements, reference shall be made to good practice [3(8)].

B-6.4.9 *Use of Lifts for Fire Evacuation*

A fundamental objective of fire engineering design for egress is that there shall be alternative, safe and intuitive means of egress from the scene of a fire; these routes shall be available to all building users.

NOTE — Manual handling of wheelchairs occupied by their users in a fire evacuation staircase, even with adequate training for everyone directly and indirectly involved, is hazardous for the person in the wheelchair and for those people giving assistance. The weight of an average unoccupied powered wheelchair, alone, makes manual handling impractical. Evacuation chair devices can allow vertical movement on stairs of people with mobility impairments. Some evacuation chairs require a wheelchair user to transfer out of their own chair into the evacuation chair. This transfer operation requires manual handling (for example handling of one work colleague by others), and there is a risk of injury during the transfer process or if the wheelchair user uses an oxygen tube, or has a catheter or a colostomy bag. The transfer can also infringe the independence and dignity of the individual concerned.

Evacuation of occupants through assisted evacuation by use of fireman's lift should be planned while evacuation through designated lifts suitably planned and installed for use of occupants for safe evacuation are desirous to be provided.

Such lifts used for evacuation should be easily accessible, clearly identifiable and be suitably protected from the increase of smoke, heat and flame. The controls for the lift shall be located in the areas where users must wait and this area shall be designed to ensure a tenable environment provided during the entire time that the evacuation is taking place.

Such lifts should not be used for evacuation unless built for this purpose and suitably protected by the building design.

The fire evacuation shall comply with the requirements given in Part 4 'Fire and Life Safety' of the Code and lifts for evacuation including fireman's lift shall comply with the requirements given in Part 8 'Building Services, Section 5 Lifts, Escalators and Moving Walks: 5A Lifts' of the Code.

B-6.5 Escalators and Moving Walks

Escalators and moving walks are very common in public buildings. They can greatly facilitate circulation for all building users in large, extensive and complex modern building types.

However, the location of escalators and moving walks should always be considered in relation to the position of adjacent fire protected lift shafts and lobbies, staircases and their associated areas of rescue assistance.

During normal periods of maintenance and servicing, escalators and moving walks will not be operational.

In the event of a fire emergency, building users attempting to evacuate usually tend to re-trace their routes of entry, whatever the nature of the hazard and wherever it is located. It should be assumed that the electrical supply to escalators and moving walks is terminated or turned off during such emergencies.

For important reasons of safety, therefore, inclined moving walks should comply with the requirements for ramps in buildings with respect to slope and length.

For important reasons of safety, special warning notices and indicators shall be provided at the top and bottom of escalators where step rises reduce suddenly and dramatically when not operational.

Some individuals, in particular older people, might have more than one impairment. Some individuals are not able to use an escalator or moving walk independently and rely on assistance/support being provided by a companion.

Safety shall be the prime consideration when choosing or installing escalators and moving walks.

Lifts are the preferred method of vertical travel for most people with disabilities and in particular wheelchair users.

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Persons with a wheelchair generally cannot use horizontal moving walks. An inclination of up to 6° will exclude a majority of wheelchair users from using a horizontal walkway independently. Hence, alternative, like an accessible battery carts, may be provided to them in appropriate cases. Moving walks shall be free of projecting objects and obstacles up to a height of 2 100 mm. A minimum level of illumination of 100 lux shall be provided on moving walks.

A surface of the escalator that contrasts visually with the approach and the use of audible signals or pre-recorded messages that indicate the start and finish of the escalator help blind and partially sighted people. Such signals or recording are not normally provided by the escalator manufacturer as standard.

Signs should be provided to indicate the location of other facilities, such as lifts, and these facilities should be in close proximity to the escalators and moving walks and be easy to find.

Reference shall also be made to other requirements given in **5.2** of Part 8 'Building Services, Section 5 Lifts, Escalators and Moving Walks: 5B 'Escalators and Moving Walks' of the Code.

B-6.6 Vertical and Inclined Lifting Platforms

B-6.6.1 *General*

Where it is impracticable or impossible to provide an accessible lift or a ramp in an existing building, vertical or inclined lifting platforms should be provided as a reasonable alternative for vertical circulation within the building. These are special passenger elevating devices for persons with disabilities. These may have either vertical or an inclined movement. These shall be able to be used safely, independently and also with an accompanying person. All control devices shall also be accessible and usable for powered wheelchair and walking aids users. If driving, guiding or lifting mechanisms present hazards at the sides of a platform, the mechanisms shall be guarded to protect the users. The guarding shall be smooth, hard and continuous.

B-6.6.2 *Vertical Lifting Platforms* (*see* Fig. 60)

For maximum level changes of 2 500 mm, vertical lifting platforms may be installed. For level changes of more than 1 200 mm, the lift shall be placed in a closed structure with doors at different accessible levels. Vertical lifting platforms may have a variety of openings for entry and exit.

B-6.6.3 *Inclined Lifting Platforms* (*see* Fig. 61)

Inclined lifting platforms consist of three elements; a railing, an electric generator and a moving platform. The operating system of the lift may be lateral or

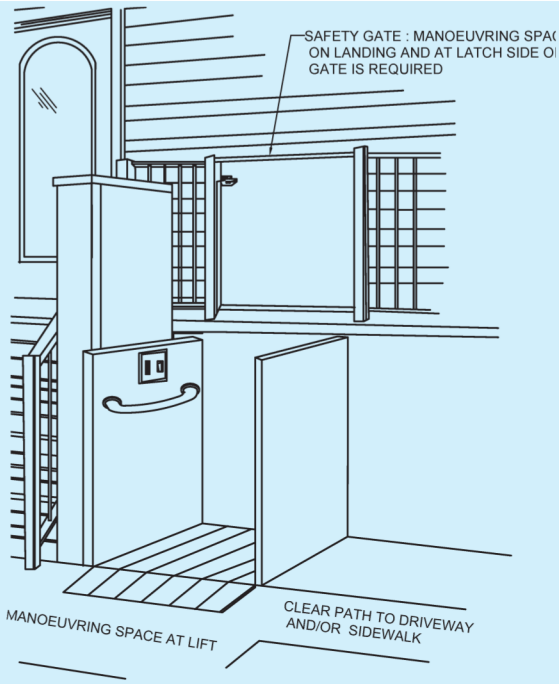


FIG. 60 VERTICAL LIFTING PLATFORMS

suspended. Inclined lifting platforms may be installed along the stair wall as long as they do not obstruct the required width of the exit. The platform may be folded when not in use.

Platform lifts may be installed on all types of stairs including switch back stairs, that is, those with a rotation of 180° and spiral staircases. Inclined lifting platforms are usually used to connect one or more floors or to overcome split levels in existing buildings.

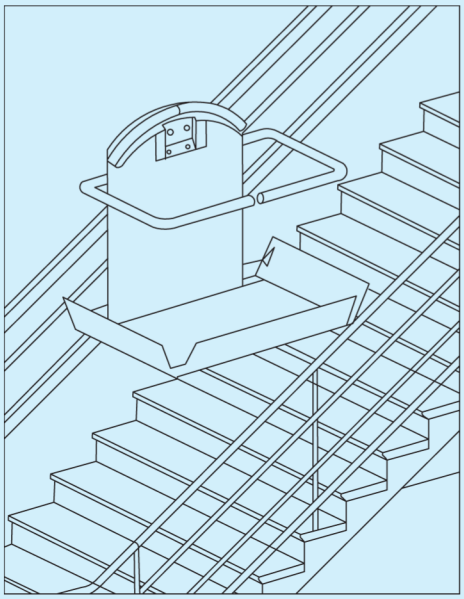


FIG. 61 INCLINED LIFTING PLATFORMS

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B-6.6.4 *Platform Lift Dimensions*

The minimum width of the platform lift shall be 1 100 mm and the minimum length shall be 1 400 mm for the use of manual and powered wheelchairs with assistance.

In existing buildings of minor public importance and with few visitors, where sufficient space is not available, other dimensions may be considered, for example 900 mm × 1 250 mm.

B-7 OPERATING CONTROLS AND DEVICES

B-7.1 General

The design and construction of operating controls and devices should be such as to enable them to be operated safely and independently by everybody.

Operating controls and devices include, but are not limited to,

a) door handles and locks;
b) lever, mixer or cross-head taps;
c) activation devices;
d) window openers and locks; and
e) electric outlets and switches.

The operable part of controls shall be located adjacent to the clear floor space. Controls should be easy to use, for example by hands-free operation or by a closed fist or using the elbow. Minimum manual effort should be required, as for opening and closing doors.

All switches and controls should be easy to understand without requiring specialist knowledge.

Sufficient lighting of the control devices and all relevant information should be provided.

Round or oval type door knobs are not suitable for people with mobility impairment, for people of small stature or less strength, and for children.

The use of photoluminiscent pictogram signs shall be provided, where appropriate.

B-7.2 Location, Heights and Distances

Devices, controls (fuse boxes, switches, push-buttons, intercoms, etc), etc, shall be installed at an accessible height for reaching and operating, between 800 mm and 1 100 mm above floor level and shall be located at a minimum of 600 mm with a preference of minimum 700 mm, from any internal corner.

NOTE — As an exception, electrical wall socket outlets, telephone points and TV sockets can be located at a minimum height of 400 mm above floor level.

Requirements and recommendations on lifts landing controls and car controls shall be as per **B-6.4.4**, **B-6.4.5** and good practice [3(8)].

Control devices placed on a horizontal surface should be placed at a height between 800 mm and 900 mm and within 300 mm from the edge of the surface.

Reading metres should be located between 1 200 mm and 1 400 mm from the floor.

Heights of switches, socket outlets, reading controls and controls on a horizontal surface are illustrated in Fig. 62.

Safety provisions as given in Part 8 'Building Services', Section 2 'Electrical and Allied Installations' of the Code shall be followed.

Door handles should be placed according to Fig. 63. In Fig. 63, the figure on the left shows the height of a handle for pushing or pulling the door, the middle figure shows a vertical door handle, and the figure on the right shows an example of a pull rail that may allow a wheelchair user to close the door behind him, for example in a toilet.

If fire and safety related, all controls should be intuitive and obvious to use. Wherever, fire extinguishers are provided, one fire extinguisher should have a maximum weight of 5 kg or 6 litre or even less.

Fire alarm calls should be located between 1 000 mm and 1 100 mm above floor level.

B-7.3 Location of Controls from Walls, Corners and Opening Doors

The minimum distance of the centre of switches and devices to control doors or windows, etc, shall be 600 mm from any internal corner or any projecting element (*see* Fig. 64) and the recommended distance is 700 mm.

Controls for powered door openers to hinged doors should be located so that the doors do not interfere with wheelchairs, canes, mobility aids, etc. Controls for powered door openers to hinged doors should be located at a minimum of 1 000 mm from the swing of the arc of the door so that the door is clear of people in wheelchairs, scooters or other assistive devices (*see* Fig. 65). The opening time shall be sufficient for a person using wheelchair or assisting devices to pass through the door safely before it closes.

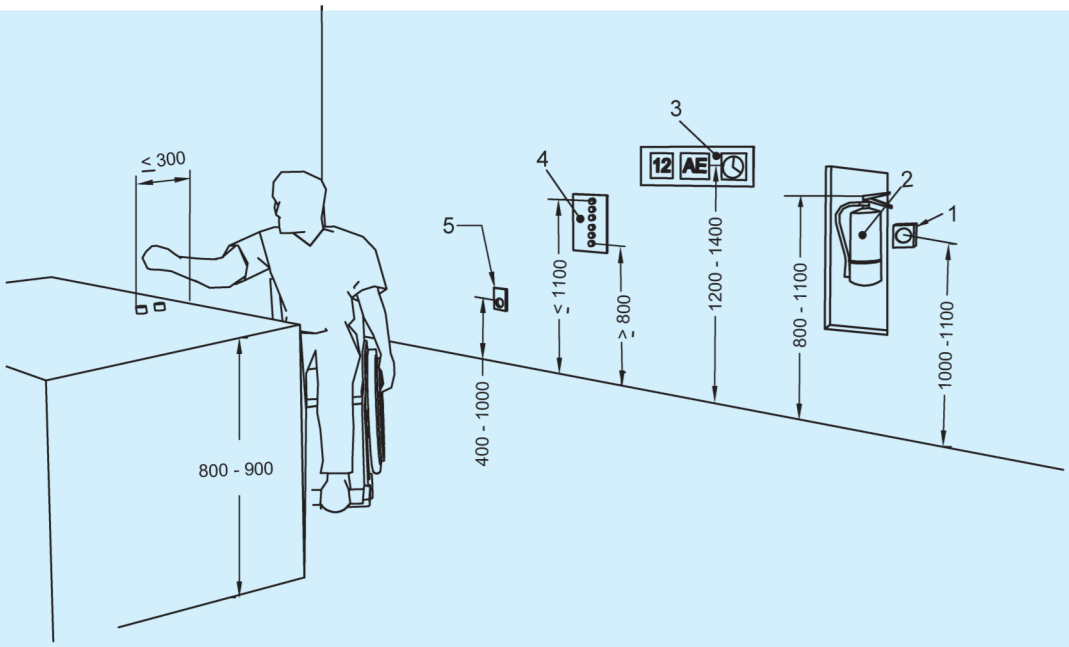
B-7.4 Operation

To help people with diverse abilities, the controls as far as possible shall be operable by one hand and require no tight grasping, pinching or twisting of the wrist.

For persons with reduced dexterity or impaired vision, electrical switches should have large push plates.

Grab bars and door or window handles should be at least 80 mm long. Lever handles should be

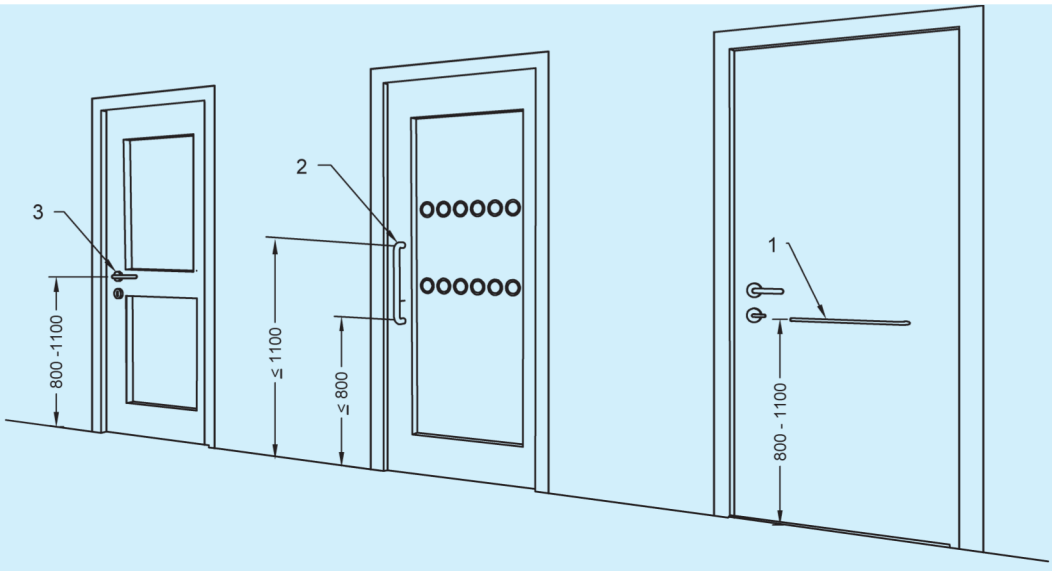
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Key
1 Fire alarm, call point
2 Fire extinguisher
3 Meter indicators
4 Control devices
5 Socket outlets

All dimensions in millimetres.

FIG. 62 HEIGHTS OF SWITCHES, SOCKET OUTLETS, READING CONTROLS AND CONTROLS ON A HORIZONTAL SURFACE

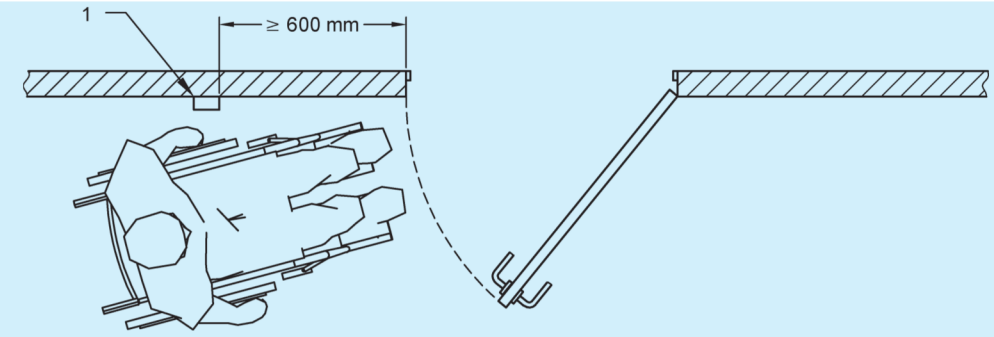


Key
1 Horizontal pull bar, toilet room door
2 Vertical handle
3 Lever type handle

All dimensions in millimetres.

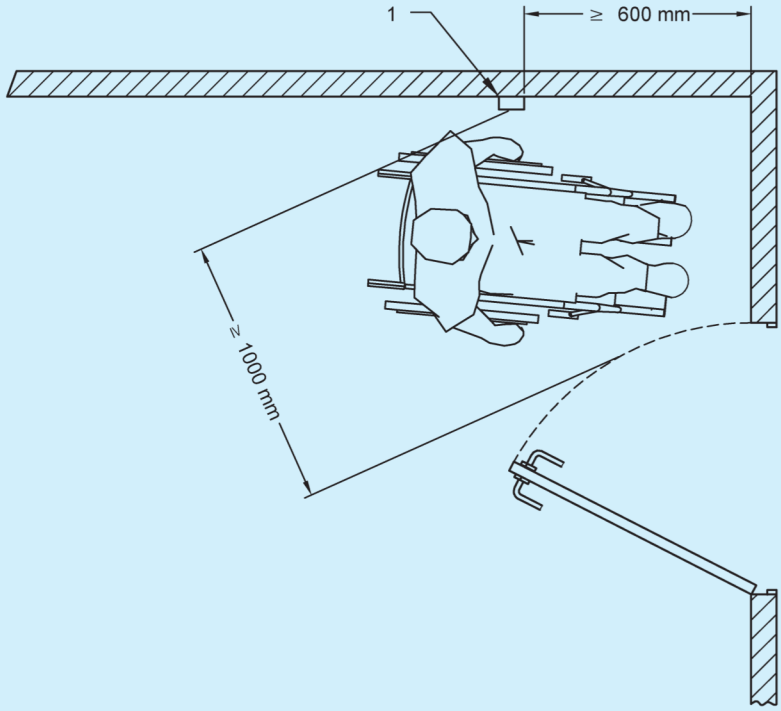
FIG. 63 DOOR HANDLE TYPES AND HEIGHTS

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Key
1 Door control, access control

FIG. 64 POSITION OF DOOR AND ACCESS CONTROLS



Key
1 Door control, access control

FIG. 65 DISTANCE OF CONTROLS FOR POWERED DOOR OPENERS

between 19 mm and 25 mm in diameter; 'D-Lever' handles are preferred (*see* Fig. 66). A vertical bar for sliding doors should be 30 mm to 50 mm in diameter. The clearance between the bar and the wall should be 45 mm to 65 mm. The backset of a latch/lock should be a minimum of 30 mm. Other door furniture should be 30 mm from the door edge. Suitable clearance should be provided between adjacent fixtures and fittings to prevent accidental operation.

Operating force on control buttons and push plates should be 2.5 N to 5.0 N. Control for drinking water fountains shall be operable with one hand with an operative force of not more than 20 N.

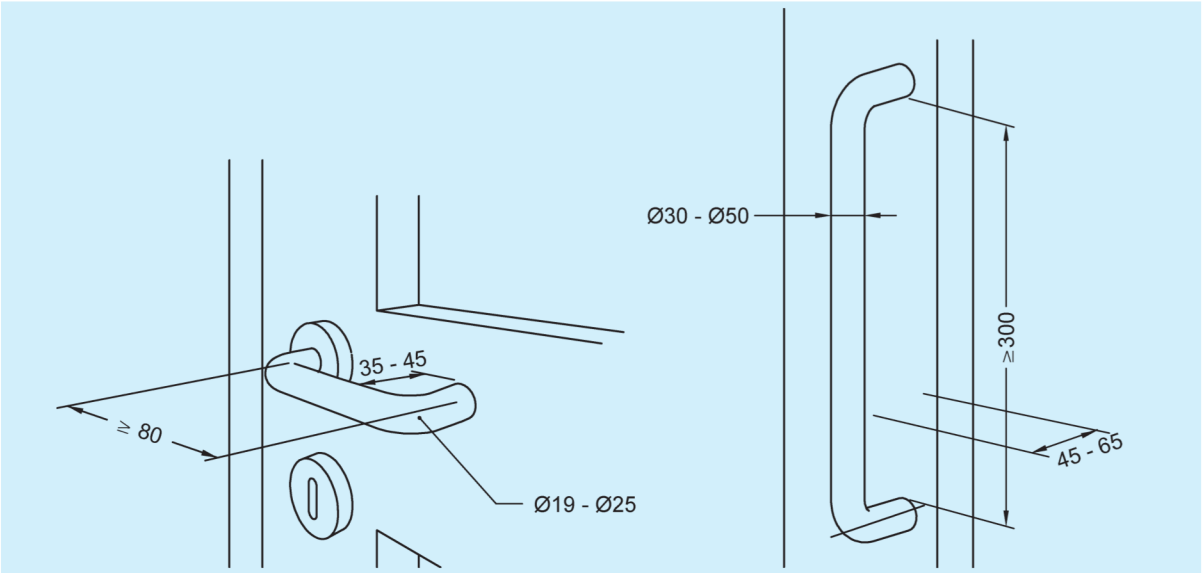
B-7.5 Identification

Buttons and devices should be identified by visual contrast. Information should be in raised tactile and Braille signage. All important controls should have an integral Braille indication.

B-7.6 Usability

Control devices for different functions should be

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All dimensions in millimetres.

FIG. 66 EXAMPLES OF D-LEVER AND VERTICAL DOOR HANDLES

different. Control devices for similar functions should have a similar design and activation mechanism and be the same for identical functions throughout the facility.

B-7.7 Telephones

B-7.7.1 Telephones shall be on a clear accessible route with approach from the front or the side (*see* Fig. 67). All information should be provided in at least two of visual, oral and tactile forms. The telephone keypad shall have a tactile point on the number five (*see also* **B-7.9**).

B-7.7.2 *Public Telephones*

Public telephones shall be located beside the access route and shall be easily detected by people with vision impairments.

Where more than one public telephones are provided, at least one phone shall be accessible.

A clear knee space of minimum 700 mm in height and minimum 600 mm in depth and 900 mm in width shall be provided underneath to accommodate wheelchair user's knee (*see* Fig. 68).

Counter tops, where provided, shall be between 750 mm and 800 mm from the floor. The depth of the counter top shall be not less than 480 mm.

Side protection shall be considered according to **B-2.6.2.**

The height of all operable parts of the telephone shall be between 800 mm and 1 100 mm. The minimum length of the telephone cord shall be 900 mm.

The international symbol of accessibility shall be displayed to identify the location of such telephones.

If a public telephone is provided in an enclosed booth, the opening of the booth shall have a clear width of at least 900 mm. The enclosed space shall have clear unobstructed dimensions of at least 900 mm × 1 200 mm, which should not be restricted by fixed seats.

B-7.8 Mailbox/Dropbox

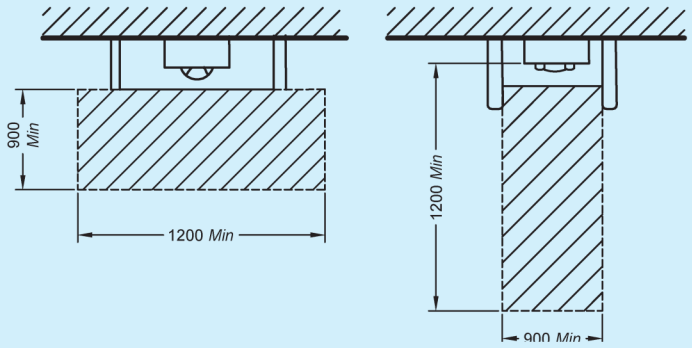
The mail/drop box slot should be located at the height of maximum 1 200 mm. It should have a clear floor space of 900 mm × 1 200 mm.

B-7.9 Vending Machine, Card Access, Dispensing Machines and Automatic Teller Machines (ATMs), etc

Machines for dispensing money, tickets or small goods should be accessible and should be located on an accessible level. The approach to dispensers should be clear and unobstructed, at least 900 mm wide. A knee space of minimum 700 mm in height and minimum 600 mm in depth and 900 mm in width should be provided to ease access for wheelchair users (*see* Fig. 69). The clear area immediately in front of the machine should be at least 1 500 mm × 1 500 mm, to allow a wheelchair user to approach the controls sideways, and to turn around after use and to provide some privacy.

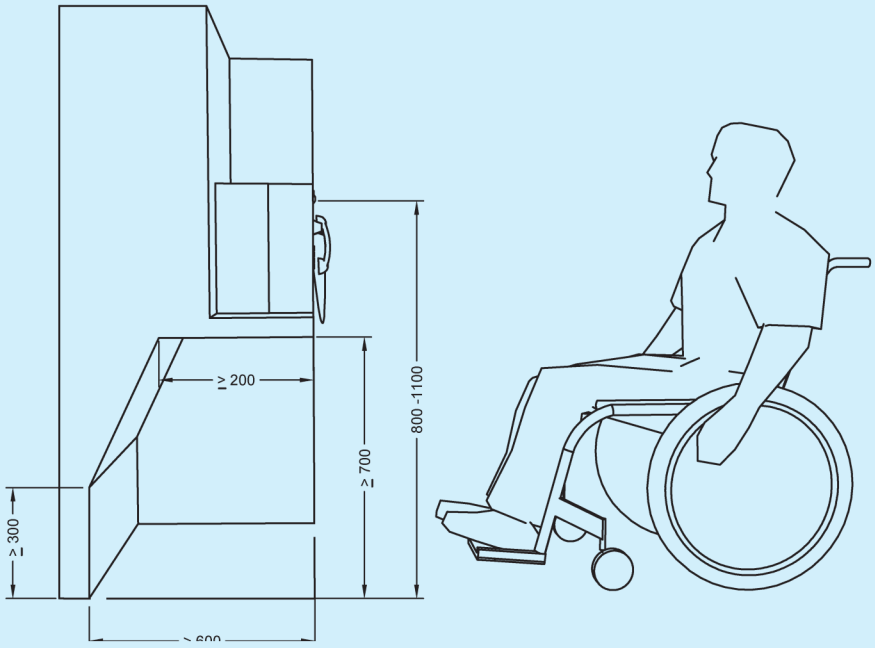
Touch screen ticket dispensers at train/bus stations, etc, should not be the only type of ticket dispenser, as they are inaccessible to people with impaired vision. A numeric keypad should also be provided to make it

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All dimensions in millimetres.

FIG. 67 SPACE ALLOWANCE FOR A WHEELCHAIR USER FOR USING TELEPHONE



All dimensions in millimetres.

FIG. 68 HEIGHT OF TELEPHONE CONTROLS FOR WHEELCHAIR USERS

accessible for visually impaired users.

Glare from sun, artificial lighting and street lighting on the screen should be avoided.

The operation of the machine should be easy to understand.

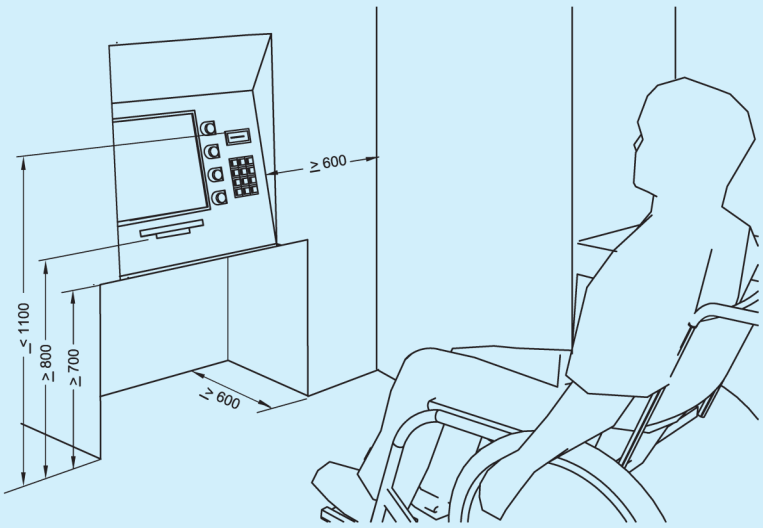
Where card access or coin slot is provided, they shall,

a) have a slot located at a height of between 800 mm and 1 000 mm above the floor, preferably between 800 mm and 900 mm,
   1) with its edge bevelled, and
   2) colour-contrasted with the surrounding surface;
b) include tactile graphic symbols on the surrounding surface that,
   1) represent the card, and
   2) identify the orientation of the card/coin insertion; and
c) have both audible (beep) and visual (light) signals to indicate that access has been granted.

Where a keypad is provided, it shall,

1) be located at a height between 800 mm and 1 000 mm from the floor;
2) be colour-contrasted with the background;
3) have characters and symbols on key surfaces

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All dimensions in millimetres.

FIG. 69 EXAMPLE OF A VENDING MACHINE

that are colour-contrasted with the key surfaces;

d) where numeric,
   1) the keys shall be arranged in a 12-key ascending or descending telephone keypad layout,
   2) the number five key shall be tactilely distinct from the other keys; the raised dot on number five shall be 0.7 ± 0.1 mm high and shall have a base 1.5 mm in diameter, and
   3) function key surfaces shall have tactile symbols as follows: enter or proceed key: raised circle [o]; clear or correct key: raised left arrow [ ]; cancel key: raised letter × [x]; add value key: raised plus [+] sign; decrease value key: raised minus [–] sign; and
e) have both audible (beep) and visual (light) signals to indicate that access has been granted; and
f) have the keys readable from both a standing and a seated position.

NOTE — For ATMs and similar facilities, other requirements as laid down by the concerned authorities shall be followed.

B-7.10 Security Access Systems

Security access systems shall be designed so as to meet the needs of everyone. This includes the requirements for manoeuvring space and for controls which can be reached comfortably. *See* **B-7.9** for requirements relating to card access and keypads. Security access systems should be usable by everyone. Biometric systems (for example retinal or palm scanners) cannot accommodate all users. To negotiate the security access systems placed at building entrances, such as, airports, railway stations, metro stations, and shopping malls, relevant rules and regulations laid down by the concerned authorities shall be followed.

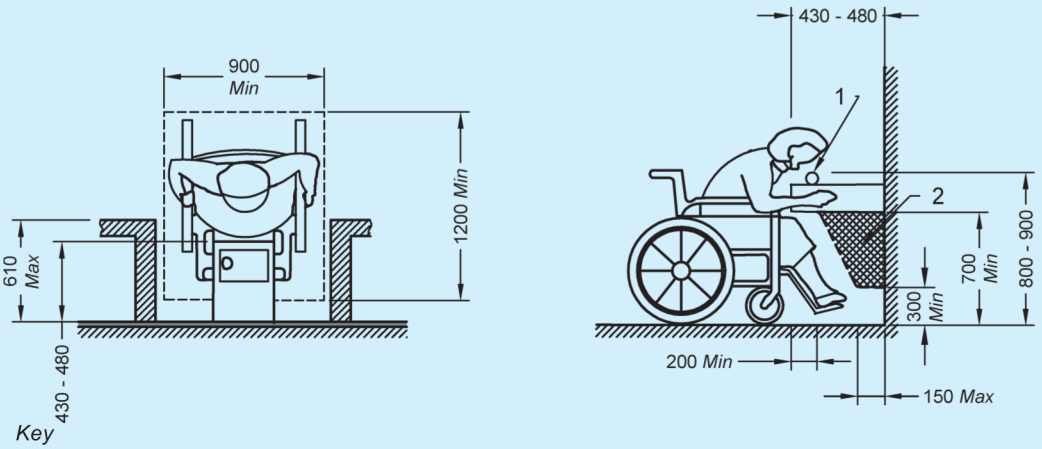
NOTE — The requirements relating to card access and keypads shall be similar to those for ATMs as laid down by the concerned authorities.

B-7.11 Drinking Water Facility

The drinking water facility (fountains, coolers, taps, etc) shall comply with the following:

a) Wall/Post-mounted cantilevered units shall have a clear floor space of at least 900 mm × 1 200 mm as shown in Fig. 70.
b) The front edge of the unit shall extend 430-480 mm from the wall. It shall have a clear knee space between the bottom of the apron/ equipment and floor or ground of at least 900 mm wide, 200 mm deep extending from the front edge of the equipment to back towards the wall, and 700 mm high. It shall have a toe space not less than 900 mm wide, 300 mm high, extending from the back wall to a maximum of 150 mm (*see* Fig. 70).
c) Freestanding or built-in-drinking water units not having a clear space under them shall have a clear floor space of at least 1 200 mm wide × 900 mm in front of the unit as shown in Fig. 71.
d) Spout heights should be between 800-900 mm, measured from the floor to the spout outlet. The maximum distance of the spout from the front edge of the drinking water facility shall be 125 mm. There shall be water glass provision; a minimum 100 mm space below the spout outlet shall be provided to allow for the insertion of a cup or glass.
e) Wall-mounted drinking water provision in an alcove is preferred, because it does not create

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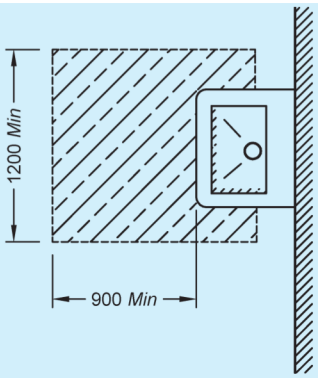


All dimensions in millimetres.

FIG. 70 CLEAR FLOOR SPACE AND KNEE SPACE REQUIREMENT FOR A WALL/POST-MOUNTED DRINKING WATER UNIT

a hazard for persons with visual impairments. The provision of two drinking facilities at different heights is very convenient for standing adults, people in wheelchairs and children. Where only one is provided, it shall be at a height of 700 mm above floor level

4) Controls shall be centrally positioned at the front of the unit or, if at the side, on both sides, not more than 180 mm from the front and shall comply with **B-7**. Control shall be easily operable with one hand with an operative force as given in **B-7**.



All dimensions in millimetres.

FIG. 71 CLEAR FLOOR SPACE FOR FREESTANDING OR BUILT-IN DRINKING WATER UNIT NOT HAVING CLEAR SPACE UNDER THE UNIT

B-7.12 Dust Bins

Dust bins should be fully accessible and easy to use for everybody.

B-8 SEATING SPACES

B-8.1 General

Seating facilities should be provided in public buildings to provide people with a place to wait and to rest. The location of seats (including reserved areas for wheelchairs) should not disturb the general circulation.

Seating facilities shall have a clear and level floor space of not less than 900 mm × 1 200 mm.

Seats should be designed with armrests to facilitate sitting down and standing up. The seats should also have back rests (*see* Fig. 72).

B-8.2 Seating in Waiting Areas

A range of different types of seating should be provided complying with the following (*see* Fig. 72):

a) Seat height 400 mm to 450 mm,
b) Back support height 750 mm to 790 mm,
c) Seat depth 400 mm to 450 mm,
d) Angle of seat to backrest 100° to 105°,
e) Armrest height 220 mm to 300 mm above seat,
f) Armrest set back from front of seat ≤ 75 mm, and
g) A minimum 150 mm set back under the seat for feet when standing up.

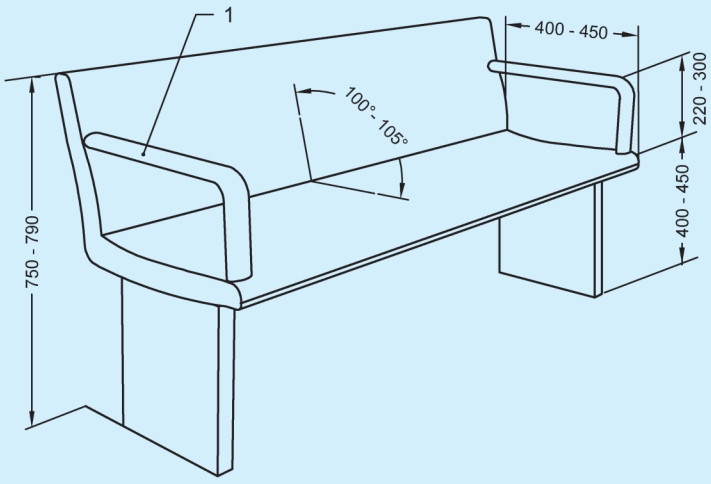
B-8.3 Seating at Desks, Tables, etc

To allow a frontal approach with a wheelchair to a table, desk, counter, telephone, etc, an unobstructed space shall be provided with a minimum free height of 700 mm, minimum free depth of 600 mm (*see* Note) and minimum width of 900 mm to accommodate knees underneath. For footrests, a minimum height of 300 mm is required (*see* Fig. 73).

NOTE — This may overlap the clear floor space by a maximum of 480 mm.

If tables with fixed seats are used, there shall be a place for at least one person in a wheelchair at the table.

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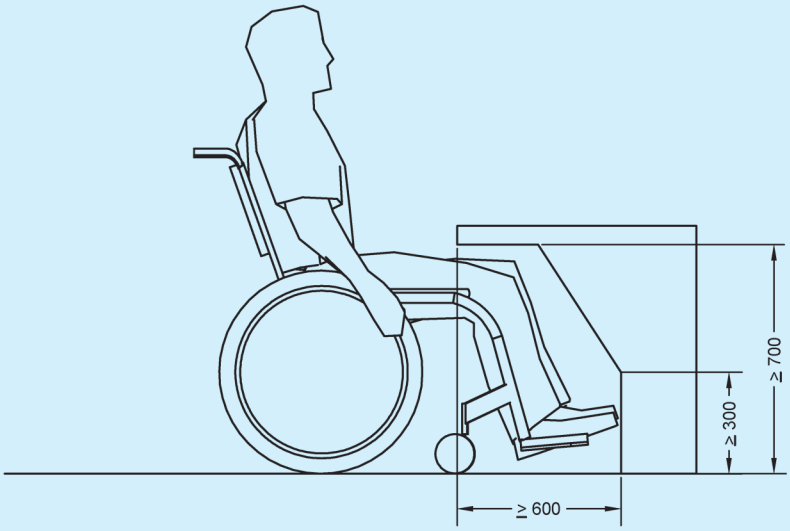


Key

1 Armrests omitted on some benches to allow lateral transfer

All dimensions in millimetres.

FIG. 72 EXAMPLE OF A BENCH WITH ARMRESTS AND BACK SUPPORT



All dimensions in millimetres.

FIG. 73 TABLE AND DESK HEIGHT FOR WHEELCHAIR USERS

B-9 TOILET ROOMS AND SANITARY ROOMS

B-9.1 General

Sanitary facilities shall be designed to accommodate a variety of users. Accessible toilets that can be used by both sexes (unisex accessible toilets) allow the greatest flexibility for people who require assistance hence is the preferred option. Wheelchair accessible unisex toilets should always be provided in addition to wheelchair accessible separate sex toilets. Similarly, a provision of an enlarged cubicle for ambulant disabled people in a separate sex toilet room can also benefit parents with children and people who need an enlarged space (for example those with luggage).

The accessible toilet room shall be located as close as possible to the entrance/reception/waiting area of the building and should be easy to find. It should not be so located that it compromises the privacy of users.

If only one toilet is decided to be provided considering the estimated requirement as per this Code, it shall be Type A unisex accessible toilet (*see* **B-9.2** for types of toilets). Where, more than one accessible toilet is provided, different options exist.

Where sanitary facilities are provided, the following shall also apply:

a) At least one unisex wheelchair user accessible toilet room of Type A, with central placement

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of WC, shall be provided, which shall always contain a washbasin.

b) One accessible toilet (Type A or Type B) in single sex toilet block (male and female section of toilet block) shall be provided depending on the footfall and space.

c) When more than one accessible corner toilet of Type B is planned, a choice of layouts suitable for left hand and right hand transfer shall be provided. In case such toilets are located in similar position on each floor of a multi-storey building, it should allow for right and left hand transfer on alternate floors. In any case, a unisex accessible toilet of Type A shall be provided on the ground floor so as to be able to meet the need for both left and right side transfers.

d) In all separate sex toilet/sanitary rooms there shall be provision for one cubicle suitable for use by ambulant disabled.

e) Where urinals are provided, there shall be urinals for wheelchair users and ambulant disabled people.

f) Where there is requirement for only one toilet or sanitary room in a building, a wheelchair accessible unisex toilet of Type A shall be provided but of a greater width to accommodate a standing height washbasin and a urinal.

g) The provision of the accessible toilets shall be such that any wheelchair user/ambulant disabled person doesn't have to travel more than 30 m on the same floor.

h) The design of toilet facilities shall incorporate ease of use for all people and location of fittings should follow a logical sequence.

j) Care shall be taken in placing mirrors and lights to avoid confusion and dazzling for visually impaired users.

k) Soap dispensers and hand towels or driers shall be placed in a convenient and logical position so that they are easy to locate, identify and use.

m) Visual contrast and lighting shall be in accordance with **B-9.16**.

n) An emergency assistance alarm according to **B-9.12**, including a reset control, should be provided in all accessible toilets and sanitary rooms.

p) If facilities are provided such as buttons or taps which operate by use of sensors, accessible signage shall be provided to explain the same.

q) Signage at accessible toilet entrance shall be as per **B-9.18**.

r) Tactile signs should be used beside rather than on doors to indicate 'Ladies' or 'Gents';

s) For the benefit of the persons with vision impairments, all general toilets shall have marked on plates with raised alphabets and braille put on the wall next to the door latch, preferably on the left side. An additional signage shall also be provided on the door at 1 500 mm height. *See also* **B-24** for other requirements of signage.

t) Many persons with visual impairments find it convenient to use the toilets where internal dimensions, accessories and fixtures placement are standardized. A tactile layout of the toilet should be provided on the wall, near the latch side at 900 mm height.

u) A distinct audio sound (beeper/clapper) may be installed above the entrance door for the identification of the toilets by persons with visual impairments.

B-9.2 Wheelchair User Accessible Toilet Rooms

B-9.2.1 This Part gives the characteristics and requirements for the two types of wheelchair user accessible toilet rooms, namely, Type A and Type B.

The clear manoeuvring space of the toilet room shall allow frontal, oblique and lateral transfer. Type A toilet with a central placement of WC allows right and left lateral transfer, and may be more suitable when assistance is needed. Types B only allow one side transfer.

The clear manoeuvring space at floor level in front of the water-closet and the washbasin in case of Type A toilets shall be 1 800 mm × 1 800 mm, except for Type B where it shall be 1 500 mm × 1 500 mm by using the 300 mm space under the washbasin as part of the total manoeuvring space.

The minimum free clearance beside the water-closet shall be 900 mm, whereas 1 200 mm is preferred for lateral transfer and assistance.

NOTE — Minimum clearance of 900 mm accommodates only 65 percent of the wheelchair users, clearance of 1 200 mm accommodates 90 percent of all wheelchair users especially also those who use powered wheelchairs.

The minimum dimensions for a Type A accessible toilet room are 2 200 mm width and 2 300 mm depth, and the minimum dimensions for a Type B accessible toilet room are 1 700 mm width and 2 200 mm depth.

NOTE — In case of existing buildings, as part of exceptional considerations, the measures given above cannot be achieved due to technical reasons, the manoeuvring space at floor level may be reduced, but it should be recognized that such a reduction limits the number of people who can use these toilet rooms.

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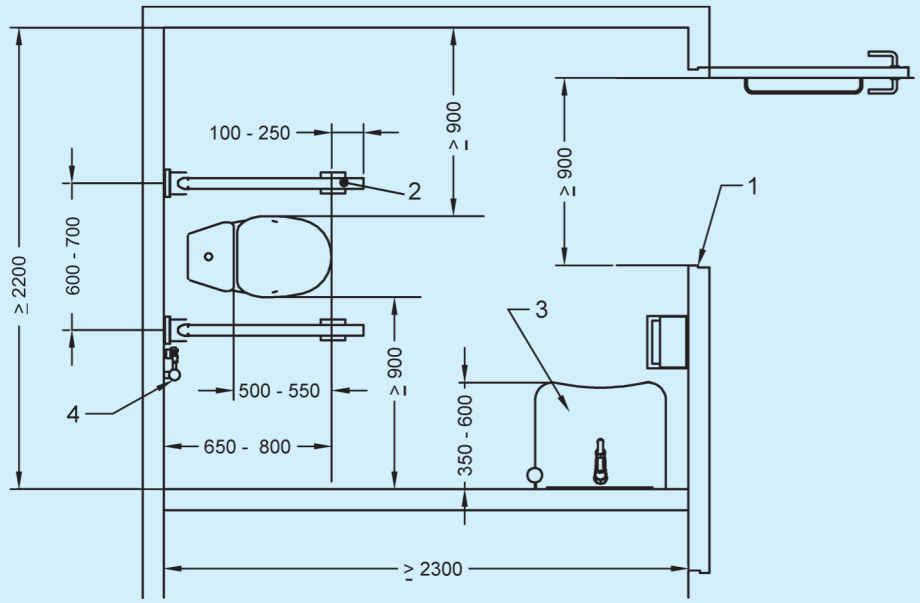
B-9.2.2 *Type A Toilet Room with Lateral Transfer from Both Sides*

B-9.2.2.1 Type A accessible toilet room has the following characteristics (*see* Fig. 74 and Fig. 75):

a) Lateral transfer from both sides,
b) Manoeuvring space uninterrupted by washbasin and pan,
c) Independent water supply beside water-closet,
d) Horizontal grab rails at both sides, and
e) Toilet paper dispensers on both folding grab rails.

B-9.2.2.2 Type A accessible toilet room shall meet the following requirements (*see* Fig. 74):

a) It shall have minimum internal dimensions 2 200 mm × 2 300 mm.
b) The layout of the fixtures in the toilet shall be such that there is a clear manoeuvring space that provides a wheelchair turning radius of 1 800 mm in front of the water-closet and washbasin in the accessible toilet unit.
c) It shall have all fixtures and utilities arranged in a manner to provide a clear space of 900 mm × 1 350 mm for wheelchair users to access them.
d) It shall have clear space of not less than 900 mm wide next to the water-closet.
e) It shall be equipped with a door complying with **B-9.4**.
f) It shall have a water-closet complying with **B-9.5**, grab bars complying with **B-9.6** and washbasin complying with **B-9.7**.
g) It shall have essential washroom accessories complying with **B-9.8**.
h) It shall have an alarm to seek emergency help, complying with **B-9.12.**
j) It shall have the toilet roll dispenser and hand water faucet mounted below the grab bars and at not more than 300 mm from the front edge of the seat and at a height between 50 mm and 200 mm from the top of the water-closet seat.
k) Cloth hooks should be set at different heights, 900 mm to 1 100 mm, and additionally at least one hook at 1 400 mm; and projecting not more than 40 mm from the wall.
m) Where possible, be equipped with a shelf of dimensions 400 mm × 200 mm fixed at a height of between 900 mm and 1 000 mm from the floor.

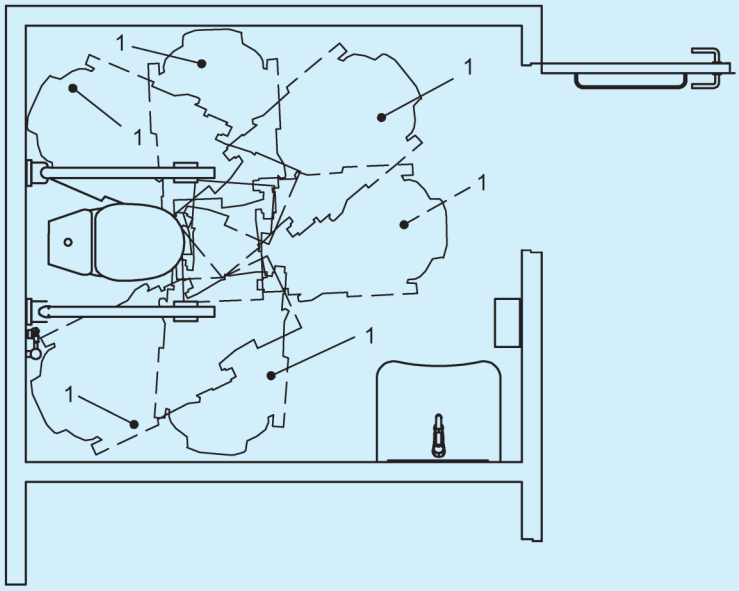


Key
1 Minimum 900 mm
2 Foldable grab bars, both sides
3 Washbasin
4 Independent water supply

All dimensions in millimetres.

FIG. 74 EXAMPLE OF TYPE A TOILET ROOM — LATERAL TRANSFER FROM BOTH SIDES

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Key
1 Possible transfer positions

FIG. 75 TYPE A TOILET ROOM TRANSFER OPTIONS

B-9.2.3 *Type B Toilet Room with Lateral Transfer from One Side Only*

B-9.2.3.1 Type B toilet has the following characteristics (*see* Fig. 76 and Fig. 77):

a) Lateral transfer only from one side;
b) Manoeuvring space reduced by washbasin;
c) Independent water supply beside water-closet, with floor drain where necessary;
d) Ability to reach small wash hand basin when seated on toilet;
e) Horizontal grab rail on wall beside the water-closet;
f) Vertical grab rail on wall beside the water-closet for getting up and sitting down (slanted grab bars are not preferred);
g) Foldable grab rail; and
h) Toilet paper dispenser fixed on the wall beside the water-closet.

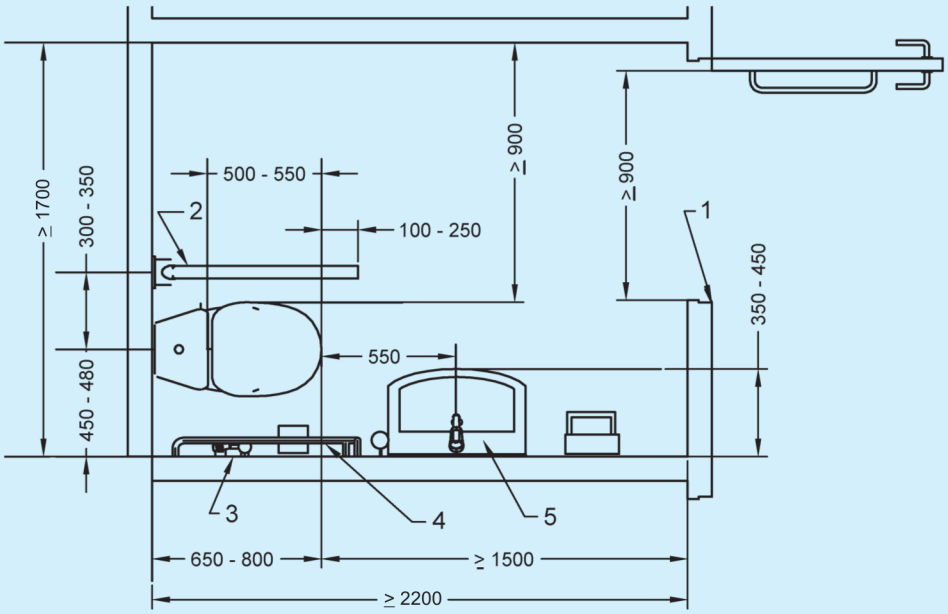
B-9.2.3.2 Type B accessible toilet room shall meet the following requirements (*see* Fig. 76):

a) It shall have minimum internal dimensions of 1 700 mm × 2 200 mm.
b) It shall have all fixtures and utilities arranged in a manner to provide a clear space of 900 mm × 1 350 mm for wheelchair users to access them.
c) It shall have clear space of not less than 900 mm wide next to the water-closet.
d) It shall be equipped with a door complying with **B-9.4**.
e) It shall have a water-closet complying with **B-9.5**, grab bars complying with **B-9.6** and washbasin complying with **B-9.7**.
f) It shall have essential washroom accessories complying with **B-9.8**.
g) It shall have an alarm to seek emergency help, complying with **B-9.12.**
h) It shall have the toilet roll dispenser and hand water faucet mounted below the grab bars and at not more than 300 mm from the front edge of the seat and at a height between 50 mm and 200 mm from the top of the water-closet seat.
j) Cloth hooks should be set at different heights, 900 mm to 1 100 mm, and additionally at least one hook at 1 400 mm; and projecting not more than 40 mm from the wall.
k) Where possible, be equipped with a shelf of dimensions 400 mm × 200 mm fixed at a height of between 900 mm and 1 000 mm from the floor.

B-9.3 WC Compartments for Ambulant Disabled People

These compartments meet the needs of ambulant disabled people who require support (*see* Fig. 78 and Fig. 79).

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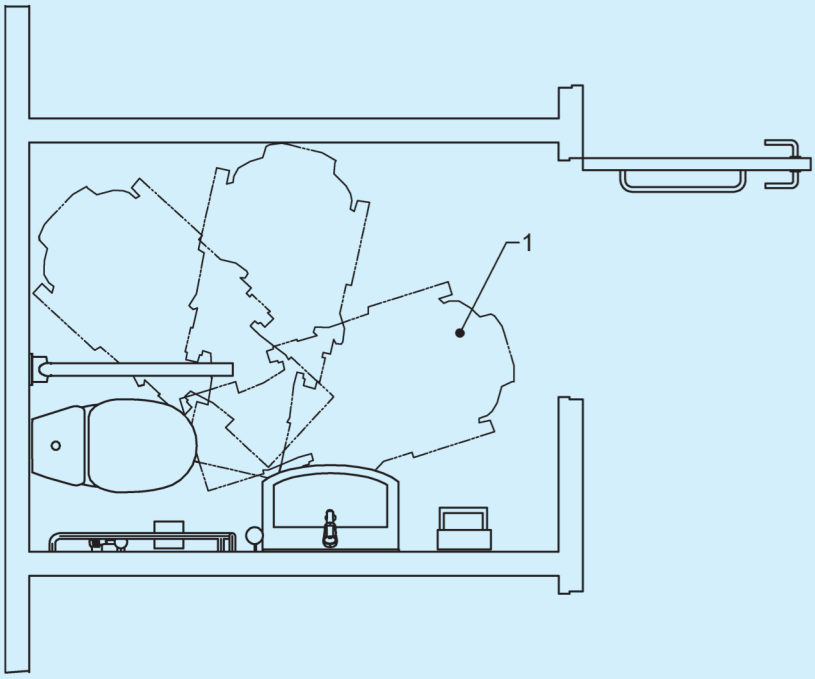


Key

1 Minimum 900 mm
2 Foldable grab bar
3 Independent water supply
4 Grab bar on wall
5 Washbasin

All dimensions in millimetres.

FIG. 76 EXAMPLE OF TYPE B CORNER TOILET ROOM — LATERAL TRANSFER FROM ONE SIDE ONLY



Key

1 Possible transfer positions

FIG. 77 TYPE B TOILET ROOM TRANSFER OPTIONS

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This type of compartment is not for the majority of people who use wheelchairs. When located in a single-sex washroom, hand washing facilities will be available communally. Where this is a standalone facility, hand washing facilities shall be provided either in a space adjacent to the WC compartment or in a compartment suitably enlarged to accommodate a wash hand basin.

Such WC compartments shall meet the following requirements:

a) It shall have a clear manoeuvring space of minimum 900 mm × 900 mm in front of the toilet.
b) It shall be equipped with a door complying with **B-9.4** and opening outwards.
c) Water-closet shall comply with **B-9.5**.
d) Grab rails complying with **B-9.6**, horizontal and vertical shall be provided on both sides of toilet.
e) It shall have other toilet accessories and fittings complying with **B-9.8**.
f) It shall have independent water supply beside water-closet, preferably a hand held toilet spray and floor drain, where necessary (*see* **B-9.9**).

B-9.4 Toilet or Sanitary Room Doors

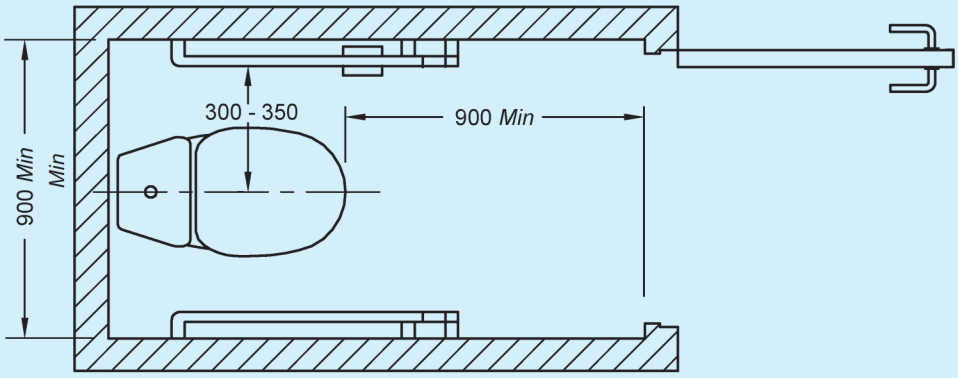
Toilet or sanitary room doors shall comply with **B-5.3**. The toilet door shall either be an outward opening door or two way opening door or a sliding type and shall provide an unobstructed and clear opening width of at least 900 mm; it shall be easy to open and close. There should be no openings under or above the door that compromises on privacy. Doors should be positioned so as not to constitute a hazard.

The toilet door shall be provided with a horizontal pull-bar, at least 600 mm long, on the inside of the door, located so that it is 130 mm from the hinged side of the door and at a height of 900 mm to 1 000 mm. A horizontal pull handle on the inside of the outward opening doors shall be provided at a height of 700 mm above the floor. The door shall be capable of being locked from the inside by a device that is operable by one hand, activated by a force not more than 22 N and which does not require fine finger control, tight grasping, pinching or twisting of the wrist.

B-9.5 Water-Closet

Water-closet shall comply with the following requirements:

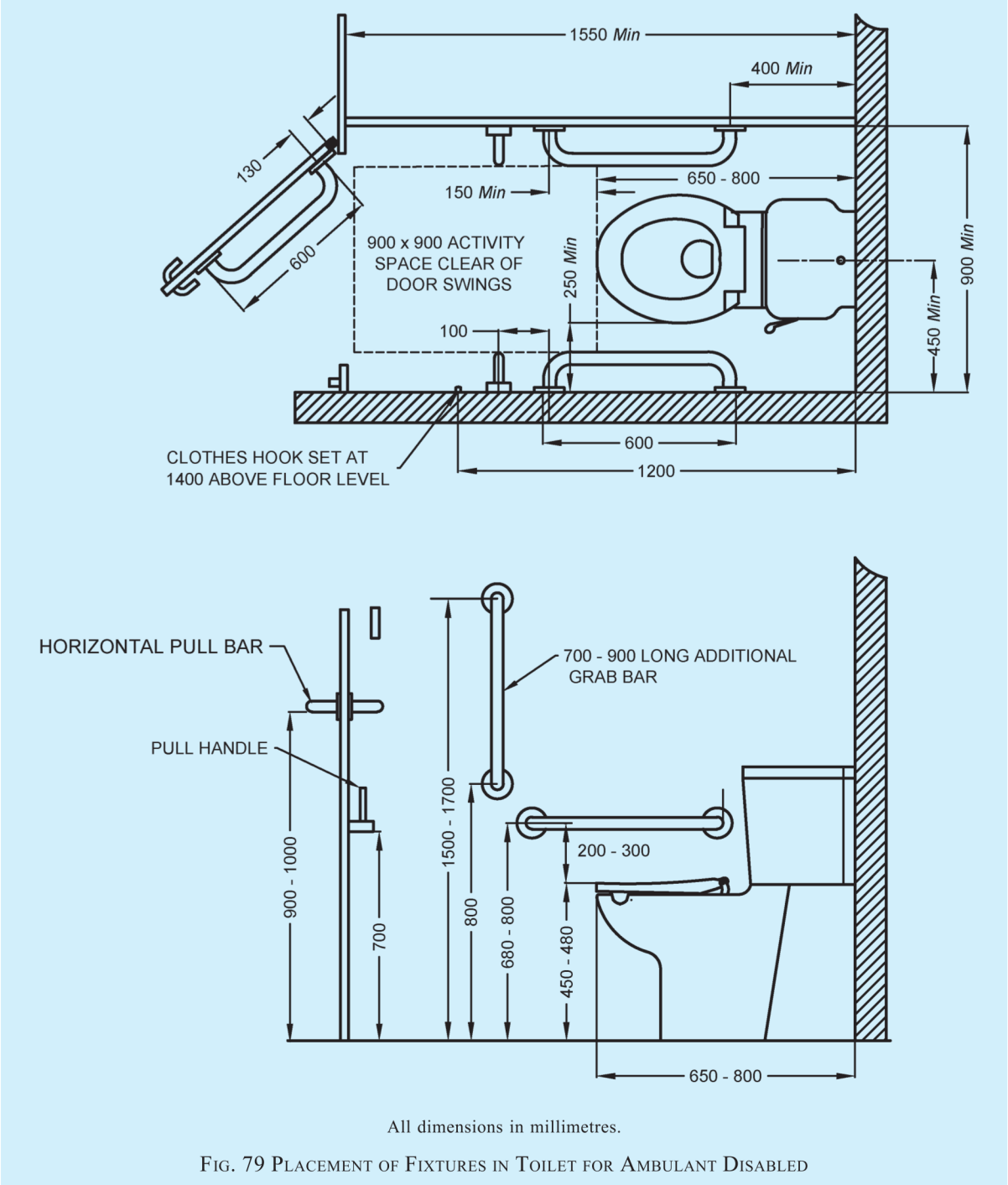
a) It shall be so located that the distance between centreline of the water-closet to the adjacent wall in case of corner toilets (Type B) be between 450 mm and 480 mm. The minimum distance of a corner toilet from the edge of the WC seat to the adjacent wall should be 250 mm. In case of Type A toilet, the distance from the edge of the WC seat to the adjacent wall shall be 900 mm, minimum on both sides to allow ease of transfer.
b) The top of the water-closet shall be between 450 mm and 480 mm from the floor.
c) The minimum distance from the front edge of the water-closet to the rear wall should be between 650 mm and 800 mm.
d) There shall be an adequate clear floor space of at least 1 300 mm depth and 900 mm width, both in front and on the transfer side, adjacent to the water-closet.
e) There shall be a suitable back support to reduce the chance of imbalance or injury



All dimensions in millimetres.

FIG. 78 TOILET FOR AMBULANT DISABLED WITH L-SHAPED GRAB BAR

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All dimensions in millimetres.

FIG. 79 PLACEMENT OF FIXTURES IN TOILET FOR AMBULANT DISABLED

caused by leaning against exposed valves or pipes. The distance from the seat to the backrest should range between 500 mm and 550 mm.

f) The water-closet shall preferably be of wall-hung or corbel type as it provides additional space at the toe level.

g) Where water cistern is used, the cover shall be securely attached and the flush control shall either be lever type or automatic, and located on the transfer side of the water-closet. The flush control shall not be located more than 1 000 mm from the floor.

h) Toilets for children should have a distance from the centre line to the adjacent wall between 305 mm and 380 mm and the water-closet height shall be between 205 mm and 380 mm.

B-9.6 Grab Bars

Grab bars complying with **B-5.5.3** shall be provided in toilet or sanitary rooms in accordance with this clause.

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On both sides of a toilet, a grab bar (whether drop-down or fixed to the wall) shall be provided at a distance between 300 mm and 350 mm from the centre line of the toilet.

On the sides where a lateral transfer is possible, a foldable grab bar (drop-down support bar) shall be provided at a height of 200 mm to 300 mm above the water-closet. The length of the foldable grab bar should overlap the front edge of the water-closet in between 100 mm and 250 mm. The positioning of a foldable grab bar should allow access from a wheelchair when folded up.

Where a wall is beside the toilet, a horizontal grab bar shall be provided at a height of 200 mm to 300 mm above the water-closet, and a vertical grab bar shall exceed from the horizontal grab bar to a height of 1 500-1 700 mm above floor level. The grab bar shall extend a distance of minimum 150 mm to the front edge of the water-closet.

Alternatively, one L-shape grab bar, 600 mm long horizontal and 700-900 mm long vertical shall be mounted on the side wall closest to the water-closet, as illustrated in Fig. 80.

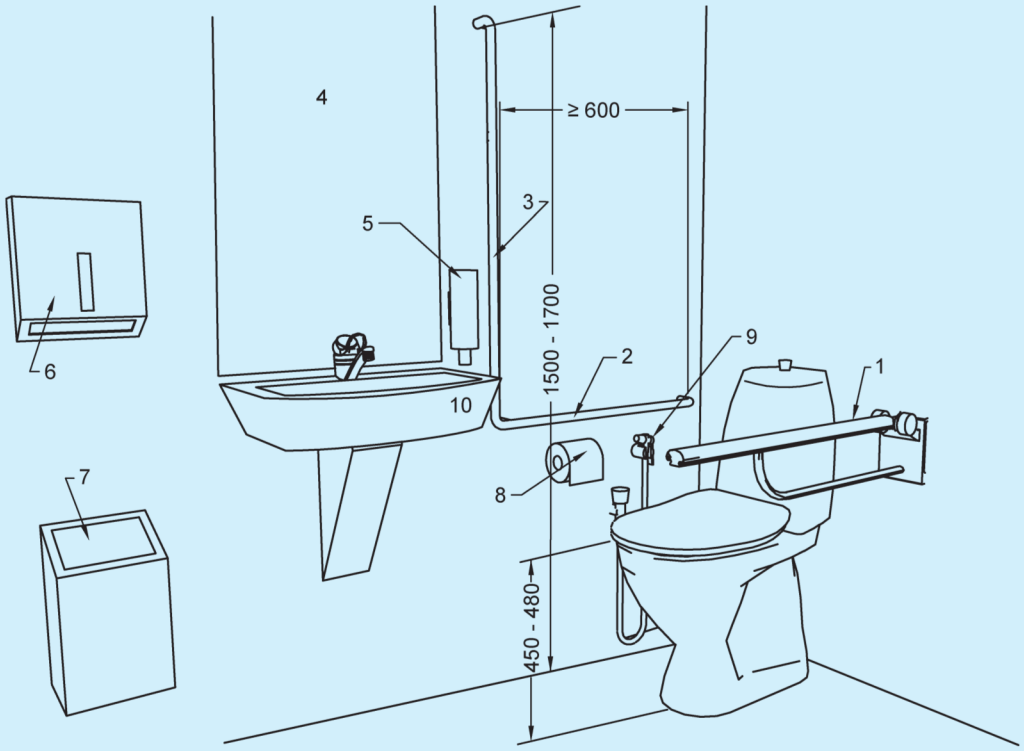
The horizontal grab bar shall be uninterrupted for its full length.

The positioning of accessories such as hand towel, soap, waste bin, etc, should not hamper the use of the grab bar.

The grab bar height for toilets for children should be between 510 mm and 635 mm.

B-9.7 Washbasin

A washbasin complying with following requirements shall be provided within an accessible toilet room (*see* Fig. 81):



Key

1 Drop down support grab bar at seat height plus 200 to 300 mm
2 Wall mounted horizontal grab bar at seat height plus 200 to 300 mm
3 Wall mounted vertical grab bar
4 Mirror, top height minimum 900 mm, bottom height maximum 900 mm above floor
5 Soap dispenser 800 to 1 000 mm above floor
6 Towels or dryer 800 to 1 100 mm above floor
7 Waste bin
8 Toilet paper dispenser 600 to 700 mm above floor
9 Independent water supply
10 Small finger rinse basin 350 mm maximum projection

All dimensions in millimetres.

FIG. 80 POSITIONING OF GRAB BARS, WATER SUPPLY AND OTHER TOILET ACCESSORIES IN TYPE B CORNER TOILET

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a) The positioning of a washbasin should allow access from a wheelchair. It shall provide a minimum clear floor space of 900 mm wide by 1 200 mm deep, of which a maximum of 480 mm in depth may be under the washbasin.

b) It shall be mounted such that the minimum distance between the centreline of the fixture and the side wall is 460 mm; and the top edge of the washbasin is between 750 mm and 850 mm from the floor.

c) The differences in stature may require lower or higher heights of washbasins and it may be advisable to have an inbuilt flexibility to increase or decrease height.

d) The space under the washbasin shall be unobstructed with a knee clearance centred on the washbasin between 680 mm and 700 mm high, and 200 mm deep. In addition, a toe clearance of at least 300 mm high shall be provided (*see* Fig. 82). The front edge of the washbasin shall be located within a distance of 350 mm to 600 mm from the wall, according to Fig. 74.

e) The hot water and drain pipes within the knee space or toe space shall be properly insulated.

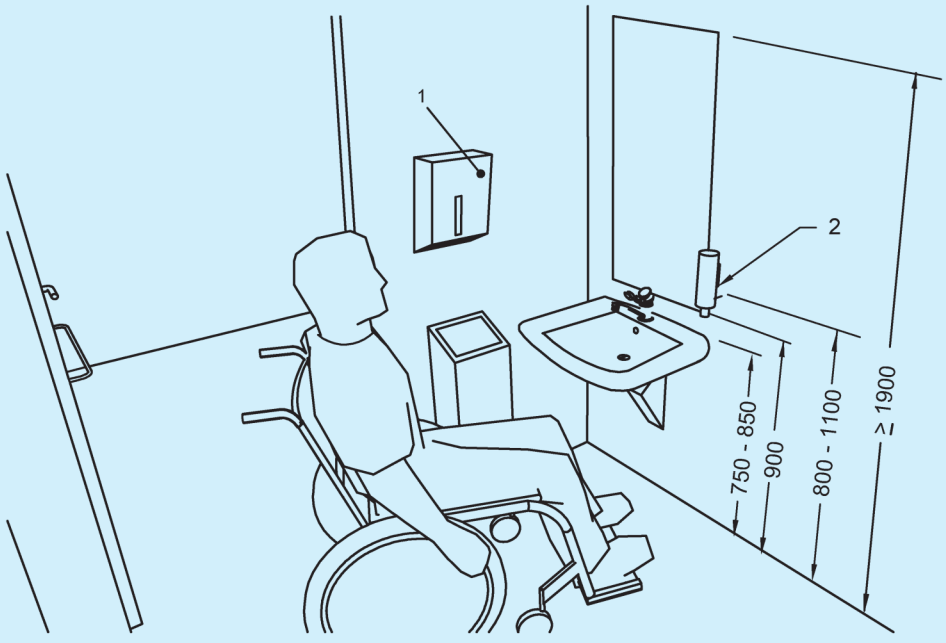
f) Automatic or lever type faucets/taps shall be provided complying with **B-9.10**.

g) In front of the washbasin, space should allow for a frontal or oblique approach by a wheelchair. The reaching distance to the tap control shall be a maximum of 300 mm, according to Fig. 82.

h) Edges on washbasins should be rounded.

j) The mirror above the washbasin shall be positioned to have the bottom edge at a height of not more than 900 mm above the floor, up to a height of 1 900 mm (*see* Fig. 81). If a second mirror is provided, the maximum height above the floor should be 600 mm, up to 1 850 mm. The mirror shall be tilted at an angle of 30° for better visibility of wheelchair user. Care shall be taken in placing mirrors and lights to avoid confusion and dazzling for visually impaired users.

k) A shelf with minimum dimensions of 200 mm × 400 mm should be provided near the washbasin at a height of 850 mm, or combined with the washbasin.

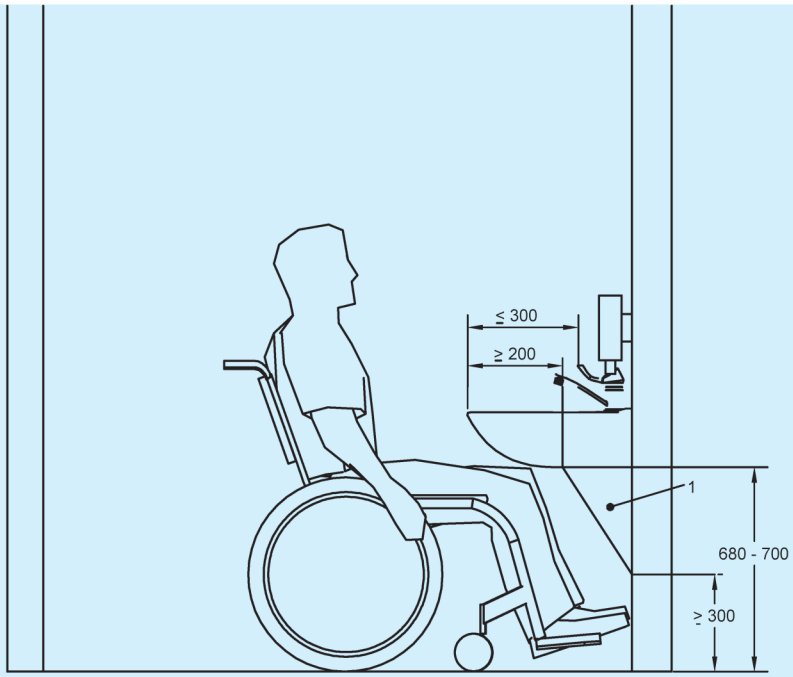


Key
1 Paper towels, 800 to 1 100 above floor
2 Soap dispenser

All dimensions in millimetres.

FIG. 81 PLACEMENT OF WASHBASIN AND MIRROR ABOVE THE WASHBASIN WITH DISTANCE OF SANITARY APPLIANCES

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Key
1 Concealed piping

All dimensions in millimetres.

FIG. 82 WASHBASIN WITH KNEE/TOE CLEARANCE

B-9.8 Other Toilet Accessories and Fittings

All other fittings, for example the water tank, hand dryer, towel, soap dispensers, waste bins, hand-held shower, etc, should be set at a height between 800 mm and 1 100 mm from the floor (*see* Fig. 80). Coat hooks should be set at different heights, 900 mm to 1 100 mm, and additionally at least one hook at 1 400 mm. Accessories shall be placed in close proximity to the basin, to avoid a person with wet hands wheeling a chair.

Dispensers for toilet paper shall be reachable from the water-closet, either under the grab bar or on the side-wall of a corner toilet at a height between 600 mm and 700 mm from the floor (*see* Fig. 80).

Light switches should be fixed inside all accessible toilet cubicles or the lighting should automatically switch on when someone enters the room. Timed light switches should not be installed or used.

Needle boxes to safely dispose of needles (for example from diabetes patients) should be provided.

If a sanitary bin is supplied, it should be reachable from the water-closet. Sanitary bins with non-touch opening devices are preferred.

Non-touch soap dispensers are preferred.

B-9.9 Water Supply

An independent water supply (hand-held shower) shall be provided next to the toilet. An alternative such as a combination bidet and rear side pan/built-in bidet can be installed.

B-9.10 Taps

Taps should be mixer, lever or sensor operated to aid operation, complying with requirements given in **B-7**. The tap controls should be set no more than 300 mm from the front of the washbasin. It is recommended that a thermostat be installed to limit the temperature of the hot water to a maximum of 40°C in order to prevent scalding. Hot and cold water taps should be identifiable by both colour and tactile markings.

B-9.11 Urinals

Wheelchair users may be able to pull themselves to a standing position to use a urinal, or they may be able to use a urinal from their wheelchair. Ambulant persons with disabilities, for example crutch users, may need support in front of urinals. Bowl urinals are preferable to slab urinals for the benefit of visually impaired.

When wall hung urinals are fitted in the washroom, it is recommended that at least one of these have its rim set at a height of 380 mm for wheelchair users and at least one have its rim set at a height of 500 mm for standing users/ambulant disabled. When installed, both should be equipped with a vertical grab rail. Urinals shall be minimum 360 mm deep measured from the outer face of the urinal rim to the back of the fixture.

The lower urinal position as shown in Fig. 83 is also beneficial to a person of lower stature. Where an

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accessible urinal is provided, the accessible approach to the same shall be ensured. This wall hung urinal should be set clear above the floor level, without any raised access platform and with a clear floor area in front of the urinal of at least 760 mm wide and 1 220 mm deep to allow forward approach for ambulant disabled and minimum of 900 mm × 1 350 mm for wheelchair users to use the urinals (*see* Fig. 84). Urinals should contrast visually with the wall to which they are attached.

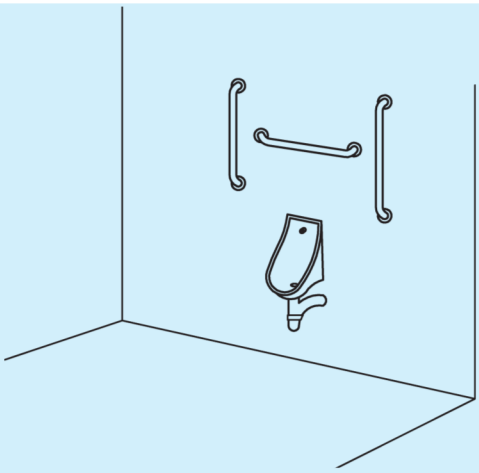
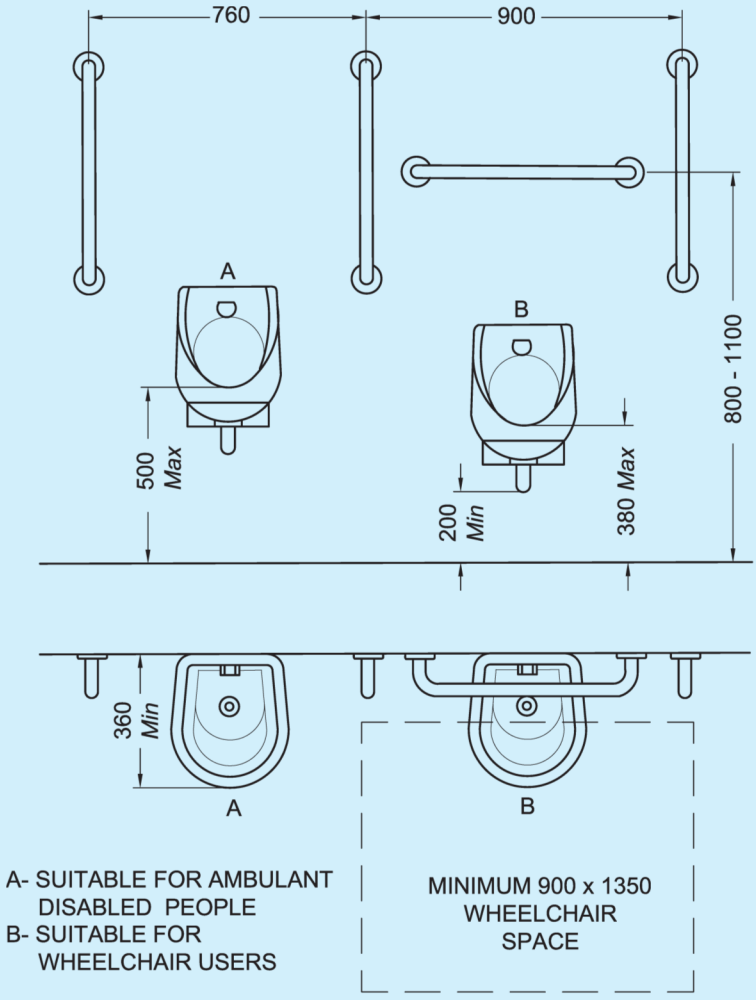


FIG. 83 URINAL FOR WHEELCHAIR USERS

B-9.12 Alarm

An assistance alarm, which can be reached from changing or shower seats, from the WC and by a person lying on the floor, shall be provided in all accessible toilets and accessible sanitary rooms. This alarm should



NOTE — Urinals shall be minimum 360 mm deep measured from the outer face of the urinal rim to the back of the fixture. Space below the urinal set for wheelchair users should be kept free of pipework up to a height of 200 mm above floor and up to a depth of 360 mm from the outer face of the urinal rim.

All dimensions in millimetres.

FIG. 84 CLEAR FLOOR SPACE AND MOUNTING HEIGHTS FOR URINALS

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be connected to an emergency help point, or where a member of staff can assist.

Visual and audible feedback should be provided to indicate that, when the alarm has been operated, the emergency assistance call has been acknowledged and action has been taken.

It should take the form of a pull cord, coloured red, with two red bangles of 50 mm diameter, one set at a height between 800 mm and 1 100 mm and the other set at 100 mm above floor level.

A reset control shall be provided for use if the alarm is activated by mistake. It shall be reachable from a wheelchair and, where relevant, from the WC, the tip-up seat in a shower or changing facility, or the bed in an accessible bedroom. The reset control shall be easy to operate and located with its bottom edge between 800 mm and 1 100 mm above floor level.

For a corner toilet room, the reset button should be above the fixed horizontal grab rail beside the toilet paper holder.

The marking of the reset control shall be both visible and tactile.

B-9.13 Emergency Warning Alarm

A visual emergency alarm shall be provided to alert people who are deaf or hard of hearing in the event of an emergency.

B-9.14 Shower and Changing Rooms

Showers and changing rooms can be used by people with different disabilities and different supporting aids, for instance, wheelchair users, ambulant disabled people, etc, using their own wheelchairs or special shower chairs.

B-9.14.1 *Shower/Changing Room Size and Space*

The shower/change area shall have level entry and have no fixed elements that prevent front and side access.

A self-contained individual shower room or changing room shall have minimum interior dimensions of 2 000 mm × 2 200 mm (*see* Fig. 85 and Fig. 86). *See* **B-9.14.6** for other requirements of individual shower room.

A shower room incorporating a corner accessible toilet room shall have minimum interior dimensions of 2 400 mm × 2 500 mm (*see* Fig. 87). In such cases, the manoeuvring areas may overlap, as shown in Fig. 87.

The minimum clear floor space or wet showering area should be 900 mm × 1 350 mm, with a transfer area of also 900 mm × 1 350 mm in the shower room (*see* Fig. 88).

If two or more shower recesses are provided, at least one shall have the seat on the opposite side.

B-9.14.2 *Shower Floor and Drainage*

The floor in the shower recess shall have a gradient between 1:50 and 1:60 sloping to a floor drain. The area outside the shower recess shall have a gradient between 1:70 and 1:80 draining towards the shower recess.

The floor of the shower shall be slip-resistant even when wet.

The transition into the shower recess shall be level without a step down or a kerb. Where unavoidable the kerb shall not be more than 12 mm high bevelled at a slope of 1:2.

The waste outlet should be centrally located and be a round type outlet, not a channel type, to ensure the stability of the shower chair.

B-9.14.3 *Shower Seat*

The shower should be fitted with a wall mounted, easily operable foldable seat that folds in an upward direction. If a foldable seat is provided, its minimum size shall be 450 mm × 450 mm, and, when folded down, have its top surface set between 450 mm and 480 mm above finished floor and spaced a maximum of 45-50 mm from the rear wall.

The shower seat shall be positioned such that the distance between the centerline of the shower seat and the adjacent wall is 450 mm to 480 mm, and the distance between front edge of the shower seat and the rear wall is 650 mm.

Enclosures for the shower cubicle shall not obstruct transfer from wheelchair onto shower seat.

The fastenings for grab bars and the construction of the foldable seat shall be able to withstand a force of 1.1 kN applied at any position and in any direction.

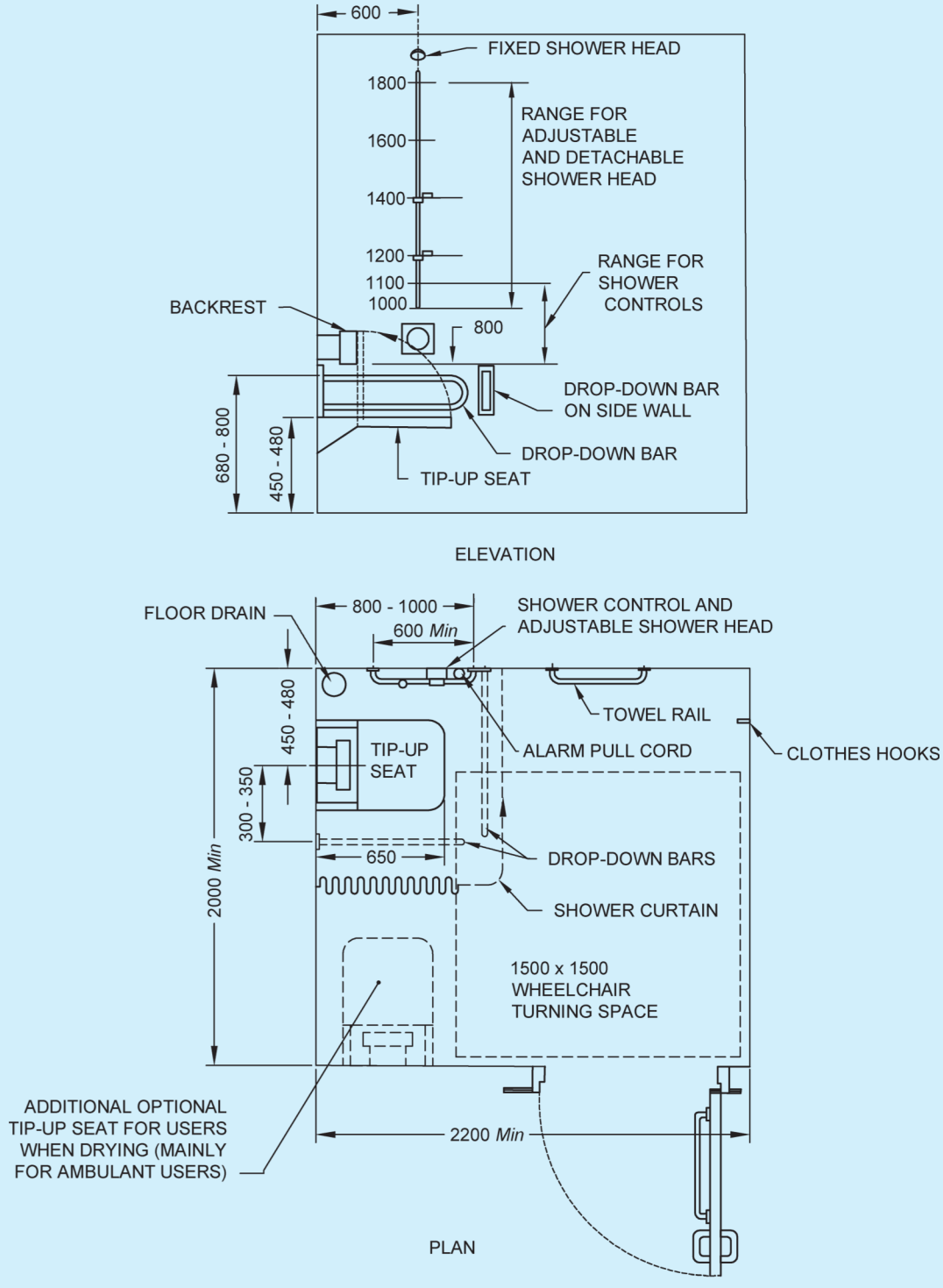
NOTE — Shower wheelchairs are sometimes used instead of shower seats.

The foldable seat shall have the following features:

a) Self-draining;
b) Slip-resistant and stable;
c) Foldable in an upwards direction; when folded, it shall not present a hazard and the grab rail shall be accessible from the foldable seat;
d) Rounded front corners (radius 10 mm to 15 mm); and
e) Rounded top edges (minimum radius of 2 mm to 3 mm).

The foldable seat should preferably be height adjustable.

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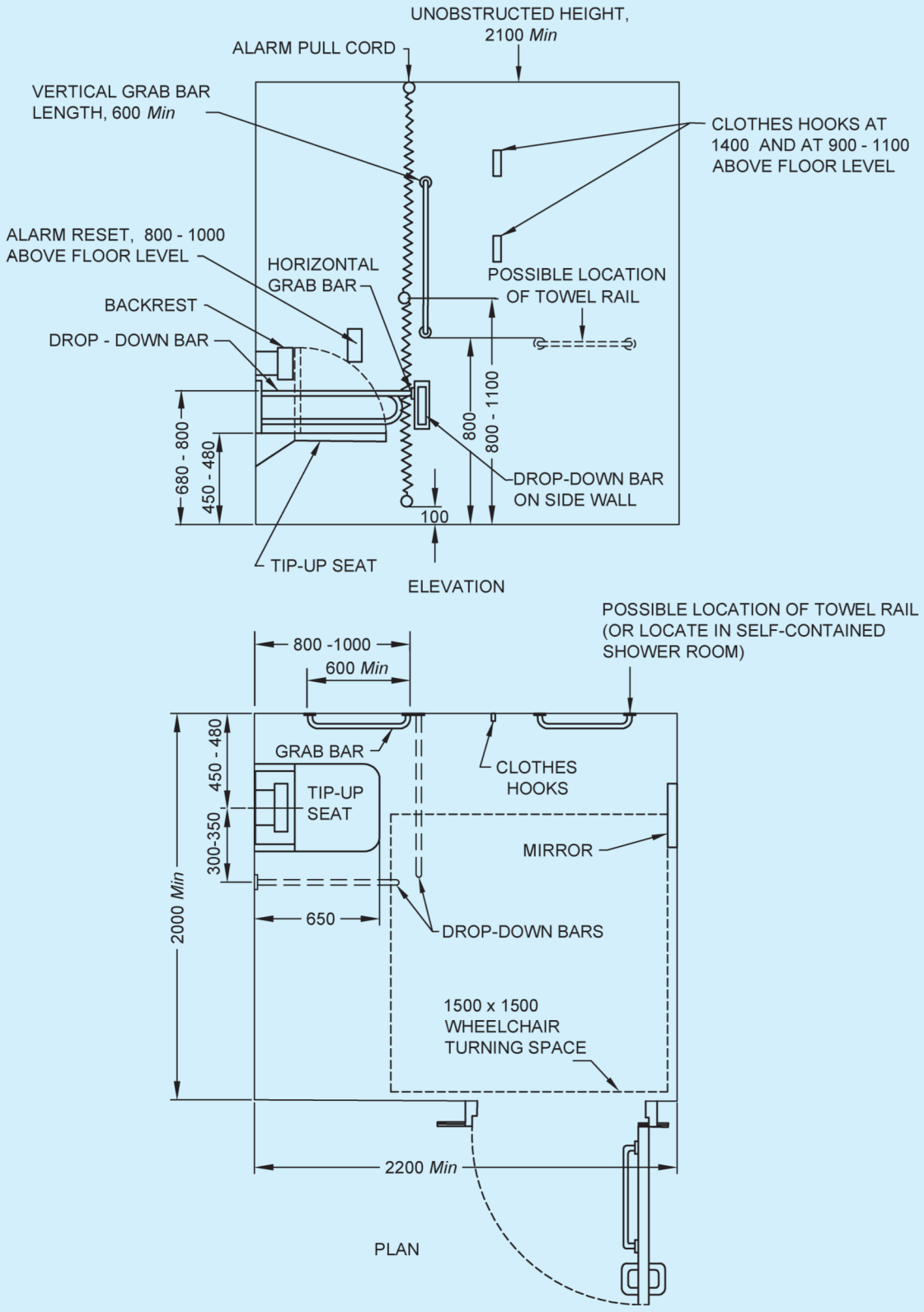


NOTE — Alarm pull cord, horizontal and vertical grab bars, shower curtain bar and towel rail not shown in elevation for clarity.

All dimensions in millimetres.

FIG. 85 SELF-CONTAINED SHOWER ROOM FOR INDIVIDUAL USE

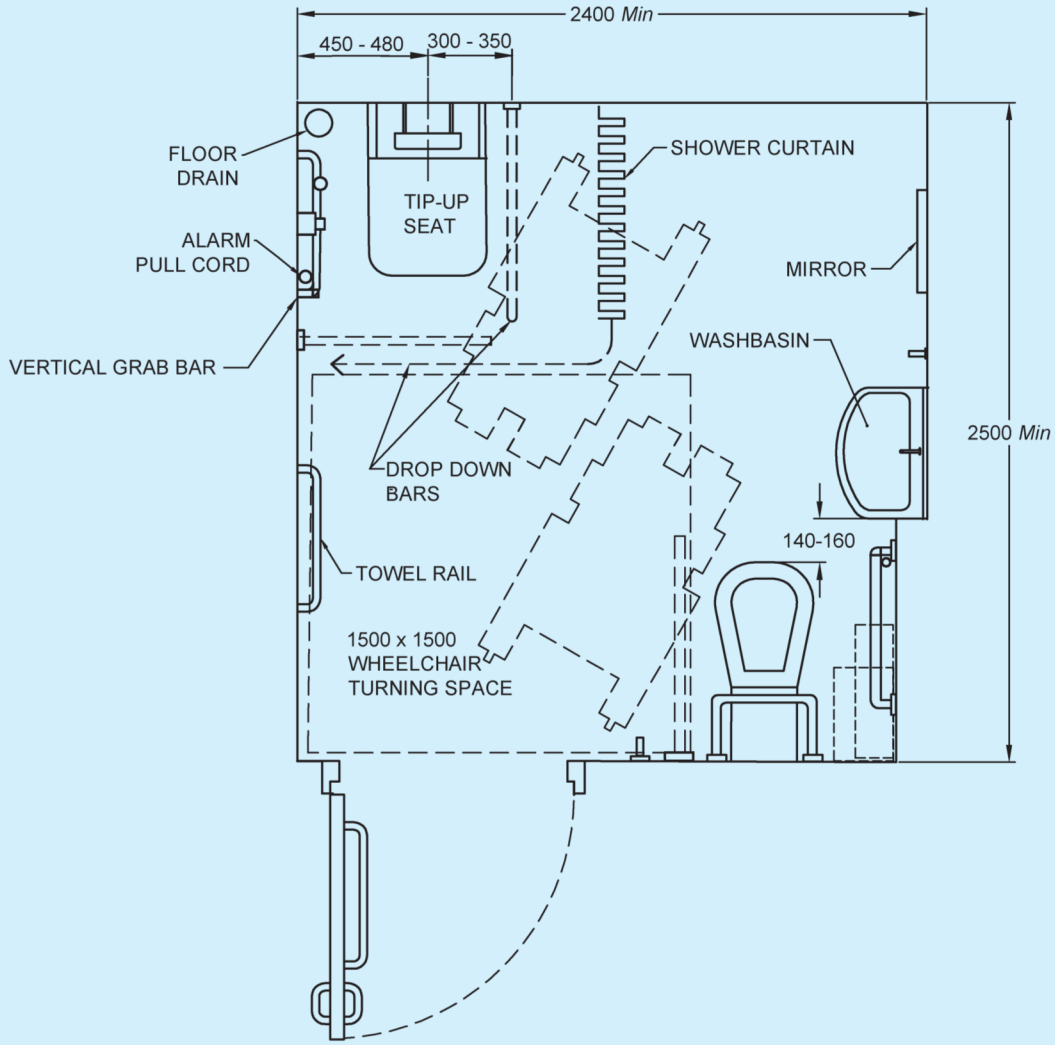
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All dimensions in millimetres.

FIG. 86 SELF-CONTAINED CHANGING ROOM FOR INDIVIDUAL USE

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NOTES
1 Layout shown for right-hand transfer to shower seat and water closet.
2 The larger washbasin are set back 200 mm to maintain the correct relationship of its leading edge with the water closet.

All dimensions in millimetres

FIG. 87 SHOWER ROOM INCORPORATING AN ACCESSIBLE CORNER TOILET FOR INDIVIDUAL USE

B-9.14.4 *Grab Bars*

Grab bars in shower shall be set according to **B-9.6** and Fig. 87. The shower area shall be fitted with at least one vertical grab bar which may hold the flexible shower head.

B-9.14.5 *Stationary, Fittings and Accessories*

The length of the flexible (adjustable and detachable) shower hose (telephone shower/ handheld shower), shall be 1 500 mm minimum. The handheld shower head should be provided between 1 000 mm and 1 200 mm above the finished floor. The shower hose fitting should be a minimum 1 300 mm above floor level.

Shower controls and folding seat shall be set according to Fig. 88. Controls shall comply with **B-7**.

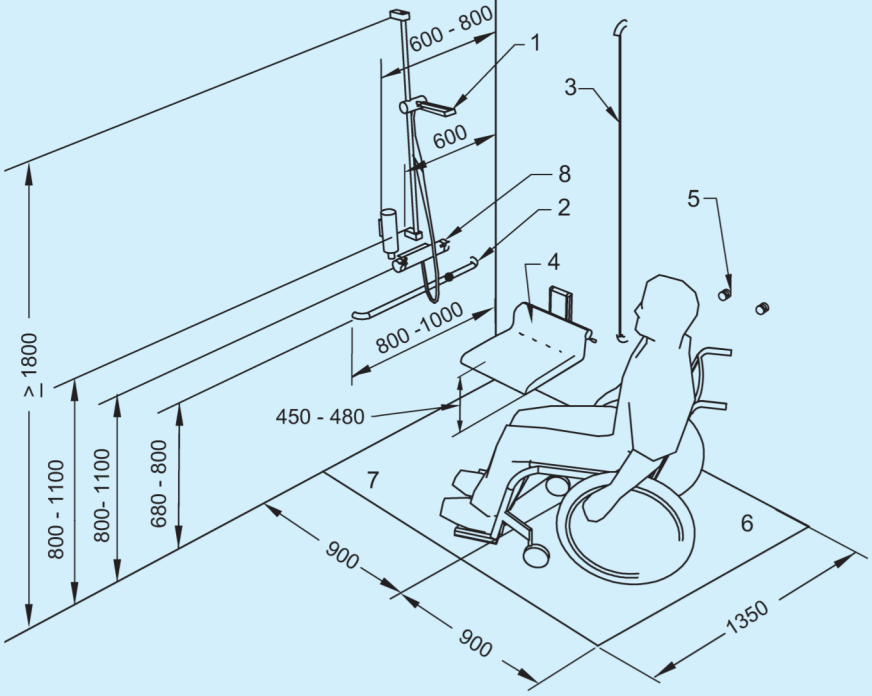
The shower room shall be equipped with a door complying with **B-9.4**. Assistance alarm(s) shall be provided in accordance with **B-9.12**.

B-9.14.6 *Individual Shower Room*

A clear floor space of at least 1 350 mm × 900 mm shall be provided on the clear side of the foldable seat, to allow access from a wheelchair, in addition to the manoeuvring space of 1 500 mm (*see* Fig. 85).

The screening of a shower recess shall be either a curtain or a door system that maintains the required circulation and manoeuvring space and does not interfere with the level entry.

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Key
1 Hand-held shower head
2 Horizontal grab bar
3 Vertical grab bar
4 Foldable shower seat
5 Towel hooks
6 Transfer area
7 Wet showering area with gradient 1 : 50 to 1 : 60
8 Shower controls

All dimensions in millimtres.

FIG. 88 EXAMPLE OF A SHOWER PLACE WITH GRAB RAILS, ADJUSTABLE SHOWER HEAD AND FOLDING SEAT

A shower head support grab bar shall be fixed on the wall in the position shown in Fig. 88.

A hand held detachable shower head shall be provided with a flexible hose of minimum length 1 200 mm, and it shall be able to reach within 100 mm of the shower floor.

An adjustable shower head holder shall be provided to support the shower head, and shall,

a) be installed on the shower head holder support grab bar as shown in Fig. 88;
b) allow the graspable portion of the shower head to be positioned at various angles and heights; and
c) allow the graspable portion of the shower head to be located at heights between 1 000 mm and 1 800 mm above the finished floor.

The fastenings, materials and construction of the seat shall withstand a force of 1.1 kN applied at any position and in any direction.

Grab bars shall be fixed on the walls in the positions shown in Fig. 88. All other devices, for example taps, soap holder, shall be situated in an accessible range between 900 mm and 1 100 mm.

B-9.15 Public Toilets

Public toilets shall also comply with the overall requirements under **B-9** with respect to the facilities provided therein so as to ensure that the same are accessible. In all public toilets, the following shall be provided:

a) Male section shall have one urinal with support grab bars for ambulant disabled and at least one urinal for children at a lower height;
b) Both male and female section shall have one WC for ambulant disabled;
c) One Type A unisex accessible toilet room with independent entrance; and
d) Depending on footfall, one Type B accessible toilet in both male and female toilet groups.

B-9.16 Contrast and Lighting

Fixtures and fittings in sanitary facilities should visually

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contrast with the items and surface on which they are positioned. Use of the same colour everywhere, for example white basins and white tiles, etc, shall be avoided and colour and tonal contrast should be used to differentiate elements in the environment.

Light switches should be fixed inside all accessible toilet cubicles or the light should automatically switch on when someone enters the room. Timed light switches should not be installed or used.

The minimum illumination measured at 800 mm above floor level shall be 200 lux in the area of the washbasin.

B-9.17 Floor Surface

The floor surface shall be slip resistant, anti-glare and firm.

B-9.18 Signage

Signage shall be clearly visible incorporating the international symbol of accessibility and shall comply with the requirements given in **B-24**. Signage for unisex accessible toilet, toilet for ambulant disabled, unisex change rooms or fitting rooms, unisex shower rooms shall be as shown in Fig. 89. Signage for Type B accessible toilet shall also indicate available transfer option, that is, right hand or left hand as shown in Fig. 90.

B-10 RECEPTION AREAS, COUNTERS, DESKS AND TICKET OFFICES

B-10.1 Hearing and Lip-Reading

Reception areas, counters, ticket offices, especially in

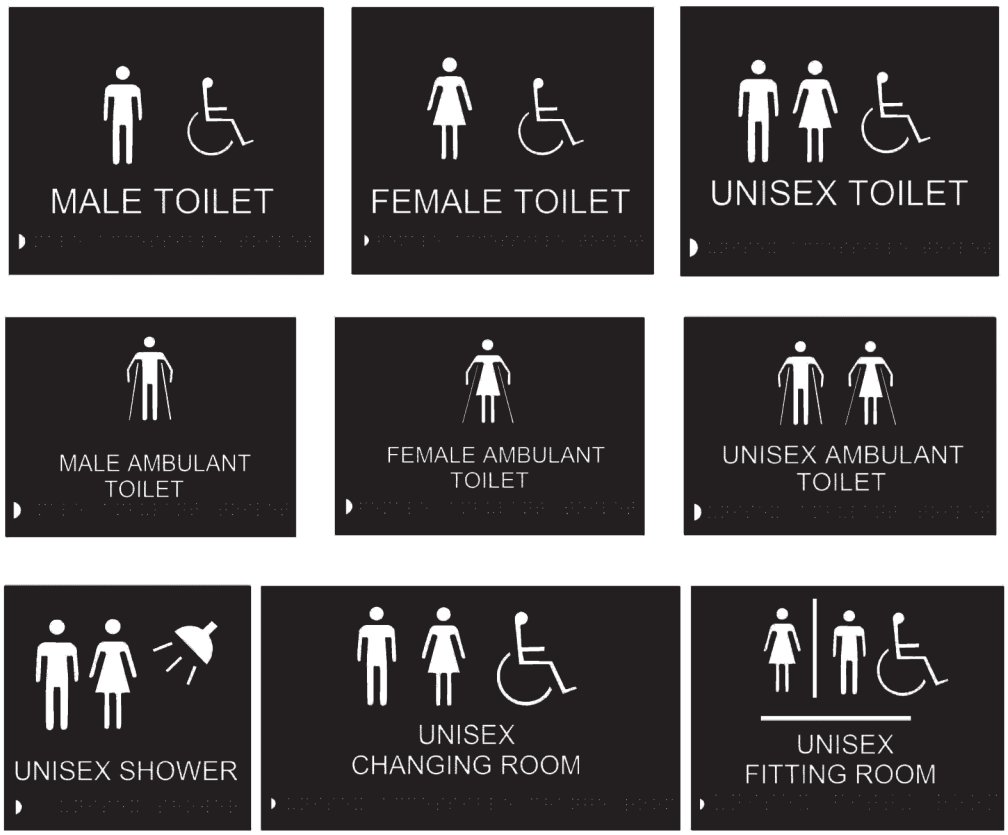


FIG. 89 SIGNAGE FOR DIFFERENT SANITARY FACILITIES

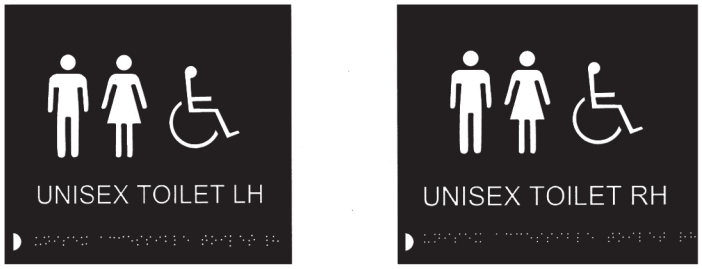


FIG. 90 SIGNAGE INDICATING TRANSFER OPTIONS (RIGHT HAND OR LEFT HAND) IN UNISEX ACCESSIBLE TOILET

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noisy environments or those equipped with a separating security screen, should have at least one position fitted with a hearing enhancement system (for example induction loop system) to assist hearing-aid users, as described in **B-21**, and be clearly marked with the appropriate signage/symbol.

Positioning of service counters in front of windows where bright sunshine may come should be avoided as it causes the user's face to be in shadow and hence difficult to lip-read. Service counters equipped with a service screen are particularly difficult. Reflections and glare should be avoided.

B-10.2 Location

Counters and reception desks should be located and clearly identified so that they are easily recognizable from a building entrance. Information reception areas should be positioned near the main entrance. Entrance flooring systems or tactile ground surface indicators can help in locating reception counters for people who have vision impairment. Such products should be designed to minimize trip and slip hazards.

General design requirements for colour and visual contrast should be considered (*see* **B-24.3**).

B-10.3 Space to Manoeuvre

Counters, desks and ticket offices should be accessible to wheelchair users on both sides. A clear manoeuvring space at least 1 500 mm × 1 500 mm shall be provided in front of the counter on the receptionist's side and on the visitor's side; 1 800 mm × 1 800 mm is preferred.

B-10.4 Height

B-10.4.1 The counter level shall be between 750 mm and 800 mm from the floor. Clear knee space underneath shall be minimum 700 mm (*see also* Fig. 91).

B-10.4.2 Reception desks where writing is done by the visitor (for example at hotel receptions) should allow frontal approach by wheelchair users with space to provide clearance for wheelchair user's knees. The counter level and clear knee space underneath shall be as per **B-10.4.1**. At least a part of the desk should also be at a height suitable as a writing place for standing people, between 950 mm and 1 100 mm (*see* Fig. 91).

B-10.5 Lighting

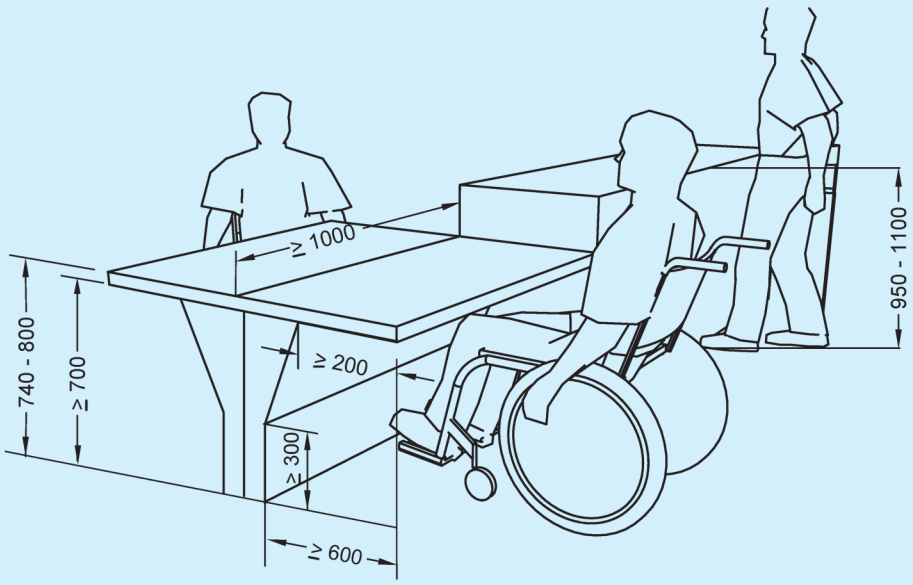
To facilitate lip reading, lighting should provide even illumination. The reading and writing surfaces at counters, desks and ticket offices shall be illuminated to a level of at least 200 lux in the room, and on the desk in a range of 350 lux to 450 lux.

B-10.6 Ticket Systems

If a queue number ticket system is used, it shall be suitably designed to be accessible. All control devices shall be located according to **B-7**. All necessary information shall be given in simple wording with sufficient visual contrast and based on the two-sense-principle (*see* **B-7**, **B-21**, **B-24.1.2**, and **B-24.3**). The ticket machine and the calling system shall provide visual and audible output.

B-11 CLOAKROOM

Attended cloakrooms are staffed rooms where bags/luggage/other articles can be stored securely. Typically, a ticket or receipt is given to the customer, with a



All dimensions in millimetres.

FIG. 91 HEIGHTS OF COUNTERS SUITABLE FOR WHEELCHAIR USERS AND PEOPLE STANDING

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corresponding ticket attached to the garment or item. A cloakroom shall comply with the requirements given for reception/counters (*see* **B-10**).

B-12 AUDITORIUMS, CONCERT HALLS, SPORTS ARENAS AND SIMILAR SEATING

B-12.1 Hearing Enhancement Systems

A hearing enhancement system should be provided. The system should also be provided on the stage/platform (*see* **B-21**).

B-12.2 Lighting for Sign Language Interpretation

Adequate provision should be made to facilitate sign language and lip reading. Lighting on the faces and hands of presenters and people signing should be provided at an angle of 45° to 50° from horizontal at ceiling level for people with a hearing impairment to be able to read the presenter's lips and the signer's lips and hands. A suitable contrasting backdrop should be provided, to assist in reading the presenter's lips and hands.

B-12.3 Designated Seating Areas for Wheelchair Users

At least 1 percent of seats shall be designated as seating areas (*see* **B-8** for requirements of seating spaces) for wheelchairs users, with a minimum of two.

For total seats exceeding 51, it is recommended to provide the designated seating areas in the following manner:

a) Total seats 51 to 100, minimum three designated seating areas for wheelchair users;
b) Total seats 101 to 200, minimum four designated seating areas for wheelchair users; and
c) One additional seating area should be provided for every two hundred additional seats or part thereof.

These spaces should be integrated among other seats and allow two wheelchair users to stay together. It is recommended that the armrest on the seats at the end of the row lift up to allow people to transfer from the wheelchair onto a seat. To accommodate groups of wheelchair users, in an auditorium with fixed seats, a minimum of 15 seats shall be foldable or removable to increase the number of designated areas for wheelchair users when necessary.

Some seats should be wider in order to allow larger size people to sit properly.

B-12.4 Access to Stage and Backstage

Access to the stage and to the backstage area shall be provided. Adequate provision should be made to direct the user to the designated spaces.

B-12.5 Row and Seat Numbers

The row and seat numbers should be legible to people who have impaired vision. They should be tactile, of adequate size and have enough visual contrast to the background on which they are mounted. The requirements given in **B-24** should also be considered.

B-12.6 Accessible Changing Rooms

The minimum number of accessible changing rooms should be provided depending on the type and use of the building.

In the event that changing rooms are provided alongside a toilet area, these should comply with the specifications given in **B-9.14**.

A fixed bench should be set at a height of 450 mm to 480 mm above floor level. The bench should be no less than 500 mm wide, 2 000 mm in length, and be provided with a grab bar at a height of 700 mm to 800 mm with a clearance of between 50 mm and 65 mm from the wall.

A clear space of 1 500 mm × 1 500 mm shall be beside the bench.

Coat hooks should be set at different heights, 900 mm to 1 100 mm, and additionally at least one hook at 1 400 mm.

Coat hooks, benches, locker handles and other furnishings should offer good colour and tonal contrast to their backgrounds. Non-slip floor surfaces should be used, and good lighting as well as matte finished surfaces and furnishings should be provided.

An alarm/call bell/switch may be provided (*see* **B-9.12**).

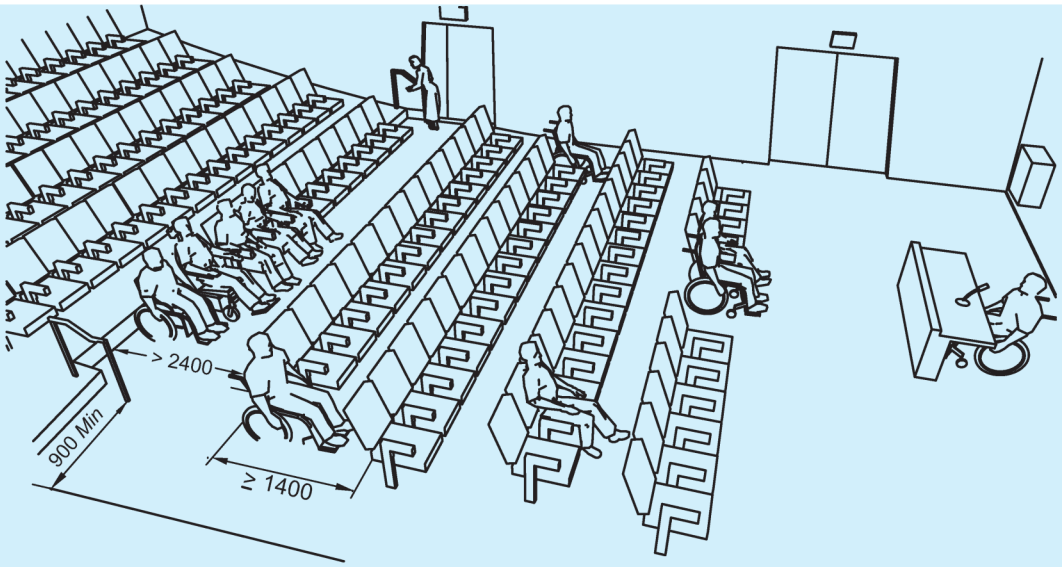
Changing rooms shall have a minimum area of 4 m^2.

B-13 CONFERENCE ROOMS AND MEETING ROOMS

The requirements for sufficient acoustic provision shall be provided in conference rooms and meeting rooms. Accessible toilet facilities, as per **B-9** should be as near as possible to such rooms. A sound augmentation system should be provided. Reverberation time for speech, music, etc, should be as per Part 8 'Building Services', Section 4 'Acoustics, Sound Insulation and Noise Control' of the Code.

All equipment in conference rooms shall be usable by people chairing or participating in the meeting and shall be at a height between 800 mm and 1 000 mm. *See also* **B-7** for requirements of controls and operating devices.

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All dimensions in millimetres.

FIG. 92 EXAMPLES OF VIEWING SPACES FOR WHEELCHAIR USERS

B-14 VIEWING SPACES IN ASSEMBLY AREAS

B-14.1 Floor Area

The floor area for a wheelchair viewing space shall be connected to an accessible path of travel and shall meet the following requirements (*see* Fig. 92):

a) It shall be at least 900 mm × 1 400 mm;
b) The depth of the row shall be minimum 2 400 mm;
c) It shall have clear and level surface;
d) It shall have sufficient manoeuvring space;
e) Spaces for several wheelchair users shall be provided. They shall be located beside regular seating rows, for the wheelchair user to be able to stay by his/her accompanying person, if relevant; and
f) It is recommended that the armrest on the seats at the end of the row (aisle seats) lift up to allow wheelchair users to transfer from the wheelchair onto a seat.

Some seats should be provided with foldable armrests, considering transferences (*see* **B-12.3**); some other seats should be wider, considering larger size people.

B-14.2 Sight Lines

Wheelchair user viewing spaces shall provide viewing spaces that are,

a) comparable to those for all viewing positions with a minimum unobstructed eye level up to 1 200 mm; and
b) not reduced or obstructed by standing members of the audience.

Row and seat number identification signs shall be legible to persons who are visually impaired (*see* **B-24**).

B-15 BARS, PUBS, RESTAURANTS, ETC

In restaurants a minimum of 25 percent of the tables shall be usable by wheelchair users according to **B-8.3**. In bars, a minimum of 25 percent of bar counters shall not be more than 800 mm height, and shall have an unobstructed lateral access for wheelchair users.

Sufficient manoeuvring space between tables and the route to the accessible toilet facilities shall be provided.

The general design requirements for colour and visual contrast should also be considered, as described in **B-24.3**.

In self service restaurants, tray slides and counters shall be mounted at 800 mm from the floor for wheelchair users. Food shelves shall be mounted at a maximum height of 1 200 mm and aisle space of minimum 900 mm shall be provided. Where stools and high tables are provided, low tables suitable for wheelchair users shall be provided. Cantilevered table or tables with straight legs at each corner are preferable to central pedestals that might restrict wheelchair access.

B-16 TERRACES, *VERANDAHS* AND BALCONIES

Terraces, *Verandahs* and balconies shall be accessible to all people, including people with mobility impairments.

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Parts of these facilities should be covered with a canopy, to give shelter against the weather (sun/rain/snow).

Walking surfaces shall be slip resistant.

B-17 ACCESSIBLE BEDROOMS IN NON-DOMESTIC BUILDINGS

The access to accessible bedrooms in non-domestic buildings (that is hotels, guesthouses, etc) shall comply with the requirements outlined in this annex and in particular with **B-4** and **B-5**. The minimum number of accessible bedrooms in non-domestic buildings shall be in accordance with Table 8.

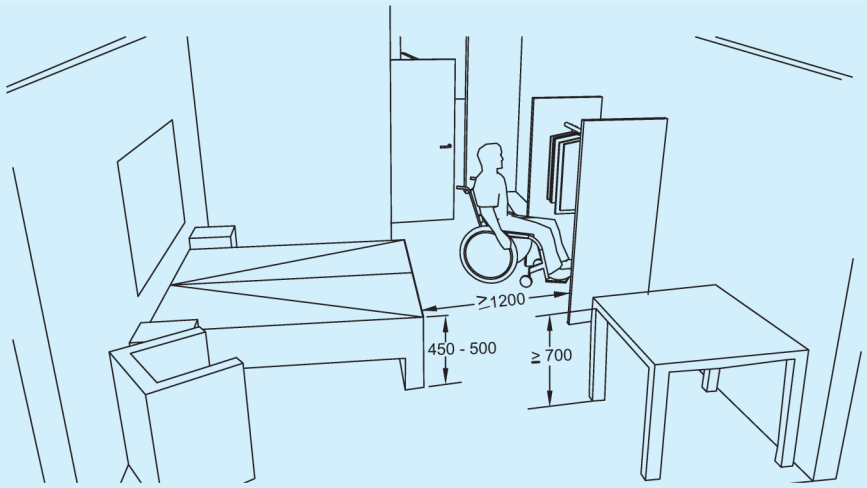
Rooms accessible for wheelchair users shall be designed for two beds. If a single bedroom accessible for wheelchair users is provided, a queen size bed is preferred, 1 500 mm width × 2 000 mm length.

Free space on at least one of the long sides of the bed shall be provided. This space should be 1 500 mm, and shall not be less than 1 200 mm. At the foot of the bed, at least 1 200 mm is required (*see* Fig. 93 and Fig. 94).

Sufficient clear manoeuvring space is needed to gain access to facilities, including the shower.

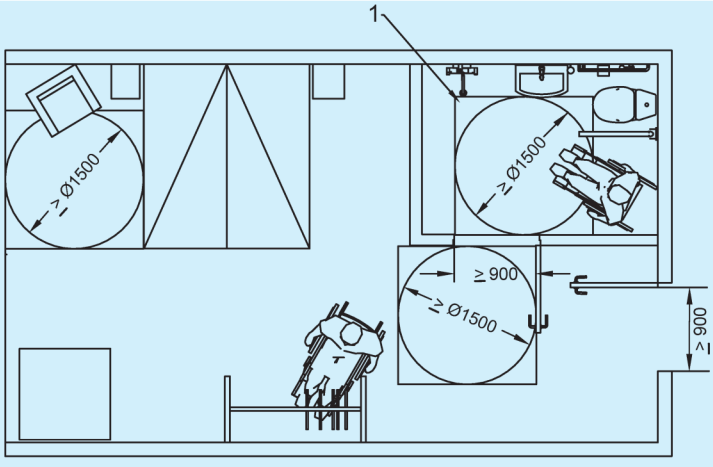
There should be a bench for luggage at a height between 450 mm and 650 mm.

The minimum height of a bed shall be between 450 mm and 500 mm, when it is compressed under a 90 kg weight.



All dimensions in millimetres.

FIG. 93 EXAMPLE OF SPACE ALLOWANCES FOR ACCESSIBLE BEDROOM



Key
1 Shower area

All dimensions in millimetres.

FIG. 94 EXAMPLE OF SPACE ALLOWANCES FOR ACCESSIBLE BEDROOM AND TOILET/SANITARY ROOM

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For communication for people with hearing, vision and cognitive limitations, *see* **B-21**.

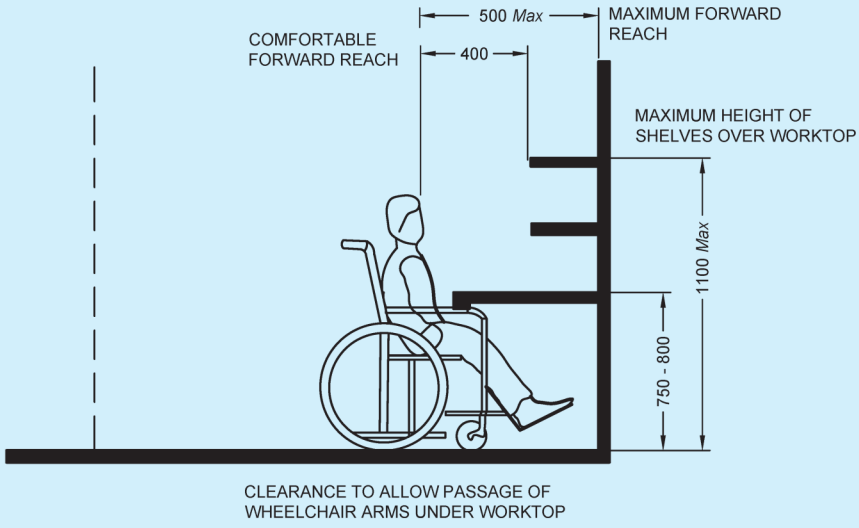
Visual and audible alarm systems shall be accessible to warn people with visual and hearing impairments.

Figures 87 and 88 shall be considered for accessible shower with an accessible toilet.

B-18 KITCHEN AREAS

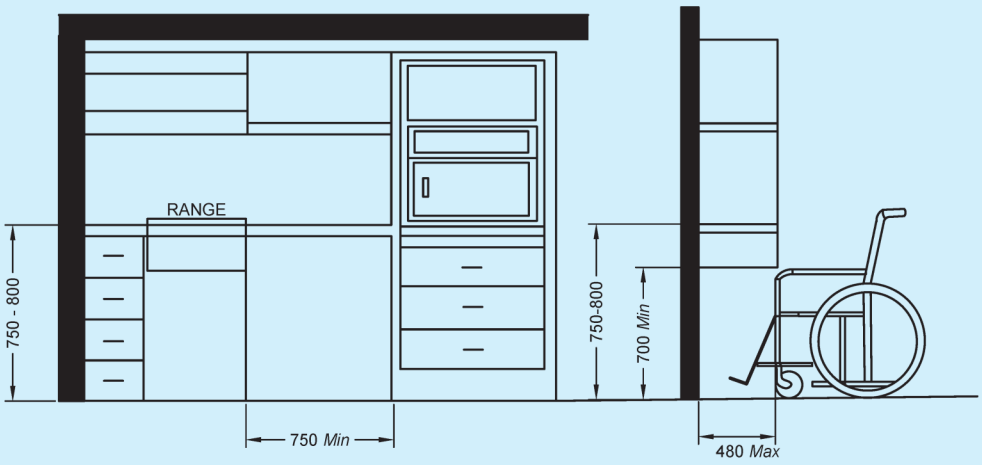
Kitchen areas shall take into account general design considerations in respect of manoeuvring space, slip resistant walking surface and accessible height of controls and devices. Wheelchair turning radius of at least 1 500 mm should be provided between the counter and the opposite walls. Floor surface should allow for easy wheelchair manoeuvrability. Essential kitchen appliances (oven, refrigerator, etc) should be usable by persons both standing and sitting in a wheelchair, and a worktop should be located beside all appliances.

The sink taps should be reachable and easy to operate with one hand. The sink should be reachable for a wheelchair user. If a knee recess is provided under a sink, its underside should be insulated. Counter tops should be between 750 mm and 800 mm in height and provide for clear knee space for a wheelchair user. The clear knee space for a wheelchair user is at least 900 mm wide, 480 mm deep and 680 to 700 mm high (*see* Fig. 95 and Fig. 96). Counter tops/slabs should have rounded edge. All surfaces should be smooth to facilitate sliding of heavy items from one area to another. Slide-out working spaces are useful in providing an over-the lap working surface. For people with ambulatory disabilities, stools (preferably with



All dimensions in millimetres.

FIG. 95 REQUIREMENTS FOR COUNTER TOP



All dimensions in millimetres.

FIG. 96 KITCHEN SHELVES AND CABINETS

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back and foot rests) should be provided strategically at the main work area.

A section of the shelves should be within reaching distance for a wheelchair user, between 300 mm and 1 100 mm above floor surface.

All controls and operating mechanisms should comply with **B-7.**

B-19 STORAGE AREAS

The minimum manoeuvring space and reachability for wheelchair users should be taken into consideration when designing and constructing a storage area. Part of the shelves should be within reaching distance for a wheelchair user, between 300 mm and 1 100 mm above the floor. If a door is provided, it should open outwards.

B-20 ACCESSIBLE HOUSING

B-20.1 Exterior, Entrance and Access within the Building

The site planning and development, approach to the building and access at entrance and within the building shall be in accordance with **B-2**, **B-4** and **B-5**.

B-20.2 Interior

B-20.2.1 *Furniture Arrangement*

Sufficient manoeuvring space should be made available (at least 1 500 mm turning radius) for wheelchair user or person ambulating with an assistive device such as a walking frame or a white cane. Clear passage should be allowed from one room to the other. Unrestricted access should be provided to electrical outlets, telephones and wall switches. All controls and operating mechanisms shall comply with **B-7** and a clear floor space for the wheelchair, of at least 900 mm × 1 200 mm should be provided in front of all the utilities and furniture.

B-20.2.2 Floor Surface

Floor surface shall comply with **B-5.2.7**.

B-20.2.3 *Doors and Windows*

Doors and windows shall comply with **B-5.3** and **B-5.4**, respectively.

B-20.2.4 Vertical circulation within the house shall be in accordance with **B-6**.

B-20.3 Bedroom

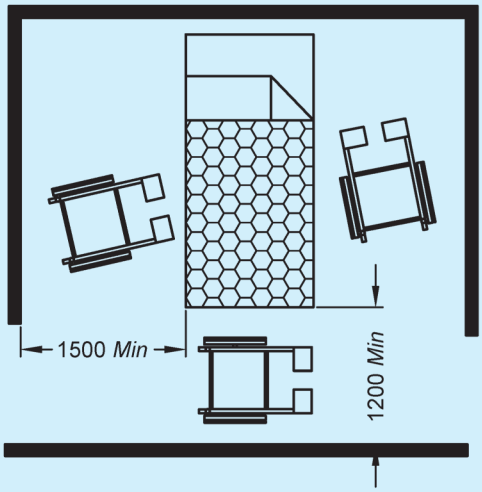
The bedroom should be planned to provide a 1 500 mm turning in space for wheelchair, at least near all the doors. There should be a clear floor space of at least 900 mm × 1 200 mm in front of all furniture.

The minimum height of a bed shall be between 450 mm and 500 mm, when it is compressed under a 90 kg weight. Stability may be improved by placing the bed against a wall or in corner of the room (except for when the wheelchair user plans to make the bed). The bed should be so positioned so as to provide free space on at least one of the long sides of the bed. This space should be 1 500 mm, and shall not be less than 1 200 mm. At the foot of the bed, at least 1 200 mm is required (*see* Fig. 97).

A bedside table or cabinet between 450 mm and 900 mm from the floor may be useful to hold a lamp, telephone, necessary medications and a call bell if assistance is needed.

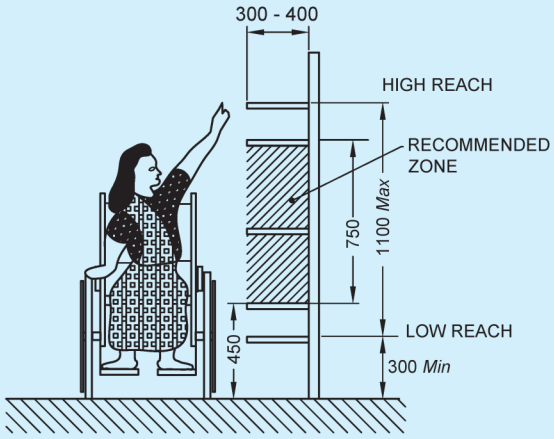
Wall hook installed at a height of 1 100 mm to 1 300 mm may be a useful addition to the closet area.

The closet should have a clear floor space of at



All dimensions in millimetres.

FIG. 97 SPACE AROUND BED



All dimensions in millimetres.

FIG. 98 STORAGE SPACE

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least 900 mm × 1 200 mm. It should have the clothes bar at a height of 1 200 mm from the floor. The shelves should be installed at various levels between 300 mm and 1 100 mm from the floor surface (*see* Fig. 98). The door handle should be conforming to **B-7**.

B-20.4 Living Room

At least 1 500 mm turning in space for wheelchair should be provided near all entry points to the living room. A living-dining combination is preferable to a kitchen-dining combination (except when the wheelchair user does the cooking).

The seating space for a wheelchair user at the dining table should provide a clear knee space. The clear knee space for a wheelchair user is at least 900 mm wide, 480 mm deep and 680 to 700 mm high.

Floor surface should comply with **B-5.2.7**.

There should be a clear floor space for the wheelchair of at least 900 mm × 1 200 mm in front of all the fixtures. Chair seat heights should not be less than 500 mm.

Controls and operating mechanisms should comply with **B-7**.

B-20.5 Toilet or Sanitary Room

Toilet or sanitary room shall comply with **B-9**.

B-20.6 Kitchen

Kitchen shall comply with **B-18**.

B-21 ACOUSTIC ENVIRONMENT

B-21.1 General

The acoustic environment in a building should be suitable for its intended function for all building users. This includes all hearing people especially the hard of hearing. For deaf and hard of hearing people, good lighting is essential to understand the sign language interpreter and/or optical information devices. Many people with some degree of hearing loss have assistive devices to amplify sound, such as hearing aids or cochlear implants.

However, if the acoustic environment is not supportive of these devices, they do not work effectively. In addition, many people who have a mild or temporary hearing loss and do not have assistive devices may not be able to access information or communicate effectively. Most people with hearing loss and people without hearing loss rely on sight to lip read or interpret facial expressions; therefore where the acoustic environment is regarded as important, suitable lighting, colour and visual contrast should be considered to benefit all building users.

Information normally conveyed in visual form may not be accessible to people who are blind or partially sighted. This information should also be conveyed audibly; the clarity (speech transmission index) of this information is affected by the acoustic environment.

The following design considerations should be taken into account to maximize the functionality of the acoustic environment, and to support the use of assistive devices.

B-21.2 Acoustic Requirements

People with hearing impairments have particular difficulty in making out sounds and words in noisy environments. Adequate sound insulation should minimize noise from both outside and inside the building. Noise can often be mitigated, for example by introducing a buffer zone between a meeting area and extraneous noise, or partitioning a restaurant. The acoustics in a room are essentially connected with its location in the building and with the acoustic insulation of the building elements. The distribution of noise within the room itself and from exterior sources depends on the sound absorption of the surrounding surfaces and furnishing of the room. The calculation of acoustic absorption is significant in rooms where acoustic quality is important and also where noise reduction is required.

Good acoustics shall be achieved by optimizing the reverberation time, by considering the use/purpose of the room and by ensuring a low background noise level. The optimum reverberation time of a room should be determined having regard to the volume and the intended purpose of the room.

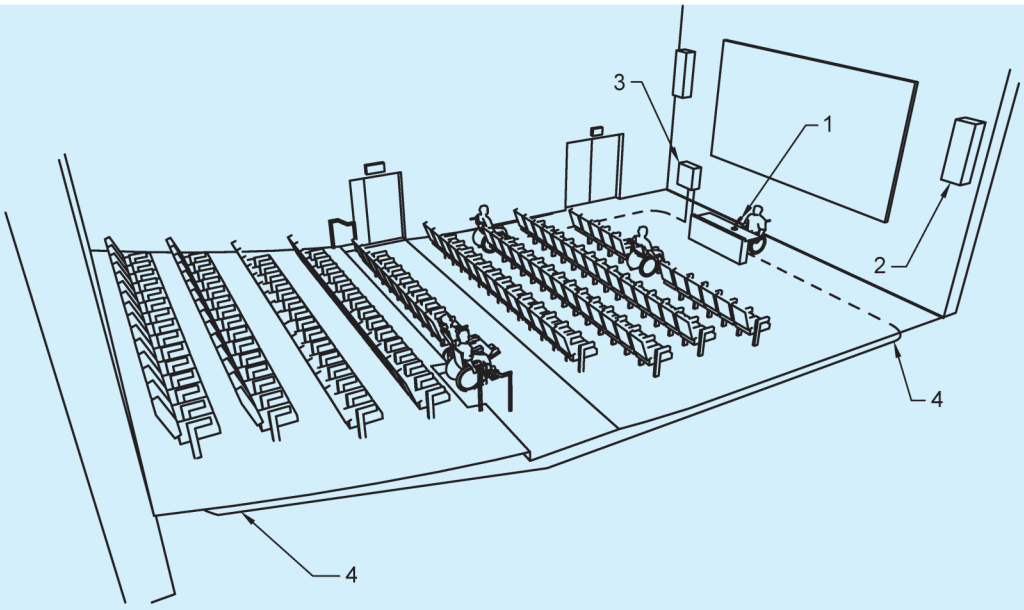
The geometry and shape of the room, as well as the distribution of sound absorbing and reflecting surfaces, are important. Surfaces that absorb sound should be carefully selected, as well as surfaces that reflect it. To develop an effective acoustic environment, sound absorbent surfaces can be used on floors and ceilings.

The optimum reverberation times for communication, speech only or music performance are different and depend on the size and shape of the room. Requirements for reverberation time shall be as per Part 8 'Building Services', Section 4 'Acoustics, Sound Insulation and Noise Control' of the Code.

B-21.3 Hearing Enhancement Systems

A hearing enhancement system fitted at an information point can significantly assist communication for a person with a hearing impairment who uses a personal hearing aid, or has a cochlear implant. Hearing aids or cochlear implants may have a Telecoil (T-switch) which

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Key
1 Microphone
2 Loudspeakers
3 Induction loop amplifier
4 Induction loop

FIG. 99 EXAMPLE OF INDUCTION LOOP SYSTEM IN CONFERENCE ROOM

allows the listener to receive the sound signal directly.

NOTE — Hearing enhancement systems amplify audible communication and can be helpful to people who have a hearing impairment. They include a direct wire system, an inductive loop system, an infrared system, or a radio frequency system. All of these systems transmit a signal. Special purpose receivers are required for infrared and radio frequency systems, while hearing aids equipped with a T-switch are capable of receiving the signal from an induction loop system. Receivers can be equipped to be compatible with hearing aids.

Hearing enhancement systems, for example induction loops and infrared signal transmitting systems, shall be provided in conference and meeting areas. All seats, including the front scene, should be covered by hearing enhancement systems like induction loops (*see* Fig. 99). Portable hearing enhancement systems may be an alternative.

B-22 LIGHTING

B-22.1 General

The planning of artificial lighting should be co-ordinated with the planning of natural lighting, the choice of surfaces and colours. Lighting can be used to accentuate interior colour, tone and texture schemes, and to facilitate orientation. The lighting should not lead to glare or excessive contrast.

B-22.2 External Lighting

The routes to and around a building shall have sufficient artificial lighting to facilitate awareness of changes of level or gradient. The positioning of lights should not cause glare, reflection or shadows. Ramps, entrances, steps, signage, etc, to the building should be well lit artificially, with an illuminance of at least 100 lux.

B-22.3 Natural Lighting

It should be possible to shade windows from bright light.

B-22.4 Artificial Lighting

Lighting should provide visual conditions consistent with the visual task, orientation and safety. Key factors are,

a) level of illumination of horizontal and vertical surfaces;
b) limitation of glare from a light source or reflections;
c) uniformity and luminance distribution;
d) direction of lighting and shading; and
e) colour rendering.

NOTE — Good artificial lighting where needed is crucial for everyone, ensuring that vision impaired people are able to use buildings safely and conveniently, and that people with hearing impairments are able to lip read.

B-22.5 Lighting to Facilitate Wayfinding

Lighting should facilitate wayfinding. Building elements should be marked by increased illumination.

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The lighting in critical locations such as entrances, corridors, stairs, changes of level and workstations should facilitate their identification.

Time dependent switch devices shall have a progressive switch off to reach the next switch. An automatic switch on detection system shall cover the complete surface of ramps and stairs. Lighting shall provide sufficient time necessary for users to travel safely along ramps.

Lighting which switches off when people are still on ramps or stairs should be avoided.

NOTE — Ramps and stairs are the most hazardous places for falls.

B-22.6 Controllable and Adjustable Lighting

All lighting, including natural light, should be controllable to avoid glare. Artificial lighting may be adjustable to suit individual needs.

B-22.7 Light Levels in Different Areas

Good light levels should be provided in hazardous areas such as stairs or changes in levels along a route, around doors and at communication or information systems. A minimum light level should be provided according to the visual task as given in different clauses of this annex.

B-22.8 Lighting in Auditoriums

Lighting conditions that support lip reading and sign language should be provided. The environment should be designed to avoid reflection and glare, and it should be possible to adjust both natural and artificial light.

B-22.9 Glare and Shadows

Lighting should not produce glare. Glare and shadows may be avoided by,

a) shielding or shading light sources;
b) use of indirect lighting;
c) appropriate location of light source in relation to the direction of vision and to the object that is to be observed;
d) up lighters, with light sources at floor or low level, should not be used;
e) avoidance of windows at the end of corridors;
f) avoidance of light sources against dark surfaces by choosing light colours for ceilings or walls; and
g) avoidance of abrupt transitions from light to dark spaces. Indoor and outdoor lighting around the doorway should be suitably adjusted to prevent dazzle when entering or leaving the building.

NOTE — Due to the increase of optical scatter in the eye, the effects of glare are exacerbated for elderly people and for individuals with some types of vision impairments (for example cataracts, corneal edema, and vitreous opacities). Glare can cause discomfort and interfere with task performance by decreasing the perceived contrast in visual displays (that is disability glare).

The provisions given in Part 8 'Building services, Section 1 Lighting and Natural Ventilation' of the Code in respect of glare shall also be complied with.

B-23 EMERGENCY EVACUATION IN BUILDINGS

Means of egress, alarm panel, alerting systems, evacuation plans, emergency evacuation routes, provision of area of rescue assistance/refuge areas and signages in such areas shall be in accordance with Part 4 'Fire and Life Safety' of the Code.

B-24 ORIENTATION AND INFORMATION, SIGNAGE, GRAPHICAL SYMBOLS AND VISUAL CONTRAST

B-24.1 Orientation and Information

B-24.1.1 *General*

The built environment should be designed, constructed and managed to facilitate orientation. Orientation means to find one's way, to avoid obstacles which could cause hazards, and to know when one has reached the destination.

Suitable provision shall be made at the entrance to the building and at decision points within the building to describe the location and nature of the building. In very complex buildings, visual, audible and tactile information should be provided.

Means to achieving satisfactory orientation conditions are,

a) planning layouts;
b) wayfinding and guided paths with TGSI (as given in this annex), other physical support of information (*see* **B-24.3**);
c) signage and symbols (*see* **B-24.2**);
d) visual contrast (*see* **B-24.3**);
e) choice of colours (*see* **B-24.3.2**);
f) avoiding surfaces which might make orientation more difficult;
g) lighting (*see* **B-22**); and
h) visual, audible and tactile information according to the two-sense principle (*see* **B-24.1.2**).

Orientation should be facilitated by differences in acoustics, material, light and colour. The design should indicate the use of the building elements.

To facilitate people with vision impairments who have

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some residual vision, routes to be followed should have a difference in luminance to the surroundings (*see* **B-24.3**).

Additional illumination or visual contrast and tactile information, such as a change in material or tactile walking surface indicators, should be provided at decision points such as entrances, staircases, lifts, etc, to assist orientation and wayfinding.

Tactile ground surface indicators should be used to indicate directional orientation information where no other clues indicate the path of travel. Across large areas, halls and complex buildings, blind people need a tactile route or guiding pattern to follow (*see* **B-2.5**).

In complex buildings, an audible beacon should be installed in addition to visual and tactile information to provide information on decision points.

B-24.1.2 *Principle of Two Senses*

Supportive measures for information and wayfinding shall be provided in a format that is accessible to people with sensory impairments according to the principle of two senses, as given below (*see also* **B-6.4.7**):

a) audible/tactile information for people with vision impairments, and
b) visual information for people with hearing impairments.

B-24.1.3 *Audible Information*

Consideration should be given to provide suitable amplification and acoustic conditions; the message should be easily understandable and unambiguous. *See also* the principle of two senses in **B-24.1.2**.

Public address systems should be clearly audible and equipped with a hearing enhancement system as described as given in **B-21**.

Emergency information and warning systems are described in **B-6.4.8**, **B-9.12** and **B-9.13**.

B-24.1.4 *Levels of Information*

Information should be clear, concise, accurate and timely. Clarity of information can be defined as information that is legible and easily understood. Clarity of information therefore presupposes that people are able to distinguish between the different types of information that they receive.

Information can be divided into three levels,

a) *Level 1* — Safety information;
b) *Level 2* — General information; and
c) *Level 3* — Advertising information.

It is important that these three levels of information be clearly distinguished.

Information should be complete but concise. Too much information is difficult for people to retain.

All information provided should be accurate and consistent.

NOTE — Universally accepted pictograms should be used in preference to text.

B-24.2 Signage and Graphical Symbols

B-24.2.1 *General*

Signs should be readable and legible for people who have vision or mental impairments. Well-illuminated, clear and readable signs shall be placed at a consistent height (*see* **B-24.2.4**).

Information with text should be supplemented with graphical symbols to facilitate comprehension for everyone (*see* **B-24.2.16** for graphical symbols).

Signs should be provided in relief and Braille (*see* **B-24.2.10**).

The signs should be made of robust materials and be easy to change, clean and repair. Some suggested materials for signage are wood, acrylic and aluminium composite panel (ACP).

An excessive quantity of signs in close proximity should be avoided, as well as visual material placed too close to wall fixed signs (for example posters, timetables, etc).

Where Braille is used as a complementary or independent feature to tactile signs it should be easy to locate.

B-24.2.2 *Main Types of Signs*

The main types of signs are:

a) *Orientation signs* — Sketches, plans, models, etc.
b) *Directional signs* — Directional information from point A to B.
c) *Functional signs* — Explanatory information.
d) *Informative signs* — Purely informative, for example a name.
e) *Signs for emergency exits* (*see* Part 4 'Fire and Life safety' of the Code).

B-24.2.3 *Placement of Signs*

B-24.2.3.1 *Placement outside the building*

Informative signs shall be located adjacent to the entrance door and be illuminated and clearly visible. The sign shall be placed on the latch side. Design and size of letters shall be in accordance with **B-24.2.5**.

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Communication systems shall also be placed on the latch side and preferably in a range of 1 000 mm to 1 200 mm above ground level.

B-24.2.3.2 *Placement in the building*

Orientation signs should be located in accessible places adjacent to, but not directly in, main access routes so that they can be examined without disturbance.

In public buildings there should be an orientation plan immediately inside the main entrance. This plan should follow all relevant design criteria stated in this Part and in **B-24.3**.

Directional signs should clearly direct people to the facilities. They should be located where directional decisions are made and constitute a logical orientation sequence from the starting point to different points of destination. They should be repeated, not too often, but every time there is a possibility of alteration in the traffic direction.

Directional signage to washrooms should be provided in all parts of a precinct or building.

Stairwells should have information signs identifying all points of entry and exit.

Floor numbers shall be located on each floor at top and bottom of stairs, on handrails and on each side of the outer frame of each lift-car entrance on each floor and prominently displayed elsewhere so they are visible from the lift car at each level.

B-24.2.4 *Height and Location of Signs*

Directional and functional signs should be located below 1 600 mm where they are easy to approach, to touch and read the raised signs with the fingers (*see* **B-24.2.10** to **B-24.2.12**).

Signs should be located where they are clearly visible to people who are seated, standing or walking.

Signs should be placed between 1 200 mm and 1 600 mm from the floor or ground surface. It should be possible to approach the sign to be read from a short distance (*see* Fig. 100).

Where it is likely that the sign may be obstructed, as in a crowded situation, the signs shall be placed at a height of at least 2 100 mm above the floor. The same requirement applies to signs fixed to the ceiling or projecting from walls. In that case, there should be two signs; one that can be seen from a distance above other people's heads, one as a complement at the height recommended above.

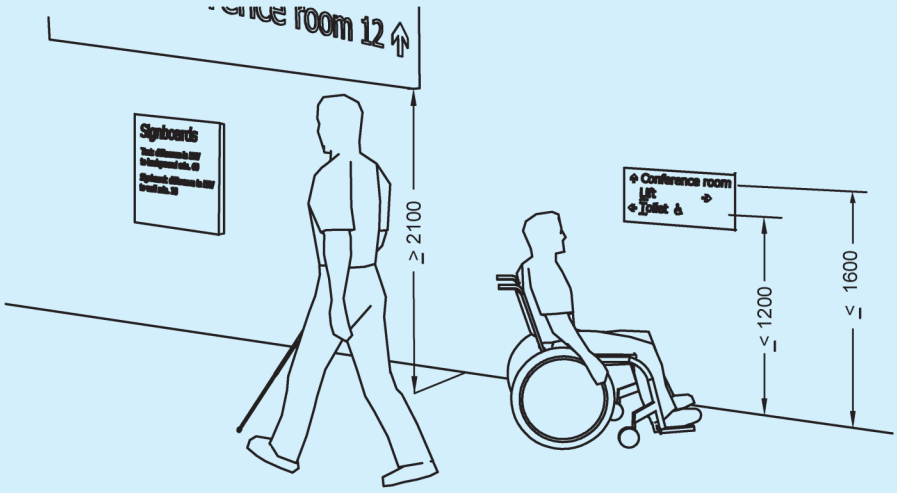
Where there is sufficient space, door signs shall be located on the latch side of the door within 50 mm to 100 mm of the architrave (*see* Fig. 101).

B-24.2.5 *Font and Size of Lettering*

The fonts should be easy to read. The font style should be a sans serif font similar to Helvetica or Arial medium.

The letter height depends on the reading distance. A letter height between 20 mm and 30 mm for each metre of viewing distance is preferred. The letter height should not be less than 15 mm.

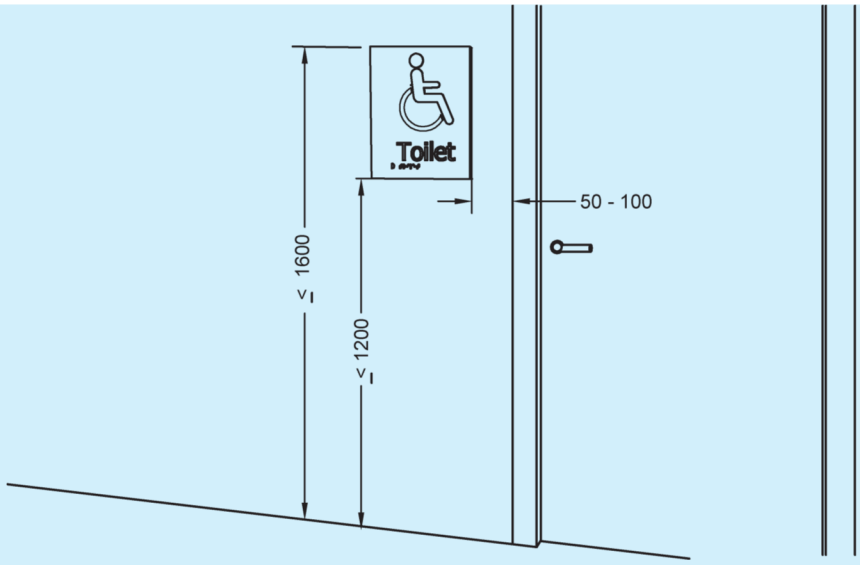
Usage of too many type sizes on any one sign should be avoided. Also italics, script texts, condensed texts, light stems should be avoided. Consistent font stem widths should be used.



All dimensions in millimetres.

FIG. 100 HEIGHT OF SIGNS

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All dimensions in millimetres.

FIG. 101 LOCATION OF DOOR SIGNS ON THE LATCH SIDE OF THE DOOR

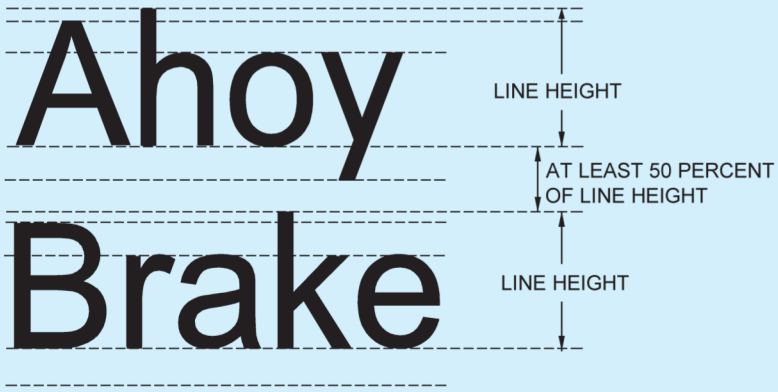


FIG. 102 LINE HEIGHT AND SPACING

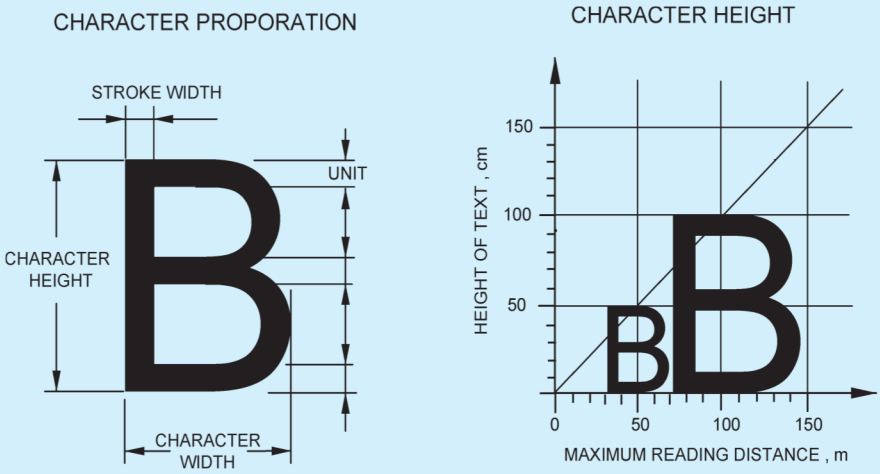


FIG. 103 DIMENSIONS OF CHARACTER IN A SIGNAGE SYSTEM

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It is recommended that messages of single words or groups of words begin with an upper case letter and continue with lower case letters (sentence case).

The words should not be placed too close together. Adequate height spacing should separate the lines. Lines of text should be ranged from a vertical line (unjustified).

Signs with a single word may be centre justified, else the text should be left justified.

The spacing between two lines shall be 50 percent of the line height (*see* Fig. 102).

A style shall be chosen based on a character width-to-height ratio within 3:5 and 1:1 and the stroke width-to-height ratio between 1:5 and 1:10. It shall be consistent for each sign (*see* Fig. 103).

B-24.2.6 *Differences in LRV*

Minimum difference in LRV for small targets, such as signs and inscriptions, to signboards, should be 70 points.

Signboards should have a minimum difference in LRV from the background of 30 points.

Red-green combination should be avoided. Difficulties in perception can also appear when using the colours green, olive green, yellow, orange, pink and red (*see also* **B-24.3** for contrast).

B-24.2.7 *Glare Free*

Signs should be glare free when mounted. This depends on how the sign is placed, the material and the illumination. The background, graphical symbols, logos and other features shall be of a matte or low sheen finish.

B-24.2.8 *Illumination*

Signs should be well illuminated with no glare with uniform lighting over the surface of the sign of between 100 and 300 lux. Minimum acceptable level of lighting for directional signage, maps and text panel is 200 lux. Signs can be luminescent or artificially lit.

B-24.2.9 *Understandable*

Signs should be readily understandable. They should be designed so as to be simple and easy to interpret. The message should be unambiguous.

Short sentences and simple words should be used. Abbreviations and very long words are hard to understand and should be avoided.

B-24.2.10 *Provision of Raised Tactile and Braille signs*

Signs on panels in lifts, room numbers of rooms in hotels, doors to public toilets and so on shall be raised tactile and include Braille (*see also* **B-24.2.4**).

The preferred height of raised tactile information is between 1 200 mm and 1 600 mm. Signs with tactile information placed at a lower height should be mounted at an angle from the horizontal (preferably 20° to 30°, maximum 45°).



Key

1 Raised tactile letters and graphical symbols, height 15 mm to 55 mm, minimum relief 0.8 mm (1 mm to 1.5 mm relief is preferred)

2 Braille text

3 Braille Locator

FIG. 104 EXAMPLE OF RAISED TACTILE SIGNS AND BRAILLE

B-24.2.11 *Tactile Letters, Figures, Signs and Graphical Symbols*

The height of letters, figures, signs and graphical symbols shall be between 15 mm and 55 mm (*see* Fig. 104).

The minimum height of its relief shall be 0.8 mm; a height between 1 mm and 1.5 mm is preferred (*see* Fig. 104).

The profile of the relief should be shaped as a rounded upside-down turned letter V.

B-24.2.12 *Braille*

Where an arrow is used in the tactile sign, a small arrow shall be provided for Braille readers.

On signs with multiple lines of text and characters, a semi-circular Braille locator on the left margin shall be horizontally aligned with the first line of Braille text.

Braille should be raised, domed and comfortable to touch. It should be located 8 mm below the bottom line of the text and be left justified.

Common alternative formats may be used to assist people with visual impairments who are best able to interpret information through hearing or touch. Embossed letters, raised pictograms and raised arrows are tactile features that may be incorporated into signs, which may be particularly helpful to persons with visual impairments.

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B-24.2.13 *Tactile Symbols*

Tactile symbols applied on handrails, doors, maps or floor plans shall have a raised relief contour similar to tactile letters.

B-24.2.14 *Tactile Maps and Floor Plans*

Only essential information should be included on a tactile map or floor plan.

Tactile maps shall be angled between 20° and 30° from the horizontal for ease of reading, and the bottom edge shall be at a minimum height of 900 mm. The map should have a level of illumination between 350 lux and 450 lux, without glare.

The key should be located at the bottom of the map and left justified. The use of a recessed Braille locator on the left hand side should assist in locating the legend.

The map shall be orientated with the building.

B-24.2.15 *Information Displays*

If video and media information displays are used, they should be placed at a height according to **B-24.2.4** and their lettering, etc, should be in conformity with the recommendations above.

Glare from artificial and natural lighting on the screen shall be avoided by,

a) positioning the display or the screen out of direct light; or
b) shading the display or the screen.

A complementary audible information system should be provided.

B-24.2.16 *Graphical Symbols*

The international symbol of accessibility (*see* Fig. 105) shall be replicated consistently in all wheelchair signage. The preferred colour is navy blue with white lettering.

Graphical symbols should be used in conjunction with building signage system, wherever possible.

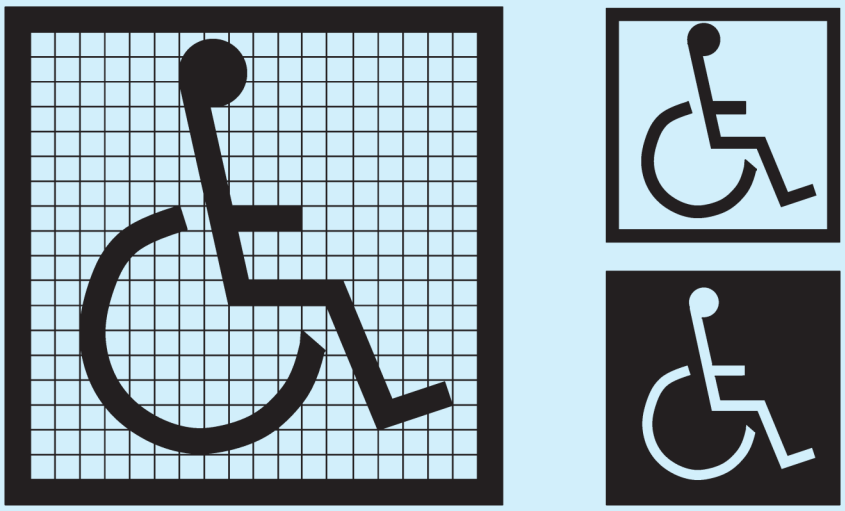
Graphical symbols shall be highly contrasted with a minimum difference in LRV of 70 points and properly illuminated. They shall be used on guides and directional signage (*see also* **B-24.3**).

Graphical symbols on directional and door signs should be tactile, and should be accompanied by raised lettering and Braille (*see* **B-24.2.13**). Signs above a height of 1 600 mm do not need to be tactile, nor to include raised lettering or Braille information.

The size of graphical symbols is dependent on the viewing distance (*D*). The minimum size of the inner outline of the frame of graphical symbols (s) can be derived from formula $s = 0.09\ D$, applicable for a viewing distance of 1 000 mm to 10 000 mm.

The following accessible graphical symbols shall be used to denote particular components of a facility. The following facilities for disabled persons shall be marked as:

a) Those relating to people with mobility impairments,
   1) car parking places (parking places, garages);
   2) access and entrances without steps to buildings, especially where they are not identical with the main entrance;
   3) accessible lifts, in cases where not all lifts are accessible; lifting platforms and similar mounting devices;



105A PROPORTIONS 105B DISPLAY CONDITIONS

FIG. 105 INTERNATIONAL SYMBOL OF ACCESSIBILITY

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NOTE — This graphical symbol also indicate full accessibility or accessible toilets.

FIG. 106 ACCESSIBLE FACILITY OR ENTRANCE



FIG. 107 SLOPED OR RAMPED ACCESS



FIG. 108 TOILETS ACCESSIBLE, FEMALE AND MALE



FIG. 109 TOILETS ACCESSIBLE, FEMALE



FIG. 110 TOILETS ACCESSIBLE, MALE

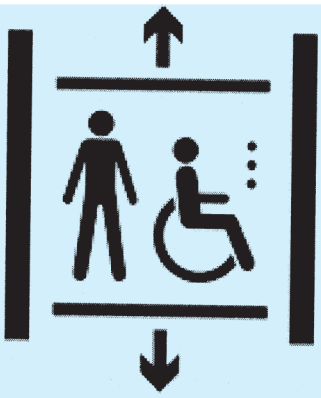


FIG. 111 ACCESSIBLE LIFT



FIG. 112 ACCESSIBILITY, BLIND OR LOW VISION

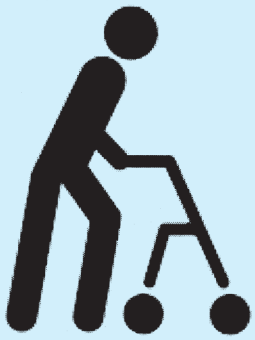


FIG. 113 ACCESSIBILITY, LIMITED WALKING CAPABILITY

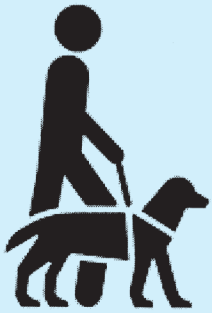


FIG. 114 ACCESSIBILITY, ASSISTANCE DOG

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FIG. 115 ACCESSIBILITY, HARD OF HEARING



FIG. 116 ACCESSIBILITY, PERSONAL ASSISTANT AVAILABLE



FIG. 117 ACCESSIBILITY, VISION IMPAIRED

4) accessible sanitary rooms;
5) wheelchair viewing spaces and accessible seating;
6) changing rooms; and
7) steps or hoists providing access to swimming pools.

b) Those relating to people with vision impairments: locations where audible and tactile information is provided.

c) Those relating to people with hearing impairments,
   1) telephones and emergency call facilities, equipped with sound amplification; and
   2) provision of an assistive listening system.

Some of the graphical symbols relevant to accessibility are shown in Figs. 106 to 118.

B-24.3 Visual Contrast

B-24.3.1 *General*

In order to facilitate orientation and to ensure safe use of an environment, adjacent surfaces, information and potential hazards shall provide a discernible visual contrast.

A minimum difference in LRV shall be provided in relation to the visual task in accordance with Table 11. Additionally, one of the two surfaces should have an LRV value of minimum 30 points for door furniture, 40 points for large area surfaces and 70 points for potential hazards and text information.

The minimum difference in the LRV shall be achieved and maintained throughout the life of the building elements. Deterioration and maintenance shall be considered at installation.

For lighting conditions lower than specified in this Code, the difference in LRVs should be higher.

NOTES

1 The LRV, sometimes also called the luminance reflectance value, or CIE Y value, is expressed on a scale of 0-100, with a value of 0 points for pure black and a value of 100 points for pure white.

2 The perception of visual contrast increases with better lighting conditions.

3 Reflections and glare from shiny surfaces can reduce visual contrast and can confuse people with vision impairments.



NOTE — Fig. 118 is a combination sign which combines a safety sign and one or more associated supplementary signs on the same rectangular carrier. The signs used in the figure are the following:

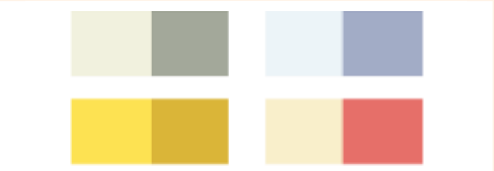
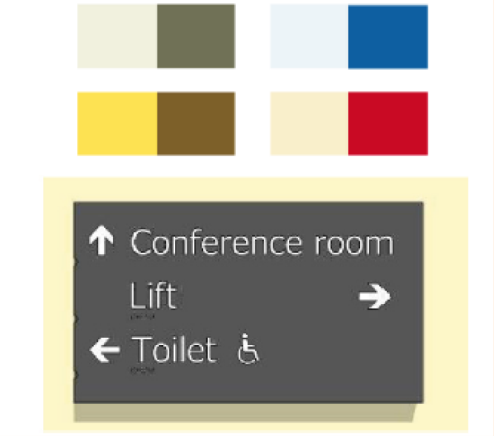
a) *Running man* (*centre of the combination sign*) — Emergency exit (right hand).
b) *Arrow* (*right*) — Supplementary arrow sign used with the emergency exit sign to indicate its location in the right direction.
c) *Supplementary sign* (*opposite to the arrow*) — Full accessibility or toilets accessible.

FIG. 118 ACCESSIBLE EMERGENCY EXIT ROUTE

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Table 11 Minimum Difference in LRV According to the Visual Task

(*Clause* B-24.3.1)

Sl No.	Visual Task	Difference on the LRV Scale	Approximate Examples of Colour Contrasting
(1)	(2)	(3)	(4)
i)	Large surface areas (that is, walls, floors, doors, ceiling), elements and components to facilitate orientation (that is, handrails, switches and controls, tactile walking surface indicators, and visual indicators on glazed areas)	≥30 points	
ii)	Potential hazards and self contrasting markings (that is, visual indicator on steps) and text information (that is, signage)	≥70 points	

For door hardware (that is, the elements and components to facilitate opening and closing doors) a difference in LRV between the product and its background of at least 15 points and a minimum light reflectance value of 30 points for one of the two surfaces is acceptable.

NOTE — Door hardware is normally positioned at the same height on a door and is either on the left or right side. This makes the location of door hardware easier than other features. In addition, the three-dimensional features of door hardware create shadows and bright spots, which further enhance their location.

Floor patterns should have a visual contrast of less than 20 points difference on the LRV scale.

NOTE — Highly contrasted floor patterns can be perceived as differences in floor level, which may confuse people with vision impairments or cognition capacity. Highly contrasted floor patterns may trigger an attack of vertigo.

B-24.3.2 *Choice of Colours and Patterns*

Different colours should be used for identification of doors, different storeys or departments in a building to aid persons with impaired cognitive ability. The colours used to facilitate orientation shall also provide minimum difference in LRV according to **B-24.3.1**. Combinations of red tones and green tones should be avoided.

Different storeys should be marked with clearly defined large numbers relating to the floor (that is, '2' for the second floor, and so on) both in the stairwells to assist those evacuating and at the lift and stair lobbies on each level.

NOTE — Colour coding floors may not be practical from a long term maintenance perspective.

In case of signage and graphical symbols, contrasting colours shall be used to differentiate the figures from the background on the signboard. The colours of signboard shall also contrast with the surrounding surface so as to be clearly distinguishable (*see* **B-24.2.6**). Information from signs may be conveyed by the colour and brightness differentials between the letter and the background. For graphical symbols, it is preferable to use blue and white colours. Colours same as safety signs shall be avoided in other signs. Primarily red, yellow or green colour is used for safety signs. The colour combinations red/green and yellow/blue should not be used in order to avoid confusing persons who are colour blind. Use of the shades of the same colour in the sign and also use of more than 5 colours in a signage should be avoided.

A preferred schedule of colour contrast for signs from their background is given below:

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Sl No.	*Background*	*Sign Board*	*Legend*
(1)	(2)	(3)	(4)
i)	Red brick or dark stone	White	Black, dark green or dark blue
ii)	Light brick or light stone	Black/dark	White or yellow
iii)	Whitewashed walls	Black/dark	White/Yellow
iv)	Green vegetation	White	Black, dark green or dark blue
v)	Back-lit sign	Black	White or yellow

B-25 MANAGEMENT AND MAINTENANCE ISSUES

B-25.1 Effective management of the built environment is essential to ensure that a building can be used by everyone. Management policies and procedures will be required to ensure that accessibility is maintained on an ongoing basis. The following management and maintenance issues, are important factors in ensuring that a building is easily accessed and used by disabled people.

B-25.2 External Issues

a) Keeping external routes, including steps and ramps, clean, unobstructed and free of surface water, dead leaves, lichen, debris, etc;
b) In car parking areas: ensuring that designated spaces are not being used by non-disabled motorists;
c) Where possible, allocating specific designated parking spaces to individual employees, marked by name or number;
d) Checking side-hung doors accompanying revolving doors to ensure they are not kept locked; and
e) Making available auxiliary aids such as portable ramps, and removing them when not in use.

B-25.3 Internal Issues

a) Ensuring that wheelchair spaces are available in seating areas;
b) Ensuring that staff understand the management issues relating to disabled people, including emergency procedures;
c) Ensuring that storage, planters, bins, etc, do not obstruct circulation space, WCs or lift call buttons;
d) Ensuring that cleaning and polishing does not produce a slippery surface;
e) Ensuring that trip hazards, such as at junctions between floor surfaces, are removed;
f) Ensuring access between moveable tables in refreshment areas;
g) Ensuring that in sanitary facilities, written instructions on the use of equipment is displayed beside each item;
h) Ensuring in sanitary facilities, that information is available on the type of sling connector and the types of sling that are compatible with their installed hoist and track;
j) Ensuring that a procedure is set up to respond to alarm calls from sanitary accommodation;
k) Ensuring that waterproof mattress covers can be made available for use in accessible bedrooms in non-domestic buildings;
m) Ensuring that, where floor sockets are provided (for example in meeting rooms), access to sockets is also available at desk level;
n) Ensuring that any temporary barriers that are used to channel customers to reception or serving points, and whose configuration needs to be changed frequently, have a semi-rigid top barrier (for example a spring-loaded band) which contrasts visually with the background against which it is seen; and
p) Ensuring that assistance is made available to carry trays where needed in refreshment areas.

B-25.4 Maintenance Issues

a) Maintaining doors, door closers and building hardware, including checking that the opening forces of self-closing doors are within acceptable limits;
b) Maintaining access control systems;
c) Checking floor surfaces, matting, surface-mounted carpets, etc, re-fixing to the floor where necessary, and replacing where damaged or worn (particularly at entrances to buildings);
d) Maintaining hearing enhancement systems;
e) Maintaining sanitary fittings, including checking that toilet seats are securely fixed, cleaning tap nozzles to ensure correct water flow, emptying and cleaning bins, and keeping equipment clean;
f) Ensuring that adjustable shower heads are lowered to be ready for the next user;
g) Ensuring that emergency assistance pull cords are kept fully extended and in working order at all times;
h) Checking the mountings of all grab bars, and the mechanism of drop-down bars, re-fixing or replacing, where necessary;
j) Servicing of all types of lifts and hoists;

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k) Ensuring that facilities, such as lifts, hoists, etc, are in working order between servicing schedules, and providing alternative arrangements in case of facilities being out of order;
m) Maintaining ventilation and heating equipment;
n) Replacing defunct light bulbs and flickering fluorescent tubes quickly; and
p) Keeping windows, lamps and blinds clean to maximize lighting.

B-25.5 Communication Issues

a) Providing information on strobe lighting prior to entry;
b) Removing and/or changing signage as necessary, for example when departments relocate;
c) Providing accurate information on facilities prior to arrival;
d) Providing audio description services;
e) Providing all relevant literature, and reviewing/revising it when necessary;
f) Ensuring that a permanently manned position is available for the emergency lift telephone communications;
g) Updating maps of buildings following changes; and
h) Replacing signs correctly after decoration.

B-25.6 Policy Issues

a) Allocating and reviewing parking spaces;
b) Changing signs when departments move;
c) Reviewing the number of disabled people attending and needing facilities;
d) Establishing and running user groups;
e) Reviewing the number of instruments supporting infra-red systems;
f) Adopting a signage policy;
g) Having the loop position always manned in branches;
h) Providing portable ramps;
j) Arranging audits of journeys made by visitors;
k) Instructing accessibility audits;
m) Ensuring that services are provided when facilities such as lifts break down;
n) Ensuring that responsibilities are defined within the organization;
p) Ensuring that accessibility improvements are picked up whenever possible during maintenance and refurbishment work;
q) Reviewing and improving evacuation procedures;
r) Training of staff;
s) Reviewing all policies, procedures and practices;
t) Reviewing the provision of auxiliary aids; and
u) Considering the impact of background noise (for example music, equipment, ventilation) on people with a range of sensory conditions (hearing, vision, autism). This is especially important in areas where voice communication is necessary, such as reception, meeting and learning spaces.

ANNEX C

(*Clause* 14)

SPECIAL REQUIREMENTS FOR LOW INCOME HOUSING IN URBAN AREAS

C-1 GENERAL

These guidelines cover the planning and general building requirements of low income housing in urban areas, for houses having a maximum plinth area of 40 m^2 including future expansion. The requirement regarding layout planning of low income housing colonies are applicable to public and private agencies/ government bodies. The requirements on design and construction of buildings for low income housing in approved layouts are applicable to all private and public agencies.

C-2 PLANNING

C-2.1 Type of Development

The type of development for low income housing shall be plotted developments as row housing/flatted development as row housing or group housing on cluster pattern (*see* Annex D).

C-2.2 Layout Pattern

C-2.2.1 In the land to be developed, at least 75 percent of the plots may be of the size less than or up to 60 m^2

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per dwelling unit in metropolitan towns and 100 m^2 in other towns and hill areas. Remaining 25 percent of the plots may be more than 60 m^2, however, no plot shall be more than 200 m^2. In case of group housing or flatted development at least 75 percent units should have a plinth area (excluding external circulation such as stairs, lifts, lobbies, etc) up to or not exceeding 40 m^2 including future expansion.

C-2.2.2 The mix of plot of different sizes should have a wide range to accommodate the need of lower income group. The project may include more than one site provided they are in the same neighbourhood.

C-2.2.3 The layout should generally conform to the following land use:

Sl No.	*Land Use*	*Percentage of Land Under Each Use*	
		General	Hill Area
(1)	(2)	(3)	(4)
i)	Saleable:		
	a) Residential	50, *Min*	35
	b) Work places, schools institutions, shops, community places, etc	20, *Max*	15
ii)	Non-saleable: Roads, pedestrian paths, drains, public and semi-public open spaces	30, *Max*	50

NOTES

1 Any neighbourhood development should have provision for basic civic and community facilities, however, where such facilities are available in proximity the same could be considered and, in that case, the area under residential use could be increased correspondingly.

2 If land required under statutory provisions of master plan/development plan is proportionately higher but serves larger city needs, readjustment of the recommended land use pattern may be considered. Such provisions should, however, be carefully reviewed by the planning authorities to keep them to the barest minimum levels.

C-2.3 Plot Area

C-2.3.1 *Plot Size*

The minimum plot size with ground coverage not exceeding 75 percent, shall not be less than 40 m^2 in small and medium town and not less than 30 m^2 in metropolitan cities. Plot sizes below 30 m^2 but not less than 15 m^2 may be permitted in case of cluster planning, however, in such cases the ground coverage and FAR shall be 100 percent and 2, respectively (*see also* Annex D for special requirements for cluster planning for housing).

NOTES

1 In exceptional cases in metropolitan cities with population more than 1 million the size of plots may be brought down to 25 m^2 in cases of low income housing colonies located in congested areas as decided by the Authority. In mega cities it may be further reduced to 15 m^2. In such cases where plot size is below 25 m^2, only cluster planning or group housing may be adopted.

2 A minimum of 25 percent of the plot size shall be left open without adversely affecting light and ventilation for habitable spaces and toilet. It shall not be made mandatory to leave set back on any side.

C-2.3.2 *Minimum Frontage*

The minimum frontage of the plot shall be 3.6 m in width.

C-2.4 Density

C-2.4.1 The density norms for plotted development and mixed development shall be as follows:

Sl No.	*Type of Development*	*Range of Densities (Gross)*
(1)	(2)	(3)
i)	Plotted development	65-120 plots per hectare
ii)	Mixed development :	
	a) Small towns	75-100 dwelling units per hectare
	b) Cities	100-125 dwelling units per hectare
	c) Metropolitan cities	125-150 dwelling units per hectare

C-2.4.2 In case of developments with per dwelling unit covered area of 15 m^2, four storeyed walk ups without future incremental growth with maximum densities of 500 dwelling units per hectare shall be permissible. In case of four storeyed walk ups, having two roomed dwelling unit where one room is for future expansion, maximum density of 400 dwelling units per hectare shall be permissible.

C-2.5 Height of Building

The height of building shall not exceed 15 m.

NOTES

1 For buildings up to the height of 15 m, there is no need to provide lifts.

2 Housing for the low-income group shall preferably be up to a maximum of two storeys.

3 Buildings for housing beyond 15 m in height should be resorted to in exceptional circumstances and it should be governed by provisions laid down in this Code.

C-2.6 Cluster Planning

For size of open cluster and open space, set backs, vehicular access and pedestrian paths in cluster

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planning, the provisions given in Annex D shall apply.

C-3 GENERAL BUILDING REQUIREMENTS

C-3.1 General

The requirements of parts of buildings shall be as given in **C-3.2** to **C-3.9**.

C-3.2 Plinth

The minimum height of plinth shall be regulated on the basis of environmental and topographical condition and higher plinth height may be required in areas prone to flooding.

C-3.3 Size of Room

C-3.3.1 *Habitable Room*

Every dwelling unit to be provided should have at least two habitable rooms. Even if one room house is provided initially it should be capable of adding a new second room in future. However, in case single room tenements are required to be provided where future additions are not possible, the carpet area of multipurpose single room should be at least 12.5 m^2. Such one room dwelling units with 12.5 m^2 carpet area of habitable space is permitted only in case of on-site rehabilitation of slum dwellers. In a house of two rooms, first room shall not be less than 9.0 m^2 with minimum width of 2.5 m and second room shall not be less than 6.5 m^2 with a minimum width of 2.1 m provided the total area of both the rooms is not less than 15.5 m^2. In incremental housing the bigger room shall always be the first room.

C-3.3.1.1 To facilitate incremental housing in case of flatted development or otherwise, habitable space at mezzanine level may be permitted. The minimum size of such a mezzanine floor should not be lesser than 6.5 m^2 and such a floor should occupy not more than 50 percent of the room area of which it is a part. Such a mezzanine floor should have appropriate openings to facilitate light and ventilation as per **C-3.6**. Minimum clear height below and above the mezzanine floor should be 2.4 m and 2.1 m, respectively.

As far as possible mezzanine floor should have direct ventilation from the external face of the building. Where this is not possible ventilation through main room may be allowed provided total area of openings in the main room is provided taking into consideration area of mezzanine floor.

Such mezzanine floor may be accessible through the main room by a ladder, whose minimum angle with vertical plane should be 22.5°. Height of the riser should be less than 250 mm.

C-3.3.2 *Water-Closet/Bath Room*

a) The size of independent water-closet shall be 0.90 m^2 with minimum width of 0.9 m;
b) The size of independent bath room shall be 1.20 m^2 with a minimum width of 1.0 m; and
c) The size of combined bath room and water-closet shall be 1.80 m^2 with minimum width of 1.0 m.

C-3.3.3 *Kitchen*

The size of a cooking alcove serving as cooking space shall not be less than 2.4 m^2 with a minimum width of 1.2 m. The size of individual kitchen provided in a two-roomed house shall not be less than 3.3 m^2 with a minimum width of 1.5 m.

C-3.3.4 *Balcony*

The minimum width of individual balcony, where provided, shall be 0.9 m and shall not be more than 1.2 m and it shall not project beyond the plot line and on roads or pathway.

C-3.4 Basement

No basement floor shall be allowed.

C-3.5 Minimum Height

The minimum height of rooms/spaces shall be as follows:

a) Habitable room : 2.6 m
b) Kitchen : 2.6 m
c) Bath/water-closet : 2.1 m
d) Corridor : 2.1 m

C-3.5.1 In the case of sloping roofs, the average height of roof for habitable rooms shall be 2.6 m and the minimum height at eaves shall be 2.0 m.

C-3.6 Lighting and Ventilation

The openings through windows, ventilators and other openings for lighting and ventilation shall be in accordance with **20.1.2**.

NOTE — The windows and other openings shall abut onto open spaces either through areas left open within the plot or the front, side and rear spaces provided in the layouts which shall be deemed to be sufficient for light and ventilation purposes. Wherever, ventilation/lighting is provided by means of *Jali* or grill of any material, total area of openings shall be calculated excluding solid portion of the *Jali* or grill.

C-3.7 Stairs

The following criteria shall be adopted for internal individual staircase:

a) *Minimum clear width*:
   1) 2 storeyed — straight : 0.60 m
   2) 2 storeyed — winding : 0.75 m

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3) 3 or more storeyed — straight : 0.75 m
4) 3 or more storeyed — winding : 0.90 m

b) *Riser* : 200 mm, *Max*

c) *Tread*

1) 2 storeyed : 225 mm, *Min* (*see* Note)
2) 3 storeyed or more : 250 mm, *Min*

NOTE — This could be reduced to 200 mm as the clear tread between perpends, with possibility of open riser as well as nosing and inclined riser to have an effective tread of 225 mm.

d) *Head room* — The minimum clear head room shall be 2.1 m.

C-3.8 Circulation Area

The circulation area on any floor including staircase, shall not exceed 8 m^2/dwelling unit.

C-3.9 Water Seal Latrine

No building plan shall be approved and no building shall be deemed to have been completed and fit for human occupation unless provision is made for water seal latrine. No dry latrine shall be allowed. Water seal latrines may also be provided on the basis of community toilets or shared toilets as per the recommendation given in good practice [3(9)].

Where leaching pits are used, it should be constructed within the premises of the households as it would be economical as well as facilitate their cleaning. However, where, due to space constraint, construction of pits within the premises may not be possible, pits may be constructed in places like lanes, streets and roads.

In case the pit is located under the road, street or foot path, the inverted level of the pipe connecting the latrine pan with the pit shall be at least 1.1 m below ground level or below the bottom of the water main existing within adistance of 3 m from the pits whichever is more. Construction of such pits may be in accordance with good practice [3(10)].

The water seal latrine should be properly maintained and kept in sanitary condition by the owner or the occupier. The contents of the septic tanks, soak pits, leach pits, etc, should be periodically emptied.

The leach pits should be cleaned only after 2 years of their being put out of service after they were full.

C-4 ROADS AND PATHWAYS

The area under roads and path-ways in such housing projects should normally not exceed 20 percent of the total land area of the project.

Access to the dwelling units, particularly where motorized vehicles are not normally expected should be by means of paved footpaths with a right of way of 6 m and a pathway of 2 m only. The right of way should be adequate to allow for the plying of emergency vehicles and also for road side drains and plantation.

Where pedestrian pathways are not meant for motorable access to the minimum, right of way of such pedestrian pathway shall be 3 m. Where houses are accessible from one side only pathway may be 2 m wide. The maximum length of such pathways should not be more than 60 m.

C-5 OTHER REQUIREMENTS

C-5.1 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in the Code.

C-5.2 One water tap per dwelling unit may be provided, where adequate drinking water supply is available. If supply is inadequate, public hydrants shall be provided. In the absence of piped water supply, hand pumps may be used for provision of water supply.

C-5.3 Recognizing the need for informal use of space for shopping and informal occupation like road side repairs, *Pan* shops, etc, it is suggested that about ¼ of the total shopping area in a layout should be reserved for such informal uses tocater to the needs of low income families.

C-5.4 The infrastructural services shall be provided before the plots are handed over to individual owners.

C-6 SITE AND SERVICES SCHEMES

C-6.1 The developed plot sizes shall be as per **C-2.3.1**. Services should be laid by the agency concerned as per the provisions of the Code. In so far as roads and pathways are concerned, they should be in line with **C-4**.

C-6.2 Site and services schemes should provide for the following:

a) Complete infrastructural needs for a permanent housing, on the periphery of individual plot or a group/cluster plots;
b) A service sanitary core in the plot;
c) A skeletal structure of columns and roof or a developed plinth; and
d) Permission to allow temporary construction on the plot.

While provisions in (a) and (d) are essential for site and services projects, recommendations in (b) and (c) are additional provisions depending upon affordability.

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ANNEX D

(*Clause* 15)

SPECIAL REQUIREMENTS OF CLUSTER PLANNING FOR HOUSING

D-1 GENERAL

These guidelines cover planning and building requirements of housing developed as clusters. These requirements are applicable to all housing projects taken up by public, private or cooperative agencies.

D-2 PLANNING

D-2.1 Plot Size

The minimum plot size permissible shall be 15 m^2 with 100 percent ground coverage and an FAR of 2. 100 percent ground coverage and FAR of 2 will be applicable up to plot size of 25 m^2. For plot sizes beyond 25 m^2, provision in accordance with good practice [3(3)] shall be applicable.

D-2.2 Plot/Plinth Area for Slum Resettlement on Same Site

In case of slum resettlement on the same site, minimum area may be reduced to 12.5 m^2 with potential for adding another 12.5 m^2 on first floor with an internal staircase.

D-2.3 Group Housing

Group housing may be permitted within cluster housing concept. However, dwelling units with plinth areas up to 20 m^2 should have scope for adding a habitable room. Group housing in a cluster should not be more than 15 m in height.

D-2.4 Size of Cluster

In ground and one storeyed structures not more than 20 houses should be grouped in a cluster. Clusters with more dwelling units may create problems relating to identity, encroachment and maintenance.

D-2.5 Size of Cluster Open Space

Minimum dimensions of open spaces shall be not less than 6 m or 3/4th of the height of buildings along the cluster open space, whichever is higher. The area of such cluster court shall not be less than 36 m^2. Group housing around a cluster open space should not be normally more than 15 m in height. Maximum cluster courtyard width and breadth shall be 13 m.

D-2.6 Setbacks

No setbacks are needed from the edges of cluster as pedestrian/vehicular access roads surrounding the cluster.

D-2.7 Right to Build in Sky

Pedestrian paths and vehicular access roads to clusters separating two adjacent clusters may be bridged to provide additional dwelling units. While bridging the pedestrian path way minimum clearance should be one storey height, length of such bridging should be not more than two dwelling units. While bridging the vehicular access roads minimum clearance should be 6 m.

D-2.8 Vehicular Access

A right of way of at least 6 m width should be provided up to the entrance to the cluster to facilitate emergency vehicle movement up to cluster.

D-2.9 Pedestrian Paths

Minimum width of pedestrian paths shall be 3 m.

D-2.10 Width of Access Between Two Clusters

Built area of dwelling unit within cluster shall have no setbacks from the path or road, space. Hence, the height of the building along the pathway or roads shall be not less than 60 percent of the height of the adjacent building subject to minimum of 3 m in case of pathway and 6 m in case of vehicular access.

D-2.11 Density

Cluster planning methodologies result in higher densities with low rise structures. With per dwelling unit covered area of 15 m^2 densities of 500 dwelling units per hectare (net) shall be permissible. Densities higher than this should not be allowed.

D-2.12 Group Toilet

Cluster housing for economically weaker section families may have group toilets at the rate of one water-closet, one bath and a washing place for three families. These shall not be community toilets, as keys to these toilets shall be only with these three families, making them solely responsible for the maintenance and upkeep of these toilets.

D-3 OTHER REQUIREMENTS

D-3.1 Requirements of Building Design

With the exception of clauses mentioned above, requirements of building will be governed by the provision of this Code and good practice [3(3)].

D-3.2 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in this Code.

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ANNEX E

(*Clause* 16)

SPECIAL REQUIREMENTS FOR LOW INCOME HABITAT PLANNING IN RURAL AREAS

E-1 GENERAL

These guidelines cover planning and general building requirements for low-income houses having a maximum built-up area of 40 m^2 including future expansion, built on notified (as notified by the State Governments) rural areas. The provisions on layout planning of low-income housing colonies in rural areas are applicable to public and private agencies/government bodies. The provisions of this Guide on design and construction of buildings for low income housing in approved layouts are applicable to all private and public agencies.

E-2 SETTLEMENT AND ENVIRONMENT PLANNING

While planning for rural settlements the following factors shall be taken into consideration:

a) Eco-system and biodiversity.

b) Topography with its direct effect on climate, likelihood of natural disasters, natural drainage, etc.

c) Identity of the place rooted in its culture and heritage.

d) Nearness and connectivity with nearby urban centres.

e) Occupation related requirements.

f) Water management.

g) Waste management.

h) Land tenure.

j) Site selected shall be conveniently approachable and suitably developed and shall not be subjected to water logging/flooding.

k) Plot size : 80 m^2, *Min*

m) Density (Gross) : 60 plots per hectare, *Max*

n) Minimum frontage : 6 m

p) Ground coverage : 33 percent (subject to a maximum of 50 percent)

q) Floor area ratio (FAR) : 2, *Max*

r) Open spaces : 1.21 hectare open space for a village with 200 houses

s) Facilities like branch of cooperative bank, a fertilizer depot, a veterinary hospital, market place and a branch of the cooperative consumer store besides facilities for educational and health care should be available within a maximum distance of 5 km from any settlement.

t) Proposed road hierarchy:

Sl No.	*Road Type*	*Road Description*	*Road Width* m	*Function/ Remarks*
(1)	(2)	(3)	(4)	(5)
i)	R1	Road which connects village to nearby areas	9	Widest road
ii)	R2	Road which take major traffic to the village	6	Main village roads with drain on both sides to facilitate drainage system of the village
iii)	R3	Internal village road	4.5	Other village roads
iv)	R4	Internal village road	3	Village lanes

E-3 GENERAL BUILDING REQUIREMENTS (HOMESTEAD)

E-3.1 General

The requirements of parts of buildings shall be as given in **E-3.2** to **E-3.7**.

E-3.2 Plinth

The minimum height of plinth shall be regulated on the basis of environmental and topographical condition and higher plinth height may be required in areas prone to flooding.

E-3.3 Size of Room

E-3.3.1 *Habitable Room*

Every dwelling unit to be provided should have at least two habitable rooms. Even if one room house is provided initially it should be capable of adding a new second room in future. In a house of two rooms, first room shall not be less than 9.0 m^2. with minimum width of 2.5 m and second room shall not be less than 6.5 m^2 with a minimum width of 2.1 m provided the total area of both the rooms is not less than 15.5 m^2. In incremental housing the bigger room shall always be the first room.

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E-3.3.1.1 To facilitate incremental housing in case of flatted development or otherwise, habitable space at mezzanine level may be permitted. The minimum size of such a mezzanine floor should not be lesser than 6.5 m^2 and such a floor should occupy not more than 50 percent of the room area of which it is a part. Such a mezzanine floor should have appropriate openings to facilitate light and ventilation as per **E-3.5**. Minimum clear height below and above the mezzanine floor should be 2.4 m and 2.1 m, respectively.

As far as possible mezzanine floor should have direct ventilation from the external face of the building. Where this is not possible ventilation through main room may be allowed provided total area of openings in the main room is provided taking into consideration area of mezzanine floor.

Such mezzanine floor may be accessible through the main room by a ladder, whose minimum angle with vertical plane should be 22.5°. Height of the riser should be less than 250 mm.

E-3.3.2 *Water-Closet/Bath Room*

a) The size of independent water-closet shall be 0.9 m^2; with minimum width of 900 mm.
b) The size of independent bath room shall be 1.2 m^2 with minimum width of 1 m, and
c) The size of combined bath and water-closet shall be 1.8 m^2 with minimum width of 1 m.

E-3.3.3 *Kitchen*

The size of a cooking alcove serving as cooking space shall not be less than 2.4 m^2 with a minimum width of 1.2 m. The size of individual kitchen shall not be less than 3.3 m^2 with a minimum width of 1.5 m. Semi-open spaces with low walls and roof may also be provided for cooking in areas where such provision is suitable with respect to climatic comfort. Provision for smokeless *Chullha* shall be made in all kitchens considering fuel efficiency and health hazard due to smoke inhalation.

E-3.3.4 *Balcony*

The minimum width of individual balcony, where provided, shall be 0.9 m. and shall not be more than 1.2 m and it shall not project beyond the plot line and on roads or pathway.

E-3.4 Minimum Height

The minimum height of rooms/spaces shall be as follows:

a) Habitable room : 2.75 m
b) Kitchen : 2.6 m
c) Bath/Water-closet : 2.2 m
d) Corridor : 2.1 m

E-3.4.1 In the case of sloping roofs, the average height of roof for habitable rooms shall be 2.75 m and the minimum height at eaves shall be 2.10 m.

E-3.5 Lighting and Ventilation

The openings through windows, ventilators and other openings for lighting and ventilation shall be as per in accordance with **20.1.2**.

NOTE — The windows and other openings shall abut onto open spaces either through areas left open within the plot or the front, side and rear spaces provided in the layouts which shall be deemed to be sufficient for light and ventilation purposes. Wherever ventilation/lighting is provided by means of *Jali* or grill of any material, total area of openings shall be calculated excluding solid portion of the *Jali* or grill.

E-3.6 Stairs

The following criteria shall be adopted for internal individual staircase:

a) *Minimum width*:
   1) 2 storeyed-straight : 0.60 m
   2) 2 storeyed-winding : 0.75 m
   3) 3 or more storeyed straight : 0.75 m
   4) 3 or more storeyed winding : 0.90 m
b) *Riser* : 200 mm, *Max*
c) *Tread*:
   1) 2 storeyed : 225 mm, *Min* (*See* Note)
   2) 3 storeyed or more : 250 mm, *Min*

NOTE — This can be reduced to 200 mm as the clear tread between perpends, with possibility of open riser as well as nosing and inclined riser to have an effective tread of 225 mm.

E-3.7 Water Seal Latrine

No building plan shall be approved and no building shall be deemed to have been completed and fit for human occupation unless provision is made for water seal latrine. No dry latrine shall be allowed. Water seal latrines may also be provide on the basis of community toilets or shared toilets as per the recommendation given in good practice [3(9)].

Where leaching pits are used, it should be constructed within the premises of the households as it would be economical as well as facilitate their cleaning. However, where, due to space constraint, construction of pits within the premises may not be possible, pits may be constructed in places like lanes, streets and roads.

In case the pit is located under the road, street or foot path, the inverted level of the pipe connecting the latrine pan with the pit shall be at least 1.1 m below ground level or below the bottom of the water main existing within a distance of 3 m from the pits whichever is

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more. Construction of such pits, may be in accordance with good practice [3(10)].

The water seal latrine should be properly maintained and kept in sanitary condition by the owner or the occupier. The contents of the septic tanks, soak pits, leach pits, etc, should be periodically emptied.

The leach pits should be cleaned only after 2 years of their being put out of service after they were full.

Location of sanitary facility either as part of the house or separately shall be decided on the basis of felt perceptions.

E-3.8 The house site shall provide space for storage of food grains and keeping cattle. A manure pit having a minimum area of 1.0 m^2 shall also be catered for. This will take care of composting of biodegradable waste.

E-4 OTHER REQUIREMENTS

E-4.1 Requirements of fire safety, structural design, building services and plumbing services shall be as specified in relevant parts of the Code.

E-4.2 One water tap per dwelling unit may be provided, where adequate drinking water supply is available. If supply is inadequate, public hydrants shall be provided. In the absence of piped water supply, hand pumps may be used for provision of water supply.

E-4.3 Drainage System

E-4.3.1 Water from drains shall be connected to village ponds and appropriate eco-friendly methods like growing of duck weed plants shall be adopted to treat waste water.

E-4.3.2 This treated water may be used for irrigation and agriculture.

E-4.4 Appropriate methods (namely conservation, ground water recharging, rain water harvesting, etc) should be employed to ensure effective water management.

E-4.5 Community Facilities

E-4.5.1 A community hall/*Baraat Ghar* shall be established.

E-4.5.2 Rural development centre shall include *Panchayat Ghar*, a *Mahila Kendra* that may also serve as a vocational training centre.

E-4.5.3 School, health centre, post office, police post, shopping, work sheds for the artisans, telephone facilities, etc, should also be established.

E-4.6 The use (to the extent possible) of locally available building materials and cost effective substitutes for scarce building materials should be deployed. Appropriate technology inputs shall be introduced for improving the local materials or conventional or traditional practices for improved efficiency.

E-4.7 The concept of 'aided self-help' shall be ensured for active participation of the prospective users and association in the construction and development of dwelling units and other community building.

E-4.8 The special needs of women headed households/ single and working women/woman in difficult circumstances should be addressed. The specific requirement of women in terms of providing necessary facilities in homes to lessen their drudgery would be given sufficient attention.

E-4.9 Protecting and promoting our cultural heritage, architecture and traditional skills should be given due importance.

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ANNEX F

(*Clause* 17)

SPECIAL REQUIREMENTS FOR DEVELOPMENT PLANNING IN HILLY AREAS

F-1 GENERAL

F-1.1 These guidelines provides requirements relating to development planning and design of buildings in hilly areas. Any area above 600 m in height from mean sea level may be classified as hilly, or any area with average slope of 30° may also be classified as hilly, considering the sensitive and fragile ecosystem of hills and mountains. However, the State Governments may identify and notify areas to be covered under 'Hilly Area', which need to be dealt with special consideration, when developmental activities are taken up.

F-1.2 Strategies for Development in Hilly Areas

Hilly areas have one of the most fragile ecosystems, which need to be conserved. Therefore planning and development strategies for hilly areas shall have to be designed with added sensitivity and stress on integrated development. The development approach shall comprise sound land use planning and settlement planning. Following strategies may be adopted for an integrated planning approach for conservation, preservation and planned development in hilly areas.

a) *Strategy 1*: *Land Conservation and Optimization*

1) *Environment inventory/impact assessment* — For planning of the new settlements or working out the strategies for the growth of the existing settlements, it is necessary to conduct detailed environmental inventory/impact assessment. The inventory would involve geological investigations, slope analysis, soil, flora and fauna analysis, climatic inventories, vulnerability to natural disasters (such as earthquakes, landslides, floods etc), etc. In addition to this the aesthetic factors, cultural, architectural and historical heritage, scenic/landscape value shall also be taken into consideration.

2) *Identification of developable area* — Identification and quantification of developable area is done by deducting the natural ecological area from the entire township jurisdiction area. Jurisdiction may be large to control the surrounding areas. The classification of land uses should be given only for developable area, while the rest of the ecological area shall be for conservation or restoration.

Hill Town Developable Area = (Hill town jurisdiction area – Natural Ecological Area)

3) *Land use optimization* — Keeping in view the scarcity of good buildable land and also the high cost of the construction, it is necessary to optimize the use of land by calculation of carrying capacity and land suitability analysis. Sustainable building approach should be adopted, such as use of cost effective and appropriate building materials and technologies.

b) *Strategy 2*: *Sustainable Development based on Watershed Management*

A watershed, also called a drainage basin or catchment area, is defined as an area in which all water flowing into, goes to a common outlet. People and livestock are the integral part of watershed and their activities affect the productive status of watersheds and *vice-versa*. From the hydrological point of view, the different phases of hydrological cycle in a watershed are dependent on the various natural features and human activities. In hilly areas or where intensive agriculture development is planned, the size of watershed preferred is relatively small. Watershed managements, that is, river basin management also is important in the context of regional planning both in terms of, as a source of water and sources of disaster risk like flood, etc. Efforts shall be made to achieve a balance between beneficiary oriented and infrastructural development programmes, keeping in view the vital importance of ecological restoration and conservation. This may be achieved through,

1) better water and land use and control of soil erosion through watershed management;
2) afforestation, silvi pasture development and replacement of annual crops with perennial shrubs and trees and plantation crops in steep slopes and development of other high value low volume crops linked with processing and marketing; and
3) rural and small industries and electronic

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and precision instruments industries may also be promoted taking advantage of favourable weather conditions.

To understand watershed system, data from latest and authentic sources should be collected, simulation models may be used to analyze (drainage pattern modification) scenarios before Development Plan Preparation and formulating building regulations.

F-1.3 In hill areas, the space standards are affected by the following and therefore these factors should be considered while setting norms in such areas:

a) Exposure to sunlight, degree of slopes and accessibility in the form of distance travelled;
b) Minimum needs of the people and the conservation principle;
c) Flexibility in norms and standards to accommodate conditions guided by difficult hill terrain and its geology;
d) Work place and residence relationship;
e) Energy needs;
f) Alternative mode of transportation communication network;
g) Communication network; and
h) Mobile and emergency facilities.

F-2 LAND USE PLANNING

The following land use structure shall be adopted in Development Planning in Hilly areas:

Sl No.	*Land Use*	*Percentage of Developed Area*		
		Small Towns	Medium Towns	Large Cities
(1)	(2)	(3)	(4)	(5)
i)	Residential	50-55	48-52	45-48
ii)	Commercial	2-3	2-3	4-5
iii)	Industrial	3-4	4-5	4-6
iv)	Public and semi-public	8-10	8-10	12-14
v)	Recreational	15-18	15-18	16-18
vi)	Transport and commerce	5-6	5-6	6-8
vii)	Ecological	Balance	Balance	Balance

NOTE — The ecological area (non-developable area) given in the table above for hill towns is applicable for the hill town jurisdiction developable area only. Hill town developable area shall be considered as area under hill town jurisdiction minus natural ecological area. Where non-developable area is defined as earthquake/landslide prone, cliffs and environmentally hazardous area, areas adjacent to faul t lines, areas with slope higher than 45°, flood plain and areas adjacent to major drainage lines for general guidance and all environmentally sensitive areas. Land suitability analysis should be an important tool in first principal approach for deciding o n land use proportions.

F-3 OPEN SPACES

The following norms shall be adopted in development planning in hilly areas:

Sl No.	*Type*	*Area Range*	*Area per 1 000 Population*	*Remarks*
		ha	ha	
(1)	(2)	(3)	(4)	(5)
i)	Tot lot	0.03-0.05	—	Minimum width 15 m
ii)	Playground	0.50-1.00	0.12 to 0.20	One for every 5 000 may be combined with schools
iii)	Parks	1.20-2.00	0.12 to 0.20	One for every 10 000 population
iv)	City parks/playgrounds/ *Maidan*/exhibition grounds/ cultural gathering grounds	—	0.12 to 0.20	For the entire town at one or more sites, depending upon design and space availability
v)	Botanical garden	10-20	—	One for every town
vi)	Recreational complex including zoo	10-12	—	One for every settlement with tourist potential

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F-4 ROADS AND PATHS

F-4.1 Street orientation shall preferably be east-west to allow for maximum south sun to enter the buildings. The street shall be wide enough to ensure that the buildings on one side do not shade those on the other side.

F-4.2 The following road widths shall be adopted for urban roads in hilly areas:

Sl No.	*Road Type*	*Width* m		
		Open Areas	Built-up Areas	Plains
(1)	(2)	(3)	(4)	(5)
i)	Arterial road	18-24	15-18	50-60
ii)	Sub-arterial road	15-18	12-15	30-40
iii)	Collector road	9-12	7.5-9	20-30
iv)	Local street	4.5-6	3-6	10-20
v)	Loop street (maximum length = 500 m)	4.5	4.5	9
vi)	*Cul-de-sac* (maximum length = 500 m)	4.5	4.5	7.5
vii)	Pedestrian path	1.5-2.5	1-1.5	1.5-4.5

F-4.3 Hill Road Manual (IRC:SP:48-1998), a publication of the Indian Roads Congress shall be referred to for detailed guidelines for planning roads in hilly areas.

F-5 COMMUNITY FACILITIES AND SERVICES

The following minimum norms shall be adopted for community facilities and services in hilly areas:

Sl No.	*Type*	*Population*	*Distance between Two Facilities* km	*Area Range* *ha*
(1)	(2)	(3)	(4)	(5)
i)	*Educational facilities*:			
a)	Primary school	4 000	1-2	0.20 to 0.30
b)	Secondary school (10 + 2)	15 000	5-7	0.30 to 0.50
c)	Industrial training centre	—	8-12	0.30 to 0.60
d)	College	30 000	8-12	2.00 to 3.00
e)	Professional college	30 000	8-12	1.00 to 1.50
f)	University	50 000	8-12	2.00 to 3.00
ii)	*Health*:			
a)	Dispensary	2 500	2-4	0.015 to 0.020
b)	Health sub-centre	3 000	2-4	0.025 to 0.067
c)	Primary health centre (25-50 beds)	20 000	16-20	0.105 to 0.210
d)	Hospital (200-250 beds)	80 000	16-20	0.840 to 2.100
e)	Veterinary centre	1 000	16-20	0.050 to 0.100
f)	Family welfare centre	5 000	5-10	0.025 to 0.050
g)	Maternity home	15 000	5-10	0.025 to 0.050
h)	Nursing home	15 000	5-10	0.050 to 0.075
iii)	*Other facilities*:			
a)	Community welfare centre	16 000	5-7	0.10 to 0.15
b)	Local convenience shopping	10 000	2-4	0.50 to 0.10
c)	Milk booth	10 000	2-4	0.04
d)	Banquet hall	10 000	5-10	0.10
e)	Religious buildings	10 000	5-10	0.10
f)	Cremation ground	10 000	5-10	0.20
g)	Informal bazaar	15 000	5-10	0.10 to 0.20

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(1)	(2)	(3)	(4)	(5)
iv)	*Services*:			
a)	Fire station	50 000	—	0.30 to 0.80
b)	General post office	50 000	10-15	0.20 to 0.40
c)	Post office	10 000	5-7	0.10 to 0.15
d)	Rural post office	2 000	2-4	—
e)	Rural post office	1 000	1-2	0.025 to 0.050
f)	Bank (tribal areas)	10 000	16-20	0.100 to 0.150
g)	Telephone exchange	50 000	10-15	0.20 to 0.40
h)	Electric sub-station (66 kV)		—	1.00
j)	Electric sub-station (11 kV)	—	—	0.05
k)	Police chowki	5 000	2-4	0.10
m)	Police station	15 000	5-10	0.50
n)	Disaster management centre	20 000	5-10	1.00
p)	LPG godown	As per requirement	—	0.15

F-6 OTHER ASPECTS FOR PLANNING FOR THE HILLY AREAS

F-6.1 Following aspects should also be considered while planning for land/building development in hilly areas:

a) The hillside with less than 30° slope are in general stable. Therefore, building sites (temporary or permanent) should in general be located on hillside with not more than 30°–45° slope. In areas where most of the land is above 30° slope, spatial regulations should control construction activity on slopes above 30°, provided that appropriate technology is used.

b) The maximum height of the building shall be fixed.

c) Flat land is normally not available in hilly regions. The houses are required to be constructed on partially sloping land made available by cut and fill. It shall be therefore necessary to protect the houses by building retaining walls/breast walls to avoid landslides occurring at time of earthquakes or heavy rains (*see* **F-7.4**).

d) Cut slopes with height less than 5 m or two to three storey heights of residential buildings are in general stable. For higher cut slopes, special investigation should be carried out and details of protection works should be worked out and implemented.

e) Site development in hilly regions consumes about 30 to 40 per cent of total cost of building complex, therefore the following investigations shall be done to obtain the following geotechnical parametres depending upon the size and complexity of the building project:

1) Type of soil rock, weathered or intact, dip of bedding planes, drainage conditions, shear planes, material between the joints, tension cracks, type of plantation, verticality of trunks of the trees, etc.

2) Cliff sides and spur faces need to be protected with appropriate technology including wire netting and/or blowing of RCC along the walls.

3) Thickness of overburden, nature of soil strata, details of soil matrix, etc.

4) Estimation of shear parametres of the in situ soil mass, which will govern the failure.

5) Drainage pattern of the area and permeability tests to observe the drainage conditions.

6) Specific slip zones in the area, if any.

f) Provisions for landslide hazard mitigation, seismic micro zonation and mitigation of liquefaction hazard should be integrated.

F-6.2 Additional Aspects for New Hill Towns

In addition to considerations given in **F-6.1**, following aspects should also be considered while planning for new hill towns:

a) The basic principles of hill architecture should be followed including use of local building materials, slanting roofs, seismic bands in structures, etc, so that they merge in cultural landscape of their regions.

b) Travelling time from nearest town to the new township should be at least 1 h or distance between the new township and the nearest town should be less than 20 km.

c) The new town should be self sufficient in infrastructure and its area should ideally not be less than 40 ha.

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d) Provision of facilities for additional (and/or floating) population should be made.

F-7 GENERAL BUILDING REQUIREMENTS

F-7.1 General

The provisions contained in this Part shall apply excepting for the specific provisions given hereunder.

F-7.2 Siting

F-7.2.1 No house shall preferably be located closer than 1 m to another house.

F-7.2.2 No house shall be located closer than 10 m to a steep slope.

F-7.2.3 No house shall be built on a landfill or on the edge of a slope known to have been levelled.

F-7.2.4 Buildings in hills shall be clustered together to minimize the exposure to cold winds. Open spaces provided shall allow for maximum south sun.

F-7.2.5 Buildings shall be located on the south slope of a hill or mountain for better exposure to solar radiation. At the same time, exposure to cold winds may be minimized by locating the building on the leeward side.

F-7.2.6 A minimum clearance of 1.5 m should be provided between toe of boundary wall and building wall.

F-7.3 Passive Systems for Climatic Control

F-7.3.1 Appropriate solar passive methods, such as orientation, double-glazing, trombe walls and solar collectors, shall be adopted to achieve climatic comfort with little use of conventional energy.

F-7.3.2 Care shall be taken in siting and design of buildings to provide passive controls to modify the effect of cold/strong winds.

F-7.4 The houses constructed on sloping land shall be protected by building retaining walls/breast walls [*see* good practices 3(11)] to avoid landslides occurring at time of earthquakes or heavy rains.

F-7.5 Maximum height of plinth level shall be 2.00 m.

F-7.6 On the uphill side of the building on a sloping site, the natural flow of the water shall be diverted away from the foundations.

The slope of ground all around building should be not less than 1:50, built in such a way that rain water does not find way to percolate in ground excessively and moves away quickly to surface drains or away on adjoining hill surface towards natural streams.

A minimum of 0.75 m wide apron should be provided all around the building to prevent entry of water into foundation.

F-7.7 Stepped terrace development and stepped storeyed building construction may be adopted for offices, schools and other building complexes because of following advantages:

a) It results in least hill cutting, disturbance to hill stability and also in least deforestation.
b) Cost of site development works, slope protection and other protection works is reduced considerably.
c) Least load comes on valley side, so danger of foundation failures is avoided.

F-7.8 Disaster Resistance

All necessary steps shall be taken in designing and building in hilly regions to achieve disaster resistance as per the relevant codes and Part 6 'Structural Design' of the Code. All natural disasters likely to affect the locality shall be taken into consideration namely earthquakes, cyclones, avalanches, flash floods, landslides, etc. For guidelines for selection of various landslide control methods for effective correction measures to avoid landslides in hill areas, reference shall be made to good practice [3(12)].

F-7.9 Drainage Facilities

Buildings to be provided with good drainage facilities to prevent excessive saturation of sub-surface formations. Construction should not obstruct existing surface drainage courses.

For guidelines relating to rainwater harvesting in hilly areas, reference shall be made to Part 9 'Plumbing Services (including Solid Waste Management), Section 2 Drainage and Sanitation' of the Code.

F-7.10 The shear walls shall be constructed on all the three sides of parking floor so that it is not a soft storey.

F-7.11 Reference shall also be made to good practice [3(13)] for guidelines relating to siting, design and selection of materials for construction of residential buildings in hilly areas.

F-8 SOLID WASTE MANAGEMENT FOR HILLY AREAS

Cities and towns located on hills shall have location specific methods evolved for final disposal of solid wastes by the concerned Authority. The municipal authority shall set up processing facilities for utilization of biodegradable organic wastes. The inert and non biodegradable waste shall be used for building roads or filling up of appropriate areas on hills. Because of constraints in finding adequate land in hilly areas, wastes not suitable for road laying or filling up shall be disposed of in specially designed landfills.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority as a guide in conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part of the Code.

	IS No.	*Title*
(1)	3861 : 2002	Method of measurement of plinth, carpet and rentable areas of buildings (*second revision*)
(2)	4878 : 1986	Byelaws for construction of cinema buildings (*first revision*)
(3)	8888 (Part 1) : 1993	Guide for requirements of low income housing: Part 1 Urban area (*first revision*)
(4)	12933	Solar flat plate collector — Specification
	(Part 1) : 2003	Requirements (*second revision*)
	(Part 2) : 2003	Components (*second revision*)
	(Part 3) : 2003	Measuring instruments (*first revision*)
	(Part 5) : 2003	Test methods (*second revision*)
	12976 : 1990	Solar water heating systems — Code of practice
(5)	3792 : 1978	Guide for heat insulation of non-industrial buildings (*first revision*)
	11907 : 1986	Recommendations for calculation of solar radiation on buildings
(6)	10976 : 1993 ISO 6440 : 1985	Wheelchairs nomenclature, terms and definitions (*first revision*)
(7)	6571 : 1991	Rehabilitation equipment — Wheelchairs, non-folding, adult size, institutional model — Specification (*first revision*)
	7454 : 1991	Rehabilitation equipment — Wheelchairs, folding, adult size — Specification (*first revision*)
	8086 : 1991	Rehabilitation equipment — Wheelchairs, folding, junior size — Specification (*first revision*)
(8)	15330 : 2003	Installation and maintenance of lifts for handicapped persons — Code of practice
(9)	13727 : 1993	Guide for requirements of cluster planning for housing
(10)	12314 : 1987	Code of practice for sanitation for leaching pits for rural community
(11)	14458	Guidelines for retaining walls for hill area
	(Part 1) : 1998	Selection of type of wall
	(Part 2) : 1997	Design of retaining/breast walls
	(Part 3) : 1998	Construction of dry stone walls
(12)	14680 : 1999	Guidelines for landslide control
(13)	14804 : 2000	Guidelines for siting, design and selection of materials for residential buildings in hilly areas

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NATIONAL BUILDING CODE OF INDIA

PART 4 FIRE AND LIFE SAFETY

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 4) deals with safety from fire. It specifies the demarcation of fire zones, restrictions on construction of buildings in each fire zone, classification of buildings based on occupancy, types of building construction according to fire resistance of the structural and non-structural components and other restrictions and requirements necessary to minimise danger to life from fire, smoke, fumes or panic before the buildings can be evacuated. The Code recognizes that safety of life is more than a matter of means of egress and accordingly deals with various matters which are considered essential to the safety of life. The Code therefore covers provisions relating to means of egress covering various components thereof namely exit access, exit and exit discharge. It also covers provisions relating to fire protection of buildings through portable and fixed firefighting installations.

Fire protection techniques have to be based on the fire behaviour characteristics of different materials and structural elements of buildings. The activities pursued by the occupants of buildings must also be taken into consideration for assessing the extent of hazards, and method should then be devised by which the hazards could be minimised. An indefinite combination of variables is involved in the phenomenon of fire, all of which cannot be quantified. The requirements of this Code should, therefore, be taken as a guide and an engineering design approach should be adopted for ensuring a fire safe design for buildings. Depending upon the type and complexities in a building, qualified and trained fire protection engineers should be associated with the planning of buildings, so that adequate fire and life safety measures could be incorporated in the building design right from the beginning.

Absolute safety from fire is not attainable in practice. The objective of this Part is to specify measures that will provide that degree of safety from fire which can be reasonably achieved. The Code endeavours to avoid requirements that might involve unreasonable hardships or unnecessary inconvenience or interference with normal use and occupancy of buildings, but insists upon compliance with minimum standards of fire safety necessary for building occupants and users. For ensuring compliance of fire protection equipment/installations to the laid down quality requirements, it is desirable to use such equipment/installation duly certified under the BIS Certification Marks Scheme.

While providing guidelines for minimizing chances of occurrence of fire through passive fire protection measures, this Part does not intend to cover all aspects of general fire prevention including sources of ignition. Nor does it cover the prevention of accidental personal injuries during the course of normal occupancy of buildings.

This Part while recognizing that panic in a building on fire may be uncontrollable, deals with the potential panic hazard through measures designed to prevent the development of panic. Experience indicates that panic seldom develops even in the presence of potential danger, so long as occupants of buildings are moving towards exits which they can see within a reasonable distance and with no obstruction or undue congestion in the path of travel. However, any uncertainty as to the location or adequacy of means of egress, the presence of smoke or fumes and the stoppage of travel towards the exit, such as may occur when one person stumbles and falls on stairs, may be conducive to panic. Danger from panic is greater when a large number of people are trapped in a confined area particularly when people are not adequately guided towards egress and safety notifications are not implemented or practiced. Consideration towards announcements and annunciations needs to be given to guide the occupants to safe egress routes and to control panic during situation of distress.

Experience has shown that concealed spaces within a building, such as, space between ceiling and false ceiling, horizontal and vertical ducts and shafts, etc, tend to act as flues/tunnels during a fire. Provision should, therefore, be made to provide fire stopping within such spaces.

Nothing in this Part of the Code shall be construed to prohibit better types of building construction, more exits or otherwise safer conditions than the minimum requirements specified in this Part.

Compliance with this Part shall not be construed as eliminating or reducing the necessity for other provisions for safety of persons using a building or structure under normal occupancy conditions. Nor shall any provision of this

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Part be construed as requiring or permitting any addition that maybe hazardous under normal occupancy conditions.

One of the major points brought out in this Part is the limitation of heights and areas of buildings based on fire safety of the occupants. Individual municipal corporations are free to alter Table 2 based on local conditions, but the ratios of areas as maintained in the table for different occupancies and types of construction shall be adhered to.

Advantage has been taken of the developments, particularly in fire resistance rating of materials, designating types of construction in a rational manner and relating the area limitations of different occupancies to different types of construction.

Halons (halogenated hydrocarbons) which exhibit exceptional firefighting and explosion prevention/suppression characteristics have been found to possess high ozone depleting potential. They come under Group II of Annex A of the Montreal Protocol on Substances that Deplete the Ozone Layer, the international environmental agreement for phasing out ozone depleting substances. Due to increasing evidence that the ozone layer is getting depleted at a faster rate than thought earlier, the Code takes into cognizance the need to promote use of halon alternatives as fire extinguishing media.

The first version of this Part was formulated in 1970 and was revised in 1983. Subsequently the first revision of this Part was modified in 1997 through Amendment No. 3 to 1983 version of the Code. This modified version of this Part included few tables for the fire resistance ratings of various building components, such as walls, columns, beams and floors. The requirements for wet riser, down-comer, automatic sprinkler installation, high velocity (10-15 m/s) water spray or foam generating system, etc, for buildings were modified. Annex giving guidelines for selection of fire detectors had been deleted and relevant Indian Standards on fire alarm system and smoke detectors had been referred. Also, an annex for determination of fire loads and flue load density for arriving at the classification of occupancy hazard and calorific values of some common materials were included. Annex for broad classification of industrial and non-industrial occupancies into low, moderate and high hazard had also been included.

The Code was then revised in 2005. In this revision, the significant modifications incorporated were: The text was divided into the following broad clauses: (a) *Fire prevention* — Covering aspects of fire prevention pertaining to design and construction of buildings on passive fire protection measures, also describing the various types of building materials and their fire rating; (b) *Life safety* — Covering life safety provisions in the event of fire and similar emergencies, also addressing construction and occupancy features that are necessary to minimise danger to life from fire, smoke, fumes or panic; (c) *Fire protection* — Covering the significant appurtenances and their related components and guidelines for selecting the correct type of equipment and installation meant for fire protection of the building, depending upon the classification and type of the building. Also, the classification of building based on occupancy was elaborated, wherein, starred hotels were covered as a new Subdivision A-6 under occupancy Group A Residential; heritage structures and archaeological monuments were covered under Subdivision D-3 occupancy Group D Assembly buildings; mixed assembly occupancies were covered as a new Subdivision D-6; underground elevated railways were covered as a new Subdivision D-7 under occupancy Group D Assembly buildings; and TV stations were covered under Subdivision E-5 of occupancy Group E Business buildings. Further, for the external stairs for exit requirements, the width and treads were increased to 1 250 mm and 250 mm, respectively; under the requirements for institutional buildings the clear width of all required exits which serve as egress from hospital or infirmary section was increased from 1.5 m to 2 m. Also, provision of patient-lift was included; and due cognizance of halon phase out programme was taken, while specifying provisions in this Part with respect to fire protection using fire extinguishers/systems.

Based on various comments received from time-to-time, an Amendment No. 2 relating to Part 4 of the 2005 version of the Code, was issued.

In this current revision, the following significant changes have been made:

General:

1) The scope of application of provisions of this Part of the Code for different occupancies has been clarified.

2) Definitions of various new terms have been included and definitions of some of the existing terms have been updated based on latest developments and use.

Fire Prevention:

3) Based on the experience in the use of the provisions of the Code in relation to various occupancies and

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subdivision classification under various building occupancy types, the same has been reviewed and updated. Also, mixed occupancy and minor occupancy have been further clarified.

4) Table 1 on fire resistance ratings of structural and non-structural elements has been updated.

5) The provisions relating to fire separating walls, fire separating floors and fire partitions have been detailed.

6) Provisions of fire safety requirements of services shafts have been rationalized and updated.

7) A separate comprehensive clause on electrical power supply distribution for fire and life safety systems has been included.

8) Detailed clauses on air conditioning systems towards safety and smoke control integration have been provided.

9) Glass facade requirements have been detailed towards fire protection and smoke exhaust aspects.

10) A separate comprehensive clause on Fire Command Centre (FCC) has been introduced covering various requirements.

Life Safety:

11) The components of means of egress have been comprehensively brought out covering specific aspects relating to exit access, exit and exit discharge. The relationship of occupant load, exit width requirements and travel distances have also been duly detailed enabling efficient planning for enhanced life safety provisions. The table on capacity factors has been modified based on aspect of width per person approach used globally.

12) Requirement for displaying the occupancy load for assembly buildings and call centres, has been included.

13) The concept of firefighting shaft for safe and efficient use by the fire fighters to access the floor on fire and also allow egress/evacuation of the occupants with simultaneous use of refuge area used as staging of the occupants, have been well integrated, including in the annex for high rise buildings.

14) Aspects of compartmentation with fire barrier and its passive fire safety requirements have been detailed for respective occupancies.

15) Pressurization of exits and smoke extraction requirements for respective areas including car parking have been updated with an approach towards selecting alternative means therefor.

16) The clause on gas supply has been comprehensively updated.

17) The clause on fire detection and alarm system has been completely reviewed and updated as per the latest practices.

Fire Protection:

18) The table on minimum requirements for firefighting installations (erstwhile Table 23 and now Table 7) has been comprehensively updated.

19) Detailed provisions have been included on fire water storage, fire pump room, sprinkler system and various alternative fire suppression systems.

Additional Occupancy-wise Requirements

20) Concept of progressive evacuation in case of hospital buildings has been included in detail to ensure life safety of the inmates.

21) Provisions relating to requirement of refuge area have been updated including for D-6 occupancy and introduced for apartment buildings of height 60 m and above.

22) Separate provisions on atrium have been included in Annex F.

23) Detailed separate provisions have been included on commercial kitchens in Annex G.

24) Detailed separate provisions have been included on car parking facilities in Annex H.

25) Separate provisions on fire and life safety requirements for metro stations and metro trainways have been included in Annex J and Annex K, respectively.

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For provisions relating to universal accessibility and barrier-free environment Part 3 'Development Control Rules and General Building Requirements' of the Code may be referred.

All standards cross-referred to in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Part of the Code is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part.

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NATIONAL BUILDING CODE OF INDIA

PART 4 FIRE AND LIFE SAFETY

1 SCOPE

1.1 This Code (Part 4) covers the requirements for fire prevention, life safety in relation to fire and fire protection of buildings. This Code (Part 4) specifies occupancy-wise classification, constructional aspects, egress requirements and protection features that are necessary to minimise danger to life and property from fire.

1.2 The provisions of this Part are applicable to,

a) all high rise buildings; and

b) special buildings, those are,

1) hotel, educational, institutional, business, mercantile, industrial, storage, hazardous and mixed occupancies, where any of these buildings have floor area more than 500 m^2 on any one or more floors;

2) educational buildings having height 9 m and above;

3) institutional buildings having height 9 m and above;

4) all assembly buildings;

5) buildings, having area more than 300 m^2 of incidental assembly occupancy on any floor; and

6) buildings with two basements or more, or with one basement of area more than 500 m^2.

unless otherwise mentioned specifically in the provisions.

NOTE — The owner of the building and parties to agreement, may however, decide to apply the provisions of this Part to buildings other than those given above.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

2.1 Assisted Evacuation — Strategy that exists during which a designated person or persons provide assistance, during an emergency, to another person(s) to leave a building or a specific part of the built environment and to reach a final place of safety.

2.2 Atrium — A large-volume space created by a floor opening or series of floor openings connecting two or more stories that is covered at the top of the series of openings and is used for purposes other than an enclosed stairway; lifts hoist-way; an escalator opening; or as a utility shaft used for plumbing, electrical, air conditioning, or communications facilities.

2.3 Authorities Concerned — An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving or accepting equipment, materials, an installation, or a procedure.

2.4 Automatic Fire Detection and Alarm System — A system comprising components and sub-systems required for automatically detecting smoke, heat or fire initiating an alarm and other actions as appropriate. This system also includes manually operated electronic fire alarm (MOEFA) system.

NOTE — MOEFA system (with or without automatic fire detection and alarm system) includes all or some of the components such as manual call stations (initiating an alarm for fire and other actions as required), talk-back system and public address system.

2.5 Building — Any structure for whatsoever purpose and of whatsoever materials constructed and every part thereof whether used as human habitation or not and includes foundation, plinth, walls, floors, roofs, chimneys, plumbing and building services, fixed platforms, *Veranda*, balcony, cornice or projection, part of a building or anything affixed thereto or any wall enclosing or intended to enclose any land or space and signs and outdoor display structures. Tents, *Shamianahs*, tarpaulin shelters, etc, erected for temporary and ceremonial occasions with the permission of the Authority shall not be considered as building.

2.6 Building, Height of — The vertical distance measured in the case of flat roofs, from the average level of the ground around and contiguous to the building or as decided by the Authority to the terrace of the last livable floor of the building adjacent to the external wall; and in the case of pitched roofs, up to the point where the external surface of the outer wall intersects the finished surface of the sloping roof; and in the case of gables facing the road, the mid-point between the eaves level and the ridge. Where the building is located in a sloped terrain, height shall be determined from the lowest level (that is approachable by the fire service vehicles) to the terrace level. Architectural features serving no other function except that of decoration shall be excluded for the purpose of measuring heights.

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2.7 Combustible Material — A material which either burns itself or adds heat to a fire, when tested for non-combustibility in accordance with accepted standard [4(1)].

2.8 Common Path of Travel — That portion of the exit access which the occupants are required to traverse before two (or more) separate and distinct routes or two (or more) exits become available. Common paths of travel are part of travel distance.

2.9 Covered Area — Ground area covered by the building immediately above the plinth level. The area covered by the following in the open spaces is excluded from covered area (*see* Table 9):

a) Garden, rockery, well and well structures, plant nursery, water pool, swimming pool (if uncovered), platform round a tree, tank, fountain, bench, *Chabutara* with open top and unenclosed on sides by walls and the like;

b) Drainage culvert, conduit, catch-pit, gully pit, chamber, gutter and the like;

c) Compound wall, gate, unstoreyed porch and portico, slide, swing, uncovered staircases, ramp areas covered by *Chhajja* and the like; and

d) Watchman's booth, pump house, garbage shaft, electric cabin or substations, and such other utility structures meant for the services of the building under consideration.

NOTE — For the purpose of this Part, covered area equals the plot area minus the area due for open spaces in the plot.

2.10 Down-comer — An arrangement of firefighting within the building by means of down-comer pipe connected to terrace tank through terrace pump, gate valve and non-return valve and having mains not less than 100 mm internal diameter with landing valves on each floor/landing. It is also fitted with inlet connections at ground level for charging with water by pumping from fire service appliances and air release valve at roof level to release trapped air inside.

2.11 Dry Riser — An arrangement of firefighting within the building by means of vertical rising mains not less than 100 mm internal diameter with landing valves on each floor/landing which is normally dry but is capable of being charged with water usually by pumping from fire service appliances.

2.12 Emergency Lighting — Lighting provided for use when the supply to the normal lighting fails.

2.13 Emergency Lighting System — A complete but discrete emergency lighting installation also fed from the standby power source to the emergency lighting lamp(s), for example, self-contained emergency luminaire or a circuit from central battery (with or without monitoring system) connected through wiring to several escape lighting luminaries.

2.14 Escape Lighting — That part of the emergency lighting which is provided to ensure that the escape route is illuminated at all material times, for example, at all times when persons are on the premises, or at times the main lighting is not available, either for the whole building or for the means of egress.

2.15 Evacuation Lift — Lift that can be used, during an emergency, for self-evacuation.

2.16 Exit — That unobstructed component of means of egress which is between the exit access and the exit discharge or public way. Exit components include exterior exit doors at the level of exit discharge, interior exit stairways, exit passageways, exterior exit stairways and exterior exit ramps (*see* Fig. 1).

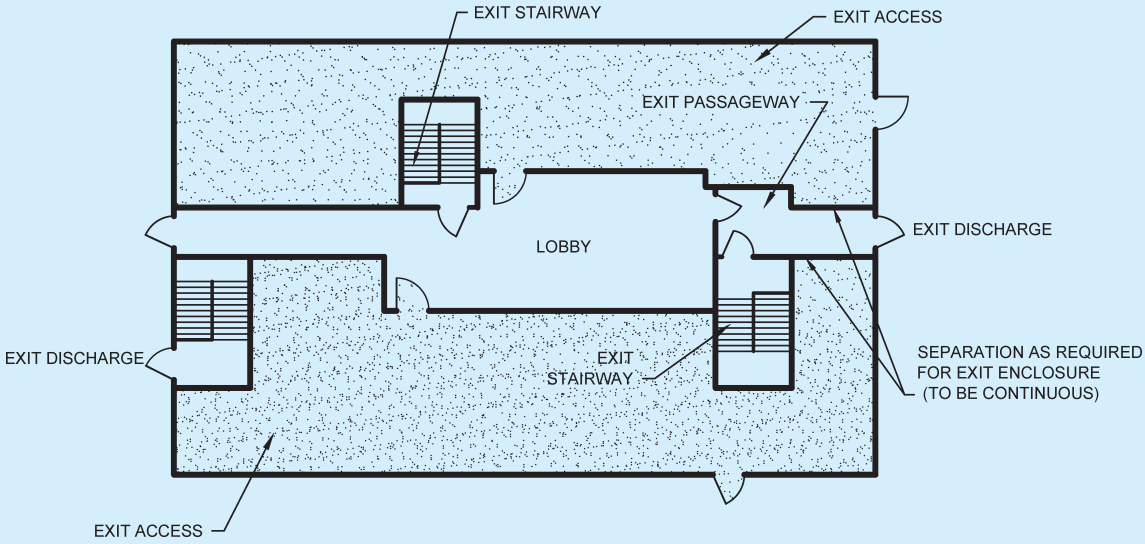


FIG. 1 COMPONENTS OF MEANS OF EGRESS

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2.17 Exit Access — That portion of a means of egress that leads to an exit (for example, doorways, staircase lobby, ramps, *Veranda*, corridor or passageway leading to an exit) (*see* Fig. 1).

2.18 Exit Access Corridor — A corridor in exit access which may not necessarily have the requirement of exits being met.

2.19 Exit Discharge — The component of a means of egress between the termination of an exit and a public way (*see* Fig. 1).

2.20 Fire Barrier (or Fire Resisting Barrier) — A fire barrier is a vertically or horizontally aligned member such as a wall or a fire curtain, or a floor. These may be with discontinuities created by openings with a specified fire resistance rating, where such members are designed and constructed with a specified fire resistance rating to limit the spread of fire that also restricts the movement of smoke.

2.21 Fire Compartment — A space within a building that is enclosed by fire barrier or fire resistant walls on all sides, including the top and bottom.

2.22 Fire Door and Fire Door Assembly — Any combination of fire door, frame, hardware and other accessories that together provide a specific fire resistant rating to the opening in terms of its stability, integrity and insulation properties, when installed in the openings in fire separation walls. Fire door is a component of fire door assembly.

NOTES

1 Wherever reference has been made to fire door or fire check door in this Part, the same shall be construed as fire door assembly.

2 Fire doors in exits shall have fire rating as required in this Part to meet the requirement of integrity and stability; and the insulation criteria shall be 20 min.

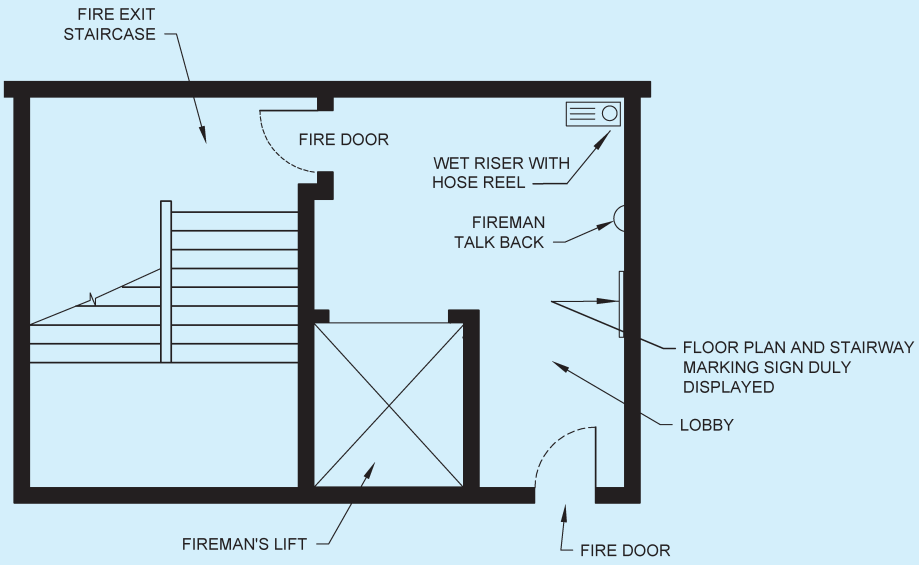
3 Fire doors in exits shall be provided with intumescent seal.

4 Fire doors in exits shall not be allowed to be on hold open position and kept closed and to close by 'door closure — spring mechanism'.

5 Fire curtains shall not be allowed as fire exits. If so provided for compartmentation, independent fire door shall be provided meeting the requirement for fire door in exits as above (of the width as required) within the prescribed travel distance requirement.

2.23 Fire Exit — A way out leading from exit access with or without panic bar provided on the door.

2.24 Firefighting Shaft (Fire Tower) — An enclosed shaft having protected area of 120 min fire resistance rating comprising protected lobby, staircase and fireman's lift, connected directly to exit discharge or through exit passageway with 120 min fire resistant wall at the level of exit discharge to exit discharge. These shall also serve the purpose of exit requirement/ strategy for the occupants. The respective floors shall be approachable from fire-fighting shaft enabling the fire fighters to access the floor and also enabling the fire fighters to assist in evacuation through fireman's lift. The firefighting shaft shall be equipped with 120 min fire doors. The firefighting shaft shall be equipped with firemen talk back, wet riser and landing valve in its lobby, to fight fire by fire fighters (*see* Fig. 2 for a typical firefighting shaft).



(LAYOUT TO BE PLANNED AS PER PROJECT BASIS MEETING ALL THE REQUIRED DETAILS)

NOTES

1 Where such lobbies and staircase in the firefighting shaft are naturally ventilated/cross-ventilated, the shaft may not be enclosed and fire door need not be provided.

2 For all enclosed firefighting shaft, the shaft's lobby should have floor plan duly displayed for the information of fire fighters.

FIG. 2 TYPICAL FIRE FIGHTING SHAFT

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2.25 Fire Load — Calorific energy, of the whole contents contained in a space, including the facings of the walls, partitions, floors and ceilings.

2.26 Fire Load Density — Fire load divided by floor area.

2.27 Fireman's Lift — A lift or a group of lifts invariably associated with all the features and requirements of a fire-fighting shaft. Such lift(s) are installed to enable fire services personnel to reach different floors with minimum delay, and shall meet the additional features as required in accordance with this Part. This lift also serves the purpose of meeting the requirement of evacuation lift for assisted evacuation.

2.28 Fire Resistance — Fire resistance is a property of an element of building construction and is the measure of its ability to satisfy for a stated period, some or all of the following criteria:

a) *Load bearing capacity* (*Stability*) (*R*) — The ability of a load bearing element to withstand fire exposure without any loss of structural stability.

b) *Integrity* (*E*) — Resistance to penetration of flame and hot gases.

c) *Insulation* (*I*) — Resistance to temperature rise on the unexposed face up to a maximum of 180°C at any single point and average temperature of 140°C.

2.29 Fire Resistance Rating — The time that a material or construction will withstand the standard fire exposure as determined by fire test done in accordance with the standard methods of fire tests of materials/ structures as per the accepted standard [4(2)].

NOTES

1 The requirement of rating of various building elements as given in this Part shall be applicable in accordance with the provisions given in the accepted standard [4(2)].

2 The fire resistance rating shall be specified in terms of minutes.

3 Fire resistance rating for non-structural material/assembly shall bear a label of compliance to such rating as per the approval of competent authority based on testing and evaluation. The label shall be permanently affixed to the material/assembly and may carry other relevant details such as name and type of the product, and manufacturer's details.

2.30 Fire Resistant Wall — Fire resistance rated wall, having opening(s) with specified fire resistant rating, which restricts the spread of fire from one part of a building to another part of the same building.

2.31 Fire Separation — The distance in metre, measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space for the purpose of preventing the spread of fire.

2.32 Fire Stop — A fire resistant material, or construction, having a fire resistance rating of not less than the fire separating elements, installed in concealed spaces or between structural elements of a building to prevent the spread/propagation of fire and smoke through walls, ceilings and the like as per the laid down criteria.

NOTES

1 Fire stop assembly for through penetrations is a combination of firestop compatible for use with the penetrant, penetration items such as cables, cable tray, conduits, ducts, pipes, etc, and their means of support through the wall or opening that together restores the fire resistance rating of the fire separating elements in terms of its integrity and/or insulation properties.

2 Fire stop assembly for joints is the one where fire stop with movement capability is used to seal the linear joints between adjacent fire separating elements, to maintain the fire resistance of the separating elements, which should be installed within its tested design limits with regard to size of the joint, type of assembly, and anticipated compression and extension of the joint.

2.33 Fire Suppression Systems

a) *Gas based systems* — Systems that use gaseous agents as fire suppression media, such as, all agents alternate to Halon gases, listed and approved for use by relevant Indian Standards; other methods/types of gas based systems where their protection is equal to or better than what is suggested above for the type of application subject to the acceptance of Authorities concerned may also fall under such systems.

b) *Water based systems* — Systems that use mainly water as firefighting media such as hydrant system, sprinkler system, water spray system, foam system and water mist system.

2.34 Fire Wall or Fire Separating Wall — A fire resistance rated wall having fire protected openings, which restricts the spread of fire and extends continuously from the foundation to the roof (and through the roof at least 1m above the roof in case of combustible roof), with sufficient structural stability under fire conditions to allow collapse of construction on one side or either side without collapse of the wall.

2.35 Floor Area (Gross) — The area of the floor within the inside perimeter of the outside walls of the floor of the building under consideration with no deductions for corridors and passage-ways, stairs, closets, thickness of interior walls, columns, lifts and building shafts or other features.

2.36 Floor Area Ratio (FAR) — The quotient obtained by dividing the total covered area (plinth area) on all

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floors by the area of the plot:

$$\text{FAR} = \frac{\text{Total covered area of all floors}}{\text{Plot area}}$$

2.37 Fire Exit Hardware — A door-latching assembly incorporating an actuating member or panic bar that releases the latch bolt upon the application of a force in the direction of egress travel, provided on exits.

2.38 High Rise Building — A building 15 m or above in height (irrespective of its occupancy).

2.39 Horizontal Exit — A defend in place or a staging arrangement, providing safety from fire and smoke originating from the area of incidence, by allowing alternative egress from a compartment to an area of refuge or another compartment at or near the same level. This also includes such egress from a compartment to an adjoining building. A horizontal exit shall be through a fire door of 120 min rating in a fire resistant wall. Horizontal exit require separation with the refuge area or adjoining compartment through 120 min fire barrier. The adjoining compartment of the horizontal exit should allow unlocked and ease of egress and exits for the occupants using defend in place strategy.

2.40 Lift Lobby — A space from which people directly enter a lift car(s) and into which people directly enter upon exiting a lift car(s).

2.41 Means of Egress — A continuous way of travel from any point in a building or structure to a public way, consisting of three separate and distinct parts, that is, exit access, exit and exit discharge.

2.42 Means of Escape — A way out of a building or structure that does not conform to the strict definition of 'means of egress' but does provide an alternate way out.

2.43 Metro Station

2.43.1 *Concourse* — Intermediate level(s) or area(s) connecting a station platform(s) to a public way through stairs, escalators or corridors.

2.43.2 *Crush Train Load* — The number of passengers inside a train when it is filled to maximum capacity permissible by rolling stock design.

2.43.3 *Entraining Load* –The number of passengers boarding a train at a platform.

2.43.4 *Headway* — The interval of time between the arrivals of consecutive trains at a platform in a station.

2.43.5 *Mass Rapid Transit* — Any station building or part thereof, permanent or temporary, through which people transit for the duration of time required to enter the building and board the train to depart the station platform or to alight from the train and depart from the station building.

2.43.6 *Non-transit Occupancy* — Occupancy not under the control of the system operating authority.

2.43.7 *Point of Safety* — One of the following: (a) An enclosed exit that leads to a public way or safe location outside the station, trainway, or vehicle, (b) An at-grade point beyond the vehicle, enclosing stations, or trainway, (c) A point on open track beyond the open or enclosed station or enclosed train-way, and (d) Any other location approved by the Authorities concerned.

2.43.8 *Station* — A place designated for the purpose of loading and unloading passengers, including service area and ancillary spaces associated with the same structure.

2.43.8.1 *Composite station* — A transit station that is constructed contiguous with non-transit occupancy.

2.43.8.2 *Enclosed station* — A station or portion thereof that does not meet the definition of an open station.

2.43.8.3 *Open station* — A station that is constructed such that it is directly open to the atmosphere, and smoke and heat are allowed to disperse directly into surrounding open atmosphere.

2.43.9 *Station Platform* — The area of a station immediately adjacent to a guideway, used primarily for loading and unloading passengers.

2.44 Mixed Occupancy — A multiple occupancy where the occupancies are intermingled.

2.45 Multiple Occupancy — A building or structure in which two or more classes of occupancy exist.

2.46 Occupancy or Use Group — The principal occupancy for which a building or a part of a building is used or intended to be used; for the purpose of classification of a building according to the occupancy, an occupancy shall be deemed to include subsidiary occupancies which are contingent upon it.

2.47 Occupant Load — Maximum number of persons that might occupy a building or portion thereof at any one time.

2.48 Place of Comparative Safety — Places within a building where people can stay little longer until evacuation, for example, refuge areas, terrace, fire/ smoke separated compartments, etc.

2.49 Pressurization — The establishment of a pressure difference across a barrier to protect exit, stairway, lobby, exit passageway or room of a building from smoke penetration.

2.50 Pressurization Level — The pressure difference between the pressurized space and the adjoining area served by the pressurized space expressed in Pascal (Pa).

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2.51 Public Way — A street, alley, or other similar parcel of land essentially open to the outside air, dedicated, or otherwise permanently appropriated to the public for public use and having a clear width and height of not less than 3 m.

2.52 Ramp — The construction, in the form of an inclined plane that is steeper than or equal to 1 : 20 (5 percent) from the horizontal, together with any intermediate landing, that makes it possible to pass from one level to another.

2.53 Refuge Area — An area within the building for a temporary use during egress. It generally serves as a staging area which is protected from the effect of fire and smoke.

2.54 Roof Exits — A means of escape on to the roof of a building, where the roof has access to it from the ground through alternative stair case or adjacent building.

2.55 Site (Plot) — A parcel (piece) of land enclosed by definite boundaries.

2.56 Smoke Barrier — A continuous membrane, or a membrane, where such membrane is designed and constructed to restrict the movement of smoke.

2.57 Smoke Compartment — A space within a building enclosed by smoke barriers on all sides.

2.58 Stack Pressure — Pressure difference caused by a temperature difference creating an air movement within a duct, chimney or enclosure.

2.59 Travel Distance — The distance to be travelled from any point in a building to a protected exit or external escape route or final exit measured along the line of travel.

2.60 Ventilation — Supply of outside air into, or the removal of inside air from an enclosed space.

2.61 Venting Fire — The process of facilitating heat and smoke to leave a building as quickly as possible by such paths so that lateral spread of fire and heat is checked, firefighting operations are facilitated and minimum fire damage is caused.

2.62 Visual Strobes/Flashing — It is an audio-visual fire alarm for alerting persons with hearing impairment with flashing light. The strobe frequency should be from 0.5 Hz to 4.0 Hz.

NOTE — Care should be taken to ensure that overlapping strobes do not combine to result in a higher frequency of flashing.

2.63 Volume to Plot Area Ratio (VPR) — The ratio of volume of building measured in cubic metre to the area of the plot measured in square metre and expressed in metre.

2.64 Water Based Systems

2.64.1 *Hydrant System* — A distribution system having a network of piping installed underground/above-ground around and/or through inside of a building with internal and/or external hydrants fitted with landing valves at regular intervals according to the occupancy. The distribution system is connected to water supply system for firefighting.

2.64.2 *Automatic Sprinkler System* — A system of water pipes fitted with sprinkler heads at suitable intervals and heights and designed to actuate automatically, control and extinguish a fire by the discharge of water.

2.64.3 *Automatic Water Spray Systems* — A special fixed pipe system connected to a reliable source of fire protection water supply and equipped with water spray nozzles for specific water discharge and distribution over the surface or area to be protected. The piping system is connected to the water supply through an automatically actuated deluge valve which initiates flow of water. Automatic actuation is achieved by operation of automatic detecting equipment installed along with water spray nozzles. There are two types of systems namely high velocity and medium velocity systems.

2.64.4 *Water Mist Systems* — A distribution system connected to a pumping and water supply system that is equipped with nozzles capable of delivering water mist to the part/entire enclosure or area, intended to control, suppress, or extinguish fire and is capable of meeting the specified performance requirements.

2.64.5 *Foam Protection System* — Firefighting systems where foam is made by mechanically mixing air with a solution consisting of fresh water to which a foaming agent (liquid concentrate) has been added. Firefighting foam is a stable aggregation of small bubbles of density lower than oil or water, and shows tenacious qualities for covering horizontal surfaces. There are three types of foam applications that is, low, medium and high expansion foams depending upon the application.

2.65 Wet Riser — An arrangement for firefighting within the building by means of vertical rising mains not less than 100 mm nominal diameter with landing valves on each floor/landing for firefighting purposes and permanently charged with water from a pressurized supply.

NOTE — For definition of other terms, reference shall be made to accepted standards [4(3)].

3 FIRE PREVENTION

3.1 Classification of Buildings Based on Occupancy

3.1.1 *General Classification*

All buildings, whether existing or hereafter erected shall be classified according to use or the character of

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occupancy in one of the following groups:

Group A	Residential
Group B	Educational
Group C	Institutional
Group D	Assembly
Group E	Business
Group F	Mercantile
Group G	Industrial
Group H	Storage
Group J	Hazardous

The details of each occupancy and example of buildings in each group are given in **3.1.2** to **3.1.10.**

3.1.1.1 *Minor occupancy*

This is purely incidental to operations in a main occupancy, which shall be considered as part of the main occupancy and shall be classified under the relevant group for the main occupancy.

3.1.1.2 *Mixed occupancy*

Where two or more types of occupancies intermingle in the same building, the entire building shall be treated as mixed occupancy and the same shall comply with **3.1.12**.

3.1.2 *Group A Residential Buildings*

These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities, except any building classified under Group C.

Buildings and structures under Group A shall be further subdivided as follows:

Subdivision A-1	Lodging and rooming houses
Subdivision A-2	One or two family private dwellings
Subdivision A-3	Dormitories
Subdivision A-4	Apartment houses
Subdivision A-5	Hotels
Subdivision A-6	Starred hotels

a) *Subdivision A-1 Lodging and rooming houses* — These shall include any building or group of buildings under the same management, in which separate sleeping accommodation on transient or permanent basis, with or without dining facilities but without cooking facilities for individuals is provided. This includes inns, clubs, motels and guest houses.

NOTE — A lodging or rooming house shall be classified as a dwelling in Subdivision A-2, if no room in any of its private dwelling units is rented to more than three persons.

b) *Subdivision A-2 One or two family private dwellings* — These shall include any private dwelling, which is occupied by members of one or two families and has a total sleeping accommodation for not more than 20 persons.

If rooms in a private dwelling are rented to outsiders, these shall be for accommodating not more than three persons per room.

If sleeping accommodation for more than 20 persons is provided in any one residential building, it shall be classified as a building in Subdivision A-1 or Subdivision A-4 as the case may be.

c) *Subdivision A-3 Dormitories* — These shall include any building in which group sleeping accommodation is provided, with or without dining facilities for persons who are not members of the same family, in one room or a series of closely associated rooms under joint occupancy and single management, for example, school and college dormitories, students, and other hostels and military barracks.

d) *Subdivision A-4 Apartment houses* — These shall include any building or structure in which living quarters are provided for three or more families, living independently of each other and with independent cooking facilities, for example, apartment houses, mansions and *Chawls*.

e) *Subdivision A-5 Hotels* — These shall include any building or group of buildings under single management, in which sleeping accommodation is provided, with or without dining facilities for hotels classified up to Four Star Category.

f) *Subdivision A-6 Starred hotels* — These shall include the hotels duly approved by the concerned authorities as Five Star and above hotels.

3.1.3 *Group B Educational Buildings*

These shall include any building used for school, college, other training institutions involving assembly for instruction, education or recreation for not less than 20 students.

Buildings and structures under Group B shall be further subdivided as follows:

Subdivision B-1	Schools up to senior secondary level
Subdivision B-2	All others/training institutions

a) *Subdivision B-1 Schools up to senior secondary level* — This subdivision shall

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include any building or a group of buildings under single management which is used for students not less than 20 in number.

b) *Subdivision B-2 All others/training institutions* — This subdivision shall include any building or a group of buildings under single management which is used for students not less than 100 in number.

In the case of temporary buildings/structures which are utilized for educational purposes, the provisions of **3.2.5.3** shall apply.

If residential accommodation is provided in the schools/ institutions that portion of occupancy shall be classified as a building in Subdivision A-3.

3.1.4 *Group C Institutional Buildings*

These shall include any building or part thereof, which is used for purposes, such as medical or other treatment or care of persons suffering from physical or mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants.

Buildings and structures under Group C shall be further subdivided as follows:

Subdivision C-1	Hospitals and sanatoria
Subdivision C-2	Custodial institutions
Subdivision C-3	Penal and mental institutions

a) *Subdivision C-1 Hospitals and sanatoria* — This subdivision shall include any building or a group of buildings under single management, which is used for housing persons suffering from physical limitations because of health or age and those incapable of self-preservation, for example, hospitals, infirmaries, sanatoria and nursing homes.

b) *Subdivision C-2 Custodial institutions* — This subdivision shall include any building or a group of buildings under single management, which is used for the custody and care of persons, such as children, convalescents and the aged who are incapable of self-preservation, for example, homes for the aged and infirm, convalescent homes and orphanages.

c) *Subdivision C-3 Penal and mental institutions* — This subdivision shall include any building or a group of buildings under single management, which is used for housing persons under restraint, or who are detained for penal or corrective purposes, in which the liberty of the inmates is restricted, for example, jails, prisons, mental hospitals, mental sanatoria and reformatories.

3.1.5 *Group D Assembly Buildings*

These shall include any building or part of a building, where not less than 50 persons congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes, for example, theatres; motion picture houses; assembly halls; auditoria; exhibition halls; museums; skating rinks; gymnasiums; restaurants; places of worship; dance halls; club rooms; passenger stations and terminals of air, surface and marine public transportation services; and stadia.

Buildings under Group D shall be further subdivided as follows:

Subdivision D-1	Buildings having a theatrical or motion picture or any other stage and fixed seats for over 1 000 persons
Subdivision D-2	Buildings having a theatrical or motion picture or any other stage and fixed seats up to 1 000 persons
Subdivision D-3	Buildings without a permanent stage having accommodation for 300 or more persons but no permanent seating arrangement
Subdivision D-4	Buildings without a permanent stage having accommodation for less than 300 persons with no permanent seating arrangement
Subdivision D-5	All other structures including temporary structures designed for assembly of people not covered by Subdivisions D-1 to D-4, at ground level
Subdivision D-6	Buildings having mixed occupancies of assembly and mercantile (for example, shopping malls providing facilities such as shopping, cinema theatres, multiplexes and restaurants/food courts)
Subdivision D-7	Underground and elevated mass rapid transit system

a) *Subdivision D-1* — This subdivision shall include any building primarily meant for theatrical or operatic performances and which has a stage, proscenium curtain, fixed or portable scenery or scenery loft, lights, mechanical appliances or other theatrical

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accessories and equipment for example, theatres, motion picture houses, auditoria, concert halls, television and radio studios admitting an audience and which are provided with fixed seats for over 1 000 persons.

b) *Subdivision D-2* — This subdivision shall include any building primarily meant for use as described for Subdivision D-1, but with fixed seats up to 1 000 persons.

c) *Subdivision D-3* — This subdivision shall include any building, its lobbies, rooms and other spaces connected thereto, primarily intended for assembly of people, but which has no theatrical stage or permanent theatrical and/or cinematographic accessories and has accommodation for 300 persons or more, for example, dance halls, night clubs, halls for incidental picture shows, dramatic, theatrical or educational presentation, lectures or other similar purposes having no theatrical stage except a raised platform and used without permanent seating arrangement; art galleries, community halls, marriage halls, places of worship, museums, lecture halls, passenger terminals and heritage and archaeological monuments, pool and billiard parlours, bowling alleys, community halls, courtrooms, gymnasiums (without spectator seating), indoor swimming pools (without spectator seating), indoor tennis courts (without spectator seating).

d) *Subdivision D-4* — This subdivision shall include any building primarily intended for use as described in Subdivision D-3, but with accommodation for less than 300 persons with no permanent seating arrangements.

e) *Subdivision D-5* — This subdivision shall include any building or structure, permanent or temporary meant for assembly of people not covered by Subdivisions D-1 to D-4, for example, grandstands, stadia, amusement park structures, reviewing stands and circus tents, arenas, external swimming pools, tennis and similar type of courts.

f) *Subdivision D-6* — This subdivision shall include any building for assembly of people provided with multiple services/facilities like shopping, cinema theatres, multiplexes, restaurants/food court.

g) *Subdivision D-7* — This subdivision shall include any building or structure like example, underground or elevated railways.

3.1.6 *Group E Business Buildings*

These shall include any building or part thereof which is used for transaction of business for keeping of accounts and records and similar purposes, professional establishments, service facilities, etc. City halls, town halls, courthouses and libraries shall be classified in this group so far as the principal function of these is transaction of public business and keeping of books and records.

Buildings under Group E shall be further subdivided as follows:

Subdivision E-1	Offices, banks, professional establishments, like offices of architects, engineers, doctors, lawyers, post offices and police stations
Subdivision E-2	Laboratories, outpatient clinics, research establishments, libraries and test houses
Subdivision E-3	Electronic data processing centres, computer installations, information technology parks and call centres
Subdivision E-4	Telephone exchanges
Subdivision E-5	Broadcasting stations, T.V. stations and air traffic control towers

3.1.7 *Group F Mercantile Buildings*

These shall include any building or part thereof, which is used as shops, stores, market, for display and sale of merchandise, either wholesale or retail.

Mercantile buildings shall be further subdivided as follows:

Subdivision F-1	Shops, stores, departmental stores, markets (any with covered area up to 500 m^2)
Subdivision F-2	Shops, stores, departmental stores, markets (any with covered area more than 500 m^2)
Subdivision F-3	Underground shopping centres

Storage and service facilities incidental to the sale of merchandise and located in the same building shall also be included under this group.

3.1.8 *Group G Industrial Buildings*

These shall include any building or part of a building or structure, in which products or materials of all kinds and properties are fabricated, assembled, manufactured or processed, for example, assembly plants, industrial laboratories, dry cleaning plants, power plants,

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generating units, pumping stations, fumigation chambers, laundries, buildings or structures in gas plants, refineries, dairies and saw-mills, etc.

Buildings under Group G shall be further subdivided as follows:

Subdivision G-1	Buildings used for low hazard industries
Subdivision G-2	Buildings used for moderate hazard industries
Subdivision G-3	Buildings used for high hazard industries

The hazard of occupancy, for the purpose of the Code, shall be the relative danger of the start and spread of fire, the danger of smoke or gases generated, the danger of explosion or other occurrences potentially endangering the lives and safety of the occupants of the buildings.

Hazard of occupancy shall be determined by the Authority on the basis of the fire loads of the contents, and the processes or operations conducted in the building, provided, however, that where the combustibility of the material, the flame spread rating of the interior finish or other features of the building or structure are such as to involve a hazard greater than the occupancy hazard, the greater degree of hazard shall govern the classification.

For determination of fire loads and fire load density for arriving at the classification of occupancy hazard, guidance on calorific values of some common materials is given at Annex A.

A broad classification of industrial occupancies into low, moderate and high hazard classes is given at Annex B, for guidance. Any occupancy not covered in Annex B, shall be classified in the most appropriate class depending on the degree of hazard.

Where different degrees of hazard of occupancy exist in different parts of a building, the most hazardous of those shall govern the classification for the purpose of this Code, except in cases where hazardous areas are segregated or protected as specified in the Code.

a) *Subdivision G-1* — This subdivision shall include any building in which the contents are of such comparative low combustibility and the industrial processes or operations conducted therein are of such a nature that there is hardly any possibility for any self-propagating fire to occur and the only consequent danger to life and property may arise from panic, fumes or smoke, or fire from some external source.

b) *Subdivision G-2* — This subdivision shall include any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with moderate rapidity or result in other hazardous situation and may give off a considerable volume of smoke, but from which neither toxic fumes nor explosions are to be feared in the event of fire.

c) *Subdivision G-3* — This subdivision shall include any building in which the contents or industrial processes or operations conducted therein are liable to give rise to a fire which will burn with extreme rapidity or result in other hazardous situation or from which poisonous fumes or explosions are to be feared in the event of a fire.

3.1.9 *Group H Storage Buildings*

These shall include any building or part of a building used primarily for the storage or sheltering (including servicing, processing or repairs incidental to storage) of goods, ware or merchandise (except those that involve highly combustible or explosive products or materials), vehicles or animals, for example, warehouses, cold storages, freight depots, transit sheds, storehouses, truck and marine terminals, garages, hangars, grain elevators, barns and stables. Storage properties are characterized by the presence of relatively small number of persons in proportion to the area. Any new use which increases the number of occupants to a figure comparable with other classes of occupancy shall change the classification of the building to that of the new use, for example, hangars used for assembly purposes, warehouses used for office purposes, garage buildings used for manufacturing.

3.1.10 *Group J Hazardous Buildings*

These shall include any building or part thereof which is used for the storage, handling, manufacture or processing of highly combustible or explosive materials or products which are liable to burn with extreme rapidity and/or which may produce poisonous fumes or explosions for storage, handling, manufacturing or processing which involve highly corrosive, toxic or noxious alkalis, acids or other liquids or chemicals producing flame, fumes and explosive, poisonous, irritant or corrosive gases; and for the storage, handling or processing of any material producing explosive mixtures of dust which result in the division of matter into fine particles subject to spontaneous ignition. Examples of buildings in this class are those buildings which are used for,

a) storage, under pressure of more than 0.1 N/mm^2 and in quantities exceeding 70 m^3,

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of acetylene, hydrogen, illuminating and natural gases, ammonia, chlorine, phosgene, sulphur dioxide, carbon dioxide, methyloxide and all gases subject to explosion, fume or toxic hazard, cryogenic gases, etc;

b) storage and handling of hazardous and highly flammable liquids, liquefiable gases like LPG, rocket propellants, etc;

c) storage and handling of hazardous and highly flammable or explosive materials (other than liquids); and

d) manufacture of artificial flowers, synthetic leather, ammunition, explosives and fireworks.

NOTE — A list of hazardous substances giving quantities, for which or exceeding which owners handling such substances are required to be covered under *The Public Liability Insurance Act*, 1991, has been notified under the '*Rules on Emergency Planning, Preparedness and Response for Chemical Accidents*' by the Govt. of India, Ministry of Environment and Forests Notification No. G.S.R. 347(E) dated 01 August 1996.

3.1.11 *Mixed Occupancy*

In case of mixed occupancy, in so far as fire protection is concerned, all the occupancies/the entire building shall be governed by the most restrictive provisions of the Code among those applicable for individual occupancies. The provisions for life safety given in the Code for individual occupancy shall, however, apply to the respective occupancies. Exits in such mixed occupancy shall be arranged so as to ensure that means of egress is not decreased in the direction of egress travel.

Further, in such mixed occupancies, the occupancies are also required to be separated (horizontally and/or vertically as the case may be) by a 240 min fire resistance rating.

3.1.12 Where change in the occupancy of any building places it in a different group or in a different subdivision of the same group, such building shall be made to comply with the requirements of the Code for the new group or its subdivision.

3.1.13 Where the new occupancy of a building is less hazardous, based on life and fire risk, than its existing occupancy, it shall not be necessary to conform to the requirements of the Code for the new group or its subdivision.

3.1.14 A certificate of occupancy shall be necessary, as required under Part 2 'Administration' of the Code, before any change is effected in the character of occupancy of any building.

3.2 Fire Zones

3.2.1 *Demarcation*

The city or area under the jurisdiction of the Authority shall, for the purpose of the Code, be demarcated into distinct zones, based on fire hazard inherent in the buildings and structures according to occupancy (*see* **3.1**), which shall be called as 'Fire Zones'.

3.2.2 *Number and Designation of Fire Zones*

3.2.2.1 The number of fire zones in a city or area under the jurisdiction of the Authority depends upon the existing layout, types of building construction (*see* **3.3**), classification of existing buildings based on occupancy (*see* **3.1**) and expected future development of the city or area. In large cities or areas, three fire zones may be necessary, while in smaller ones, one or two may be adequate.

3.2.2.2 The fire zones shall be made use of in land use development plan and shall be designated as follows:

a) *Fire Zone No. 1* — This shall comprise areas having residential (Group A), educational (Group B), institutional (Group C), assembly (Group D), small business (Subdivision E-1) and mercantile (Group F) buildings, or areas which are under development for such occupancies.

b) *Fire Zone No. 2* — This shall comprise business (Subdivisions E-2 to E-5) and industrial buildings (Subdivisions G-1 and G-2), except high hazard industrial buildings (Subdivision G-3) or areas which are under development for such occupancies.

c) *Fire Zone No. 3* — This shall comprise areas having high hazard industrial buildings (Subdivision G-3), storage buildings (Group H) and buildings for hazardous uses (Group J) or areas which are under development for such occupancies.

3.2.3 *Change in the Fire Zone Boundaries*

When the boundaries of any fire zone are changed, or when it is intended to include other areas or types of occupancies in any fire zone, it shall be done by following the same procedure as for promulgating new rules or ordinances or both.

3.2.4 *Overlapping Fire Zone*

3.2.4.1 When any building is so situated that it extends to more than one fire zone, it shall be deemed to be in the fire zone in which the major portion of the building or structure is situated.

3.2.4.2 When any building is so situated that it extends equally to more than one fire zone, it shall be deemed

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to be in the fire zone having more hazardous occupancy buildings.

3.2.5 *Temporary Buildings or Structures*

3.2.5.1 Temporary buildings and structures shall be permitted only in Fire Zones No. 1 and 2 as the case may be, according to the purpose for which these are to be used, by special permit from the Authority for a limited period and subject to such conditions as may be imposed in the permit.

3.2.5.2 Such buildings and temporary structures shall be completely removed on the expiry of the period specified in the permit.

3.2.5.3 Adequate fire precautionary measures in the construction of temporary structures and *Pandals* shall be taken in accordance with good practice [4(4)].

3.2.6 *Restrictions on the Type of Construction for New Buildings*

These shall be as follows:

a) Buildings erected in Fire Zone No. 1 shall conform to construction of Type 1, 2, 3 or 4.
b) Buildings erected in Fire Zone No. 2 shall conform to construction of Type 1, 2 or 3.
c) Buildings erected in Fire Zone No. 3 shall conform to construction of Type 1 or 2.

3.2.7 *Restrictions on Existing Buildings*

The existing buildings in any fire zone shall not be required to comply with the requirements of the Code unless these are altered, or in the opinion of the Authority, such building constitutes a hazard to the safety of the adjacent property or to the occupants of the building itself or is an unsafe building. In the event of alteration, it shall be necessary to obtain permission of the Authority for such alteration consistent with fire hazard (*see* Part 2 'Administration' of the Code).

Alterations/modifications/renovations shall be accomplished so as to ensure conformity with all the safety requirements of the new buildings. Such alterations shall not in any way bring down level of fire and life safety below that which existed earlier. Any addition or alterations or construction of cubicles or partitioning, for floor area exceeding 500 m^2 for all high rise buildings shall be with the approval of local fire authority.

3.3 Types of Construction

3.3.1 The design of any building and the type of materials used in its construction are important factors in making the building resistant to a complete burn-out and in preventing the rapid spread of fire, smoke or fumes, which may otherwise contribute to the loss of lives and property.

The fire resistance of a building or its structural and non-structural elements is expressed in minutes against a specified fire load which is expressed in kcal/m^2, and against a certain intensity of fire. The fire-resistance test for structural element shall be done in accordance with accepted standards [4(2)]. For the purpose of the Code, the types of construction according to fire resistance shall be classified into four categories, namely, Type 1 Construction, Type 2 Construction, Type 3 Construction and Type 4 Construction. The minimum fire resistance ratings of structural and non-structural members for various types of construction shall be as given in Table 1.

Non-combustible materials should be used for construction of buildings, and the internal walls of staircase enclosures should be of brick work or reinforced concrete or any other material of construction with minimum of 120 min rating. The walls for the chimney shall be of Type 1 or Type 2 Construction depending on whether the flue gas temperature is above 200°C or less, respectively.

3.3.2 It is required that a structural and/or non-structural element/component shall have the requisite fire resistance rating as per Table 1. The fire resistance rating for the structural and non-structural elements shall be based on guidelines as per approved and accepted standards. The fire rating shall be validated and certified with a view to meeting the requirements of Table 1. In the absence of any validated/certified rating, guidance may be obtained from the information available in Annex C.

3.3.3 Load bearing steel beams and columns of buildings having total covered area of 500 m^2 and above shall be protected against failure/collapse of structure in case of fire. This could be achieved by use of appropriate methodology using suitable fire resistance rated materials along with suppression system (*see* Annex C, Table 25 and Table 26).

3.3.4 The false ceiling, including all fixtures used for its suspension, shall be of non-combustible material and shall provide adequate fire resistance to the ceiling in order to prevent spread of fire across ceiling.

3.4 General Requirements of All Individual Occupancies

3.4.1 *General*

All buildings shall satisfy certain requirements, which contribute, individually and collectively, to the safety of life from fire, smoke, fumes and panic arising from these or similar causes. There are, however, certain general principles and common requirements, which are applicable to all or most of the occupancies.

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Table 1 Fire Resistance Ratings of Structural and Non-Structural Elements (minutes)
(*Clauses* 3.3.1 *and* 3.3.2)

Sl No.	Structural Element	Fire Resistance Ratings (min) for Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Exterior walls:				
	a) Fire separation less than 3.7 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	120	90	60	60
	b) Fire separation of 3.7 m or more but less than 9 m:				
	1) Bearing	240	120	120	60
	2) Non-bearing	90	60	60	60
	c) Fire separation of 9 m or more:				
	1) Bearing	240	120	120	60
	2) Non-bearing	60	60	60	60
ii)	Fire separation assemblies (like fire check doors)	120	120	120	120
iii)	Fire enclosures of exits	120	120	120	120
iv)	Shafts for services, lift hoistway and refuse chutes	120	120	120	120
v)	Vertical separation between adjacent tenant spaces	60	60	60	60
vi)	Dwelling unit separation:				
	a) Load bearing	120	120	60	60
	b) Non-load bearing	60	60	30	30
vii)	Interior bearing walls, bearing partitions, columns, beams, girders, trusses (other than roof trusses) and framing:				
	a) Supporting more than one floor	240	120	120	120
	b) Supporting one floor only	180	90	60	60
	c) Supporting a roof only	180	90	60	60
viii)	Walls supporting structural members	180	90	60	60
ix)	Floor construction	120	90	60	60
x)	Roof construction:				
	a) 5 m or less in height to lowest member	120	90	60	60
	b) More than 5 m but less than 6.7 m in height to lowest member	60	60	60	60
	c) 6.7 m or more in height to lowest member	0	0	0	0

NOTES

1 The above fire resistance rating shall be required to achieve the respective type of construction unless otherwise specified in the respective clauses for different applications/use.

2 In case of lift bank, the partition wall, if any, need not be of fire rating specified in this table.

3.4.2 *Exceptions and Deviations*

Exceptions and deviations to the general provisions of requirements of individual occupancies are given as applicable to each type of occupancy in **6.1** to **6.9**. In case of practical difficulty or to avoid unnecessary hardship, without sacrificing reasonable safety, local head, fire services may consider exemptions from the Code.

3.4.3 *Occupation of Buildings under Construction*

3.4.3.1 A building or portion of the building may be occupied during construction, repairs, alterations or additions only if all means of exit and fire protection measures are in place and continuously maintained for the occupied part of the building.

3.4.3.2 A high rise building during construction shall be provided with the following fire protection measures, which shall be maintained in good working condition at all the times:

a) Dry riser of minimum 100 mm diameter pipe with hydrant outlets on the floors constructed with a fire service inlet to boost the water in the dry riser and maintenance should be in accordance with good practice [4(5)].

b) Drums of 2 000 litre capacity filled with water with two fire buckets on each floor;

c) A water storage tank of minimum 20 000 litre capacity, which may be used for other construction purposes also.

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3.4.4 *Maximum Height, Floor Area Ratio and Open Spaces*

3.4.4.1 Every building shall be restricted in its height above the ground level and the number of storeys, depending upon its occupancy and the type of construction. The height shall be measured as specified in Part 3 'Development Control Rules and General Building Requirements' of the Code. The maximum permissible height for any combination of occupancy and types of construction should necessarily be related to the width of street fronting the building, or floor area ratios and the local firefighting facilities available.

NOTE — Set-back distances (according to the permissible height for each type of building as per the occupancy), width of streets providing approach to the building, permitted floor area ratio (FAR), permitted open space around or inside buildings, provision of adequate passageway and clearances required for firefighting vehicles, etc shall be strictly governed by the provisions of Part 3 'Development Control Rules and General Building Requirements' of the Code.

3.4.4.2 *Floor area ratio*

The comparative floor area ratios for different occupancies and types of construction are given in Table 2 (*see also* Part 3 'Development Control Rules and General Building Requirements' of the Code).

3.4.4.3 The requirements of open space around the building(s) shall be in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

3.4.5 *Openings in Fire Resistant Walls and Floors*

3.4.5.1 At the time of designing openings in fire resistant walls and floors, particular attention shall be paid to all such factors which limit fire spread through these openings and maintain fire rating of the structural members.

3.4.5.2 For Types 1 to 3 constructions, a doorway or opening in a fire resistant wall on any floor shall be limited to 5.6 m^2 in area with a maximum height/width of 2.75 m. Every wall opening shall be protected with fire-resisting doors, having the fire rating of not less than 120 min. The openings in the floors shall be protected by vertical enclosures extending above and below such openings, such enclosures having a fire resistance of not less than 120 min and all openings therein being protected with a fire-resisting assembly as specified in **3.4.5.6**.

For escalator openings, the smoke spill shall be avoided by provision of smoke barrier (of 450-600 mm) thereby creating smoke compartment. Further, the protection shall be ensured through installation of sprinklers on all sides of the cut out opening on each floor (*see* Fig. 3 for details).

3.4.5.3 For Type 4 construction, openings in the fire separating walls or floors shall be fitted with 120 min fire-resistance rated assemblies.

Table 2 Comparative Floor Area Ratios for Occupancies Facing One Public Street at least 9 m Wide
(*Clause* 3.4.4.2)

Sl No.	Occupancy Classification	Type of Construction			
		Type 1	Type 2	Type 3	Type 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	Residential	UL	2.0	1.4	1.0
ii)	Educational	UL	2.0	1.4	1.0
iii)	Institutional	UL	1.5	1.0	0.8
iv)	Assembly	UL	1.0	0.7	0.5
v)	Business	UL	2.9	2.3	1.6
vi)	Mercantile	8.0	1.8	1.4	1.0
vii)	Industrial	7.5	1.9	1.6	1.3
viii)	Storage (*see* Note 5)	6.0	1.5	1.3	1.0
ix)	Hazardous (*see* Note 5)	2.8	1.1	0.9	NP

UL — Unlimited.

NP — Not permitted.

NOTES

1 The FAR values given in this table are subject to overall restrictions on the heights of buildings in the case of educational, institutional, assembly, storage and hazardous occupancies as specified in col 2 of Table 7.

2 This table has been prepared, taking into account the combustible content in the different occupancies as well as the fire resistance offered by the type of construction.

3 This table should be modified by the Authority, taking into account the other aspects as given below:

a) Density in terms of dwelling units per hectare;
b) Traffic considerations;
c) Parking spaces;
d) Local fire-fighting facilities; and
e) Water supply, drainage and sanitation requirements.

4 The FAR values specified in this table may be increased by 20 percent for the following services:

a) A basement or cellar space under a building constructed on stilts and used as a parking space and air conditioning plant room used as accessory to the principal use;
b) Watchman's booth, pump house, garbage shaft, electric cabin or substation and other utility structures meant for the services of the building under considerations;
c) Projections and accessory buildings as specifically exempted under the Code; and
d) Staircase room and lift rooms above the topmost storey; architectural feature; and chimneys and elevated tanks of dimensions as permissible under the Code; the area of the lift shaft shall be taken only on one floor.

5 In so far as single storey storage and hazardous occupancies are concerned, they would be further governed by volume to plot area ratio (VPR) to be decided by the Authority.

3.4.5.4 *Service ducts and shafts*

Openings in walls or floors which are necessary to be provided to allow passages of all building services like cables, electrical wirings, telephone cables, plumbing pipes, etc, shall be protected by enclosure in the form of ducts/shafts having a fire resistance not less than 120 min. The inspection door for electrical shafts/ducts

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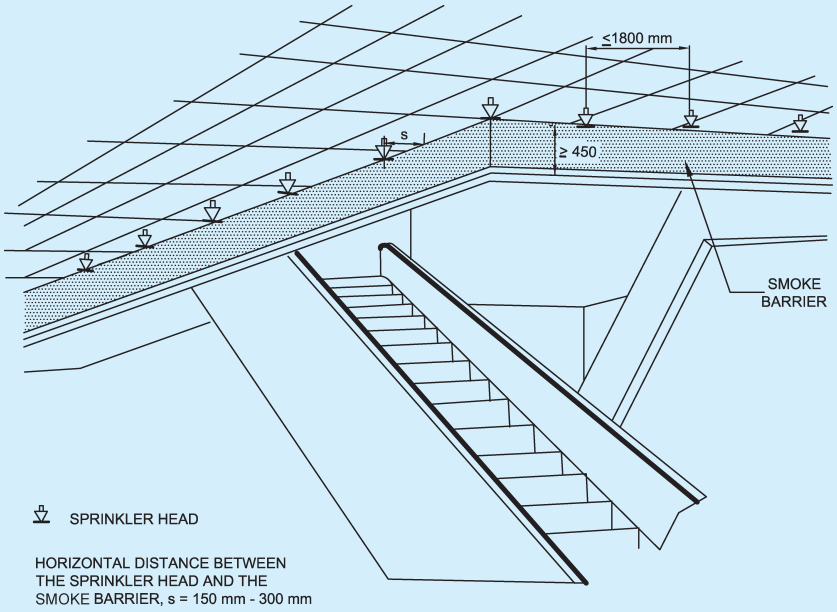


FIG. 3 SPRINKLERS AROUND ESCALATOR OPENING

shall be not less than 120 min. Further, medium and low voltage wiring running in shafts/ducts, shall either be armoured type or run through metal conduits.

The space between the electrical cables/conduits and the walls/slabs shall be filled in by a fire stop material having fire resistance rating of not less than 120 min. This shall exclude requirement of fire stop sealing for low voltage services shaft.

For plumbing shafts in the core of the building, with shaft door opening inside the building, the shafts shall have inspection doors having fire resistance rating not less than 30 min.

For plumbing shafts doors which open in wet areas or in naturally ventilated areas or on external wall of the building, the shafts may not require doors having any specified fire rating.

NOTE — In the case of buildings where it is necessary to lower or lift heavy machinery or goods from one floor to the other, it may be necessary to provide larger openings in the floor. Such openings shall be provided with removable covers which shall have the same strength and fire resistance as the floor.

3.4.5.5 *Refuse chutes*

Refuse chutes, if any provided in a building, shall have opening at least 1 m above roof level for venting purpose and they shall have an enclosure wall of non-combustible material with fire resistance of not less than 120 min. They shall not be located within the staircase enclosure or service shafts, or air conditioning shafts. Refuse chutes inspection panel and doors shall be tight fitting with 60 min fire resistance. Sprinkler protection system shall be provided for the refuse chutes. Refuse chutes shall be at least 6 m away from exits.

3.4.5.6 *Vertical opening*

Every vertical opening between the floors of a building shall be suitably enclosed or protected, as necessary, to provide the following:

a) Reasonable safety to the occupants while using the means of egress by preventing spread of fire, smoke, or fumes through vertical openings from floor to floor to allow occupants to complete their use of the means of egress. Further it shall be ensured to provide a clear height of 2 100 mm in the exit access.
b) Limitation of damage to the building and its contents.

3.4.6 *Electrical Installation*

3.4.6.1 For requirements regarding electrical installations from the point of view of fire safety, reference may be made to good practice [4(6)] and Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

In general, it is desirable that the wiring and cabling are with flame retardant property. Medium and low voltage wiring running in shafts, and within false ceiling shall run in metal conduit. Any 230 V wiring for lighting or other services, above false ceiling, shall have 660 V grade insulation.

The electric distribution cables/wiring shall be laid in a separate shaft. The shaft shall be sealed at every floor with fire stop materials having the same fire resistance as that of the floor. High, medium and low voltage wiring running in shaft and in false ceiling shall run in separate shaft/conduits.

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Water mains, gas pipes, telephone lines, intercom lines or any other service line shall not be laid in the duct for electrical cables; use of bus ducts/solid rising mains instead of cables is preferred.

All metallic items like steel structural members, etc, shall be bonded properly to the earthing system.

3.4.6.2 *Emergency power for fire and life safety systems*

Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment shall be planned for efficient and reliable power and control supply to the following systems and equipment where provided:

a) Fire pumps.
b) Pressurization and smoke venting; including its ancillary systems such as dampers and actuators.
c) Fireman's lifts (including all lifts).
d) Exit signage lighting.
e) Emergency lighting.
f) Fire alarm system.
g) Public address (PA) system (relating to emergency voice evacuation and annunciation).
h) Magnetic door hold open devices.
j) Lighting in fire command centre and security room.

Power supply to these systems and equipment shall be from normal and emergency (standby generator) power sources with changeover facility. If power supply, is from HV source and HV generation, the transformer should be planned in standby capacity to ensure continuity of power to such systems. Wherever transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables shall be taken to all transformers. The generator shall be capable of taking starting current of all the fire and life safety systems and equipment as above. Where parallel HV/LV supply from a separate substation fed from different grid is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

The power supply to the panel/distribution board of these fire and life safety systems shall be through fire proof enclosures or circuit integrity cables or through alternate route in the adjoining fire compartment to ensure supply of power is reliable to these systems and equipment. It shall be ensured that the cabling from the adjoining fire compartment is protected within the compartment of vulnerability. The location of the panel/ distribution board feeding the fire and life safety system shall be in fire safe zone ensuring supply of power to these systems.

Circuits of such emergency system shall be protected at origin by an automatic circuit breaker with its no-volt coil removed. Master switches controlling essential service circuits shall be clearly labelled.

Cables for fire alarm and PA system shall be laid in metal conduits or armoured to provide physical segregation from the power cables.

3.4.6.3 *Substation/Transformers*

Areas in substation shall not be used as storage/dump areas or for other utility purposes other than those required for the functioning of the substation.

The substation area should be adequately ventilated.

An independent, ventilated or air conditioned MV panel room shall be provided on the ground level or first basement. This room shall be provided with access from outside (or through exit passageway accessible from outside). The MV panel room shall be provided with fire resistant walls and doors of fire resistance of not less than 120 min.

If the licensees agree to provide meters on upper floors, the licensees' cables shall be segregated from consumers' cables by providing a partition in the shaft. Meter rooms on upper floors shall not open into staircase enclosures and should be ventilated directly to open air outside or in electrical room of 120 min fire resistant walls.

Electrical MV main distribution panel and lift panels shall be provided with CO_2/inert gas flooding system for all panel compartments with a cylinder located beside the panel.

3.4.6.3.1 *Oil filled substation*

A substation or a switch-station with oil filled equipment shall be limited to be installed in utility building or in outdoor location. Such substation/utility building shall be at least 7 m away from the adjoining building(s).

Substation equipment (exceeding oil capacity of 2 000 litre) in utility building shall have fire rated baffle walls of 240 min rating constructed between such equipment, raised to at least 600 mm above the height of the equipment (including height of oil conservators) and exceeding 300 mm on each side of the equipment.

All transformers where capacity exceeds 10 MVA shall be protected by high velocity water spray systems or nitrogen injection system.

3.4.6.3.2 *Dry type substation*

Transformers located inside a building shall be of dry type and all substation/switch room walls, ceiling, floor, opening including doors shall have a fire resistance

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rating of 120 min. Access to the substation shall be provided from the nearest fire exit/exit staircase for the purpose of electrical isolation.

3.4.6.4 *Standby supply*

Diesel generator set(s) shall not be installed at any floor other than ground/first basement. If the same are installed indoors, proper ventilation and exhaust shall be planned. The DG set room shall be separated by 120 min fire resistance rated walls and doors.

The oil tank for the DG sets (if not in the base of the DG) shall be provided with a dyked enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure shall be filled with sand for a height of 300 mm.

For detailed information regarding fire safety requirements for hazardous petroleum products, reference may be made to *The Petroleum Act*, 1934 and the Rules framed thereunder.

3.4.6.5 *Lightning protection of buildings*

Routing of down conductors (insulated or uninsulated) of lightning protection through electrical or other service shafts are not allowed as it can create fire and explosion during lightning. For details, *see* Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

3.4.7 *Escape Lighting and Exit Signage*

Exit access, exits and exit discharge shall be properly identified, with adequate lighting maintained in the elements of the egress systems so that all occupants shall be able to leave the facility safely.

3.4.7.1 *Lighting*

a) The exit, exit access and exit discharge systems shall be illuminated continuously. The floors of the means of egress shall be illuminated at all points, including angles and intersections, in corridors and passageways, stairwells, landings of stairwells and exit.

b) Emergency lighting shall be powered from a source independent of that supplying the normal lighting.

c) Escape lighting shall be capable of,
   1) indicating clearly and unambiguously the escape routes;
   2) providing adequate illumination along such routes to allow safe movement of persons towards and through the exits; and
   3) ensuring that fire alarm call points and firefighting equipment provided along the escape routes can be readily located.

d) The horizontal luminance at floor level on the centreline of an escape route shall not be less than 10 lumen/m^2. In addition, for escape routes up to 2 m wide, 50 percent of the route width shall be lit to a minimum of 5 lumen/m^2. In auditoriums, theatres, concert halls and such other places of assembly, the illumination of floor exit/access may be reduced during period of performances to values not less than 2 lux.

e) Required illumination shall be arranged such that the failure of any single lighting unit, such as the burning out of one luminaire, will not leave any area in darkness and does not impede the functioning of the system further.

f) The emergency lighting shall be provided to be put on within 5 s of the failure of the normal lighting supply. Also, emergency lighting shall be able to maintain the required illumination level for a period of not less than 90 min in the event of failure of the normal lighting even for smaller premises.

g) Battery pack emergency lighting, because of its limited duration and reliability, shall not be allowed to be used in lieu of a diesel engine driven emergency power supply.

h) Escape lighting luminaires should be sited to cover the following locations:
   1) Near each intersection of corridors,
   2) At exits and at each exit door,
   3) Near each change of direction in the escape route,
   4) Near each staircase so that each flight of stairs receives direct light,
   5) Near any other change of floor level,
   6) Outside each final exit and close to it,
   7) Near each fire alarm call point,
   8) Near firefighting equipment, and
   9) To illuminate exit and safety signs as required by the enforcing authority.

   NOTE — For the purpose of this clause 'near' is normally considered to be within 2 m measured horizontally.

j) The luminaires shall be mounted as low as possible, but at least 2 m above the floor level.

k) Signs are required at all exits, emergency exits and escape routes, which should comply with the graphic requirements of the relevant Indian Standards.

3.4.7.2 Exit passageway (at ground) and staircase lighting shall also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains.

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3.4.7.3 Suitable arrangements shall be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor does not get connected to two sources of supply simultaneously. Double throw switch shall be installed in the service room for terminating the stand-by supply.

The emergency lighting system shall be well maintained by periodical inspections and tests so as to ensure their perfect serviceability at all times.

3.4.7.4 *Exit signage*

Where exit access is provided through corridors/paths, the occupants shall be able to easily identify the way to exits. Exit signs shall be provided such that no point in an exit access is more than 30 m from a visible exit directional sign. An exit sign indicating the direction to an exit shall be provided at all changes in direction.

Exits shall be clearly visible and the route to reach the exits shall be clearly marked and signs posted to guide the occupants of the floor concerned. Signs shall be illuminated and wired to an independent electrical circuit on an alternative source of supply. The sizes and colours of the exit signs shall be in accordance with good practice [4(7)]. The colour of the exit signs shall be green.

NOTE — This provision shall not apply to A-2 and A-4 occupancies less than 15 m in height.

The exit sign with arrow indicating the way to the escape route shall be provided at a suitable height from the floor level on the wall and shall be illuminated by electric light connected to corridor circuits. All exit way marking signs should be so installed that no mechanical damage shall occur to them due to moving of furniture or other heavy equipment. Further, all landings of floor shall have floor indicating boards prominently indicating the number of the floor.

Photo luminescent markings shall be pasted at internal hydrant boxes.

3.4.8 *Air Conditioning, Ventilation and Smoke Control*

3.4.8.1 Air conditioning and mechanical ventilation requirements of different rooms or areas in any occupancy shall be as given in Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' and 'Section 3 Air conditioning, Heating and Mechanical Ventilation' of the Code.

Air conditioning and ventilating systems shall be so installed and maintained as to minimise the danger of spread of fire, smoke or fumes from one floor to other or from outside to any occupied building or structure.

Many high-rise buildings integrate smoke management systems into their conventional HVAC systems. In such installation, it requires special design considerations, including safe and adequate controls, acceptable and documented testing and regular maintenance systems.

Wherever batteries are provided, the same shall be segregated by 120 min fire rated construction. Ventilation to the room shall be provided as per manufacturer's instructions.

3.4.8.2 *Air handling unit*

3.4.8.2.1 From fire safety point of view, separate air handling units (AHU) for each floor shall be provided so as to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The air ducts shall be separate from each AHU to its floor and in no way shall interconnect with the duct of any other floor. Within a floor it would be desirable to have separate air handling unit provided for each compartment.

Air handling unit shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system, and shall have smoke sensitive devices for actuation in accordance with the accepted standard [4(8)] and control.

3.4.8.2.2 Shafts or ducts, if penetrating multiple floors, shall be of masonry construction with fire damper in connecting ductwork or shall have fire rated ductwork with fire dampers at floor crossing. Alternatively, the duct and equipment may be installed in room having walls, doors and fire damper in duct exiting/entering the room of 120 min fire resistance rating. Such shafts and ducts shall have all passive fire control meeting 120 min fire resistance rating requirement to meet the objective of isolation of the floor from spread of fire to upper and lower floors through shaft/duct work.

NOTE — Zoned and compartmented HVAC systems are encouraged with an approach to avoid common exhaust shafts and fresh air intake shafts which will limit the requirement of such passive measure and fire rated duct work and dampers.

3.4.8.2.3 The air filters of the air handling units shall be made of non-combustible materials.

3.4.8.2.4 The air handling unit room shall not be used for storage of any combustible materials.

3.4.8.3 *Duct work*

3.4.8.3.1 Air ducts serving main floor areas, corridors, etc, shall not pass through the exits/exit passageway/ exit enclosure. Exits and lift lobbies, etc, shall not be used as return air passage.

3.4.8.3.2 As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.

3.4.8.3.3 Wherever the ducts pass through fire walls or floors, the opening around the ducts shall be sealed

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with materials having fire resistance rating of the compartment. Such duct shall also be provided with fire dampers at all fire walls and floors unless such ducts are required to perform for fire safety operation; and in such case fire damper may be avoided at fire wall and floor while integrity of the duct shall be maintained with 120 min fire resistance rating to allow the emergency operations for fire safety requirements.

3.4.8.3.4 The ducting within compartment would require minimum fire resistance rating of 30 min. Such ducting material in substantial gauge shall be in accordance with good practice [4(9)]. If such duct crosses adjacent compartment/floor and not having fire dampers in such compartment/floor, it would require fire resistance duct work rating of 120 min. The requirements of support of the duct shall meet its functional time requirement as above.

3.4.8.3.5 The materials used for insulating the duct system (inside or outside) shall be of non-combustible type. Any such insulating material shall not be wrapped or secured by any material of combustible nature.

3.4.8.3.6 Inspection panels shall be provided in the ductwork to facilitate the cleaning accumulated dust in ducts and to obtain access for maintenance of fire dampers.

3.4.8.4 *Fire or fire/smoke dampers*

3.4.8.4.1 These dampers shall be evaluated to be located in supply air ducts, fresh air and return air ducts/ passages at the following points:

a) At the fire separation wall,
b) Where ducts/passages enter the vertical shaft,
c) Where the ducts pass through floors, and
d) At the inlet of supply air duct and the return air duct of each compartment on every floor.

3.4.8.4.2 Damper shall be of motorized type/fusible link. Damper shall be so installed to provide complete integrity of the compartment with all passive fire protection sealing. Damper should be accessible to maintain, test and also replace, if so required. Damper shall be integrated with Fire Alarm Panel and shall be sequenced to operate as per requirement and have interlocking arrangement for fire safety of the building. Manual operation facilities for damper operation shall also be provided.

3.4.9 *Heating*

3.4.9.1 Installation of chimney and heating apparatus shall be in accordance with good practice [4(10)].

3.4.9.2 *Boiler rooms*

3.4.9.2.1 Provisions of boiler and boiler rooms shall conform to *The Boilers Act,* 1923.

3.4.9.2.2 Further, the following additional aspects may be taken into account in the location of boiler room:

a) The boilers shall be installed in a fire resisting room of 180 min fire resistance rating.
b) Entry to this room shall be provided with a composite door of 120 min fire resistance rating.
c) The boiler room shall be provided with its dedicated natural or mechanical ventilation system. Mechanical ventilation system for the boiler room would be accepted with 120 min fire resistance rating ductwork, if it has interface with other mechanical areas. Ventilation system should not be allowed to be routed through electrical room area or through exit corridor/exits.
d) The oil tank for the boiler shall be provided with a dyked enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank. The enclosure shall be filled with sand for a height of 300 mm.

3.4.10 *Glazing*

3.4.10.1 The glazing shall be in accordance with Part 6 'Structural Design, Section 8 Glass and Glazing' of the Code. The entire glazing assembly shall be rated to that type of construction as given in Table 1. This shall be applicable along with other provisions of this Part related to respective uses as specified therein. The use of glass shall not be permitted for enclosures of exits and exit passageway.

3.4.10.2 Glass facade shall be in accordance with the following:

a) For fully sprinklered buildings having fire separation of 9 m or more, tempered glass in a non-combustible assembly, with ability to hold the glass in place, shall be provided. It shall be ensured that sprinklers are located within 600 mm of the glass facade providing full coverage to the glass.

   NOTE — In case of all other buildings, fire resistance rating of glass facade shall be in accordance with Table 1.

b) All gaps between floor-slabs and facade assembly shall be sealed at all levels by approved fire resistant sealant material of equal fire rating as that of floor slab to prevent fire and smoke propagation from one floor to another.

c) Openable panels shall be provided on each floor and shall be spaced not more than 10 m apart measured along the external wall from centre-to-centre of the access openings. Such openings shall be operable at a height between 1.2 m and 1.5 m from the floor, and shall be in

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the form of openable panels (fire access panels) of size not less than 1 000 mm × 1 000 mm opening outwards. The wordings, 'FIRE OPENABLE PANEL — OPEN IN CASE OF FIRE, DO NOT OBSTRUCT' of at least 25 mm letter height shall be marked on the internal side. Such panels shall be suitably distributed on each floor based on occupant concentration. These shall not be limited to cubicle areas and shall be also located in common areas/corridors to facilitate access by the building occupants and fire personnel for smoke exhaust in times of distress.

3.4.11 *Surface Interior Finishes*

3.4.11.1 The use of combustible surface finishes on walls (including facade of the building) and ceilings affects the safety of the occupants of a building. Such finishes tend to spread the fire and even though the structural elements may be adequately fire resistant, serious danger to life may result. It is, therefore, essential to have adequate precautions to minimise spread of flame on wall, facade of building and ceiling surfaces. The finishing materials used for various surfaces and decor shall be such that it shall not generate toxic smoke/fumes.

3.4.11.2 The susceptibility of various types of wall surfaces to fire is determined in terms of the rate of spread of flame. Based on the rate of spread of flame, surfacing material shall be considered as divided into four classes as follows {*see also* good practice [4(11)]}:

a) Class 1 Surfaces of very low flame spread.
b) Class 2 Surfaces of low flame spread.
c) Class 3 Surfaces of medium flame spread.
d) Class 4 Surfaces of rapid flame spread.

3.4.11.3 The uses for which surface materials falling into various classes shall be adopted in building construction are given below:

Class 1 (1)	*Class 2* (2)	*Class 3* (3)
May be used in any situation	May be used in any situation, except on walls, facade of the building, staircase and corridors	May be used only in living rooms and bed rooms (but not in rooms on the roof) and only as a lining to solid walls and partitions; not on staircases or corridors or facade of the building.

NOTE — Panelling (lining) shall be permitted in a limited area. It shall not be permitted in a vestibule.

3.4.11.4 Materials of Class 4 which include untreated wood fiberboards may be used with due fire retardant treatment as ceiling lining, provided the ceiling is at least, 2.4 m from the top surface of the floor below, and the wall surfaces conform to requirements of class [*see* Note *under* **3.4.11.3**]. Class 4 materials shall not be used in kitchens, corridors and staircases. Some materials contain bitumen and, in addition to risk from spread of fire, emit dense smoke on burning; such materials shall be excluded from use under these conditions and shall also not be used for construction of ceiling where the plenum is used for return air in air conditioned buildings.

3.4.11.5 When frames, walls, partitions or floors are lined with combustible materials, the surfaces on both sides of the materials shall conform to the appropriate class, because there is considerable danger from fire starting and rapidly spreading within the concealed cavity unknown to the occupants whose escape may be hampered thereby. For detailed information on materials and details of construction with their fire resistance rating, reference may be made to good practice [4(12)].

3.4.12 *Fire Command Centre (FCC)*

a) Fire command centre shall be on the entrance floor of the building having direct access. The control room shall have the main fire alarm panel with communication system (suitable public address system) to aid floors and facilities for receiving the message from different floors.
b) Fire command centre shall be constructed with 120 min rating walls with a fire door and shall be provided with emergency lighting. Interior finishes shall not use any flammable materials. All controls and monitoring of fire alarm systems, pressurization systems, smoke management systems shall happen from this room. Monitoring of integrated building management systems, CCTVs or any other critical parameters in building may also be from the same room.
c) Details of all floor plans along with the details of firefighting equipment and installations (2 sets laminated and bound) shall be maintained in fire command centre.
d) The fire staff in charge of the fire command centre shall be responsible for the maintenance of the various services and firefighting equipment and installations in coordination with security, electrical and civil staff of the building.

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4 LIFE SAFETY

4.1 General

Every building shall be so designed, constructed, equipped, maintained and operated as to provide adequate means of egress to avoid undue danger to the life and safety of the occupants from fire, smoke, fumes or panic during the time period necessary for escape.

For high occupancy areas, it may be required to have annunciation, announcements and voice guided/aided system to direct the occupants towards safe egress routes, areas of comparative safety or exits, and to avoid situation of panic during distress.

Every main occupancy may have certain occupancies which may be incidental to the main occupancy. The exit requirements pertaining to such incidental occupancies from the floor of the occupancy to the level of exit discharge shall be calculated to meet the requirement of the actual occupancy of such type, to ensure adequate means of egress of the occupants.

See also **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code for accessibility for elderly and persons with disabilities, for various requirements for enabling a smooth and safe egress.

4.2 General Exit Requirements

4.2.1 An exit may be a fire exit doorway; an internal staircase, exit passageway, external doorway, external staircase and these having access to the street or to a *Veranda* or to a refuge area or to the terrace or roof of a building. An exit may also include a horizontal exit leading to an adjoining building/fire compartment having its further access to unlocked/public exit at the same level.

4.2.2 Unless otherwise specified, lifts, escalators, moving walks and revolving doors shall not be considered as exits and shall not constitute any part of the required exit.

4.2.3 Every exit, exit passageway and exit discharge shall be continuously maintained free of all obstructions or impediments to full use in the case of fire or other emergency.

4.2.4 Every building having human occupancy shall be provided with exits sufficient to permit safe egress of occupants, in case of fire or other emergency.

4.2.5 In every building or structure, exits shall comply with the minimum requirements of this Part, except those not accessible for general public use.

4.2.6 No building shall be so altered as to reduce the number, width or protection of exits to less than that required.

4.2.7 For non-naturally ventilated areas, fire doors with 120 min fire resistance rating shall be provided and particularly at the entrance to lift lobby and stair well where a 'funnel or flue effect' may be created, inducing an upward spread of fire, to prevent spread of fire and smoke.

4.2.8 Exits shall be so arranged that they may be reached without passing through another occupied unit/passage in others control, if they pose challenge or restriction in means of egress.

4.2.9 Doors in exits shall open in the direction of exit. In case of assembly buildings (Group D) and institutional buildings (Group C-1), exit door shall not open immediately upon a flight of stair and all such entries to the stair shall be through a landing, so that such doors do not impede movement of people descending from a higher floor when fully opened (*see* Fig. 4A). While for other occupancies, such doors shall not reduce the pathway in the landing by more than half the width of such staircase (*see* Fig. 4B). Over-head or sliding doors shall not be installed.

4.2.10 At least half of the required exit stairs from upper floors (rounded to the next higher number) shall discharge directly to the exterior or through exit passageways.

4.2.11 Unless otherwise specified, all the exits and exit passageways to exit discharge shall have a clear ceiling height of at least 2.4 m. However, the height of exit door shall be at least 2.0 m (*see* Fig. 5).

4.2.12 Where changes in elevation of more than 300 mm are encountered in the exits, ramps or sloped surfaces shall be used with handrails and floor finish materials that contrast with the adjacent finish materials.

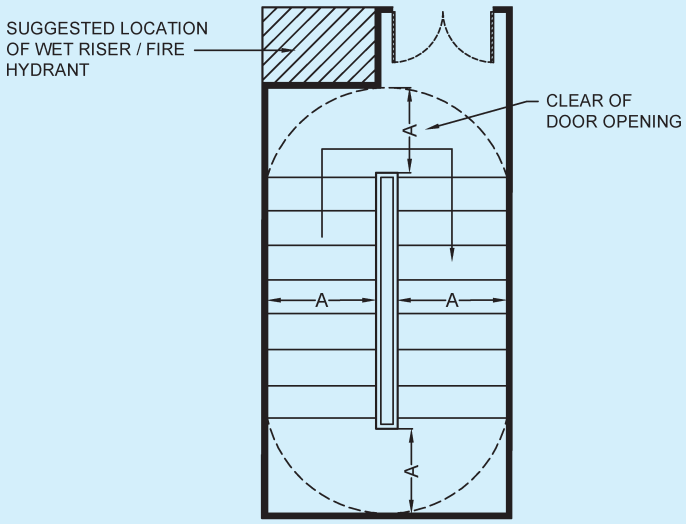
4.2.13 The capacity of the means of egress required from any storey of the building shall not be reduced along the path of egress travel until arrival to the exit discharge.

4.2.14 The lifts, escalators, moving walks, turnstiles and revolving doors shall not be considered in determining the required capacity of means of egress for the individual floor(s) or the building.

4.2.15 Turnstiles or similar devices that restrict travel to one direction or that are used to restrict unauthorized entry shall not be so placed as to obstruct any required means of egress. Alternative door openings of required exit width shall be available within 3 m of such devices, if installed.

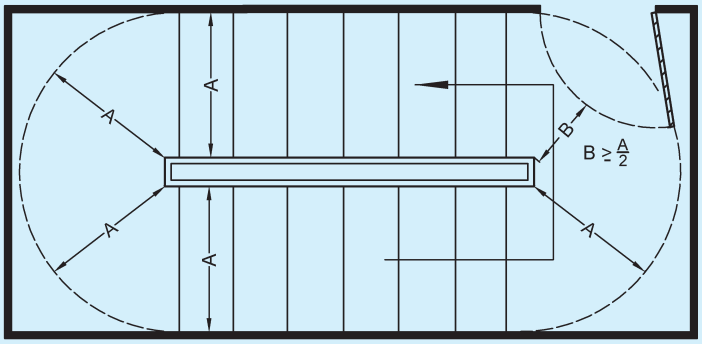
4.2.16 Suitable means shall be provided so that all access controlled exit doors, turnstiles, boom barriers and other such exits shall automatically operate to open mode during emergencies like fire, smoke, acts of

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NOTE — Door width shall be based on type of occupancy.

4A MINIMUM REQUIRED UNOBSTRUCTED CLEARANCE WITH DOOR LEAF ENCROACHING ON LANDING IN INSTITUTIONAL AND ASSEMBLY BUILDINGS



A - REQUIRED WIDTH

4B MINIMUM REQUIRED UNOBSTRUCTED CLEARANCE WITH DOOR LEAF ENCROACHING ON LANDING

FIG. 4 DOOR LOCATION AT LANDING IN FIRE EXITS

terrorism, etc, so that people can safely and quickly egress into safe areas outside. If required, a master controlling device may be installed at a strategic location to achieve this.

4.2.17 Penetrations into and openings through an exit are prohibited except those necessary like for the fire protection piping, ducts for pressurization and similar life safety services. Such openings as well as vertical passage of shaft through floors shall be protected by passive systems.

4.2.18 Walking surfaces in exit access shall comply with the following requirements for smooth exit:

a) Walking surfaces shall be nominally level.

b) The slope of walking surface in the direction of travel shall not exceed 1 in 20 unless the ramp requirements are met (*see* **4.4.2.4.3.5**).

c) Slope perpendicular to the direction of travel shall not exceed 1 in 48.

d) Walking surfaces shall be slip-resistant along the entire path of travel.

4.2.19 *Basement*

a) Basement exits shall be sufficient to provide for the capacity of the basement as determined in accordance with **4.4.2.1**. In no case shall there be less than two independent basement exits.

b) Basements having incidental occupancies to main occupancy shall be planned with exit requirements of the basements for the actual occupancy within the basement.

c) Where basement is used for car parking and also there is direct approach from any

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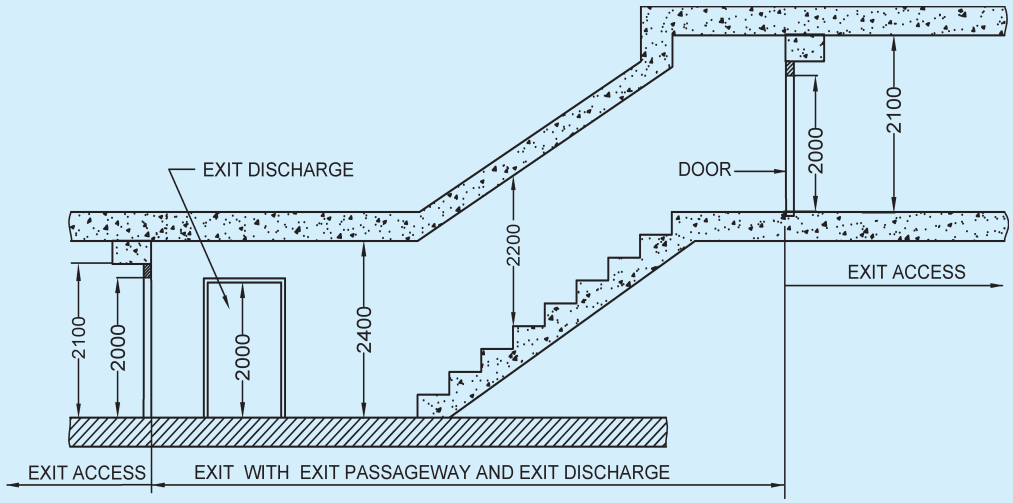


FIG. 5 MINIMUM HEAD ROOM MEASUREMENT

occupancy above to the basement, door openings leading to the basement shall need to be protected with fire doors with 120 min fire rating, except for exit discharge doors from the basements.

4.3 Occupant Load

For determining the exits required, the number of persons within any floor area or the occupant load shall be based on the actual number of occupants declared, but in no case less than that specified in Table 3. The occupant load of a mezzanine floor discharging to a floor below shall be added to that floor occupancy and the capacity of the exits shall be designed for the total occupancy load thus established.

The occupant load of each story considered individually

Table 3 Occupant Load
(*Clauses* 4.3 *and* 4.4.2.1)

Sl No.	Group of Occupancy	Occupant Load Factor (m^2/person) (*see* Note 1)
(1)	(2)	(3)
i)	Group A: Residential	12.50
ii)	Group B: Educational	4.00
iii)	Group C: Institutional (*see* Note 2):	
	a) Indoor patients area	15.00
	b) Outdoor patients area	10.0
iv)	Group D: Assembly:	
	a) Concentrated use without fixed seating	0.65
	b) Less concentrated use without fixed seating (*see* Note 3)	1.40
	c) Fixed seating	*see* Note 4
	d) Dining areas and restaurants with seating and table	1.80
v)	Group F: Mercantile:	
	a) Street floor and sales basement	3.00
	b) Upper sales floor	6.00
	c) Storage/warehouse, receiving and the like	20.00
vi)	Group E: Business	10.00
vii)	Group G: Industrial	10.00
viii)	Group H: Storage (*see* Note 5)	30.00
ix)	Group J: Hazardous	10.00

NOTES

1 Gross area shall be the floor area as defined in **2.35.** All factors expressed are in gross area unless marked net.

2 Occupant load in dormitory portions of homes for the aged, orphanages, insane asylums, etc, where sleeping accommodation is provided, shall be calculated at not less than 7.5 m^2 gross floor area/person.

3 These shall include gymnasium, table tennis room, billiard room and other gaming rooms, library, swimming pool and like.

4 In case of assembly occupancy having fixed seats, the occupant load shall be determined by multiplying the number of seats by 1.2.

5 Car parking areas under occupancy other than storage shall also be 30 m^2 per person.

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shall be required to be used in computing the number of means of egress at each story, provided that the required number of means of egress is not decreased in the direction of egress travel.

The assembly occupancies and call centres shall be required to display, limiting occupant load details positioned in a conspicuous place near the entrance of each of such respective occupancy to avoid possible overcrowding and overloading. The display shall preferably be engraved on a metal plate of not less than 300 mm × 200 mm, with letters of height and width not less than 50 mm, with detail of occupancy, area and occupancy load (*see* figure below).

The capacity of any open mezzanine/balcony shall be added to the capacity of the floor below for the purpose of determining exit capacity.

MAXIMUM OCCUPANCY

____ PERSONS PERMITTED WITHIN THIS SPACE/ROOM

IT IS CONFIRMED THAT THE FIRE EXITS ARE PLANNED FOR EGRESS OF THE OCCUPANCY AS MENTIONED ABOVE AND OCCUPANCY MORE THAN THE ABOVE IS NOT PERMITTED IN THE SPACE/ROOM AS FOLLOWS:

SPACE/ROOM DETAIL: _____

FLOOR NO. _____

SIGN: _____ DATE: _____

(MANAGER/AUTHORIZED SIGNATORY)

4.4 Egress Components

Egress components to be considered are the number of exits to which access is provided, capacity of exit access, travel distance to an exit, the obviousness of the direction to an exit, and any hindrance including due to security issues involved.

4.4.1 *Exit Access*

a) A common path of travel is desirable in exit access which leads to two independent directions to separate exits.

b) *Capacity of exit access* — The width of corridors, aisles or ramps required for exit access shall be sufficient to ensure a smooth flow of occupants to the exit. Where a corridor is the only way of access to an exit, the corridor width shall not be less than the calculated exit width.

c) Objects like tables, chairs or any other temporary/permanent structures in exit access corridors shall be avoided as this may result in congestion and also impeding smooth flow of personnel during emergencies.

d) In order to ensure that each element of the means of egress can be effectively utilized, they shall all be properly lit and marked. Lighting shall be provided with emergency power back-up in case of power failures. Also, exit signs of adequate size, marking, location, and lighting shall be provided so that all those unfamiliar with the location of the exits may safely find their way.

e) Exit access to fireman's lift and refuge area on the floor shall be step free and clearly signposted with the international symbol of accessibility.

f) Exit access shall not pass through storage rooms, closets or spaces used for similar purpose.

g) The calculation of capacity of exit access shall be in accordance with **4.4.2.4**.

4.4.2 *Exits*

4.4.2.1 *Number of exits*

The minimum required number of exits in a building shall be determined based on occupant load (*see* Table 3) and width required per person (*see* Table 4) as appropriate to the type of exit for respective occupancies, subject to complying with maximum travel distance requirement (*see* Table 5).

4.4.2.2 *Arrangement of exits*

a) Exits shall be so located that the travel distance on the floor shall not exceed the distance given in Table 5.

b) Travel distance shall be measured from the most remote point within a storey or a mezzanine floor along the natural and un-obstructed path of horizontal or vertical egress travel to the door to an exit.

c) The dead end corridor length in exit access shall not exceed 6 m for educational, institutional and assembly occupancies. For other occupancies, the same shall be 15 m (*see* Fig. 6)

d) Exits shall be placed as remote from each other as possible and shall be arranged to provide direct access in separate directions from any point in the area served.

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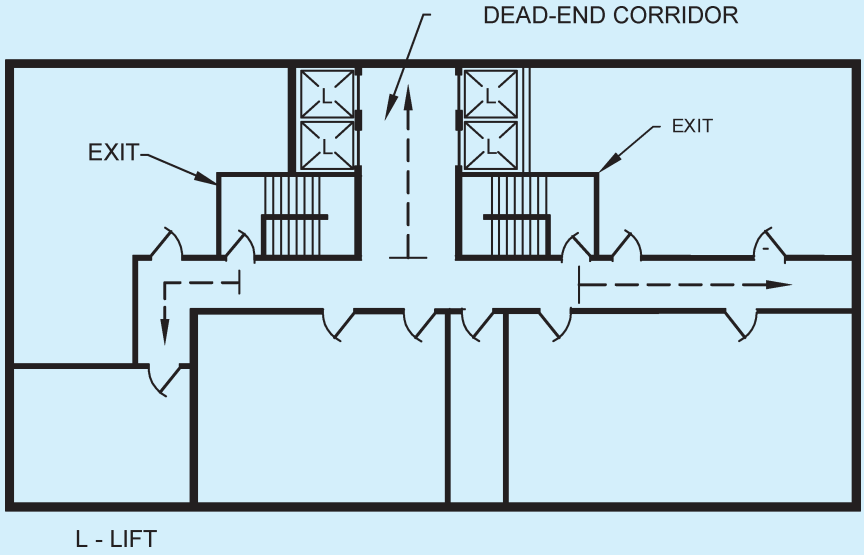


FIG. 6 DEAD END CORRIDOR

4.4.2.3 *Capacities of means of egress*

a) Exit capacity is the number of people that can pass through a stairway, and level components (door and corridor) and ramps. The total capacity of all the respective means of egress serving a floor shall be sufficient to allow egress of the entire population of the floor.

b) The unit of exit width, used to measure the capacity of any exit, shall be 500 mm. A clear width of 250 mm shall be counted as an additional half unit. Clear widths less than 250 mm shall not be counted for exit width.

c) Width per person for stairways, and level components and ramps shall be determined using the capacity factors in accordance with Table 4.

Table 4 Capacity Factors
[*Clauses* 4.4.2.1, 4.4.2.3(c) *and* 4.4.2.4.2(a)]

Sl No.	Occupancy Group		Width per Person mm	
			Stairways	Level Components and Ramps
(1)	(2)		(3)	(4)
i)	Residential	(Group A)	10	6.5
ii)	Educational	(Group B)		
iii)	Institutional	(Group C)	15	13
iv)	Assembly	(Group D)	10	6.5
v)	Business	(Group E)		
vi)	Mercantile	(Group F)		
vii)	Industrial	(Group G)		
viii)	Storage	(Group H)		
ix)	Hazardous	(Group J)	18	10

For example, if an exit doorway measures 1 000 mm in clear width, it would be defined as providing exit capacity for 1 000/6.5 occupants, that is, 153 persons (say 150 persons) and number of such exit doorways can then be calculated depending on the occupant load.

d) When calculating stairways, level components and ramps and other exit means, the capacity of the entire system shall have to be based upon the minimum capacity available from any part of the system. The corridor, if so provided shall also to be planned with consideration of exit access adequacy for the number of occupants. Further, consider the situation of doors opening to an exit stairway. If the stairway provides an exit capacity of 150 persons, and the doors leading into the stairway provide an exit capacity of 153 persons, the overall exit system would be considered to provide the minimum exit capacity of only 150 persons afforded by the stairway. The exit planning will be limited by the most restrictive exit calculation under the means of egress.

e) In the procedures for determining required egress capacity, the number of required means of egress is based on a floor-by-floor consideration, rather than the accumulation of the occupant loads of all the floors. However, the number of means of egress cannot decrease as an occupant proceeds along the egress path.

4.4.2.4 *Types of exit access and exits*

Various types of exit access and exits are doorways, corridors and passageways, horizontal exits, internal

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Table 5 Travel Distance (Based on Occupancy and Construction Type)
(*Clauses* 4.4.2.1 *and* 4.4.2.2)

Sl No.	Occupancy Group	Maximum Travel Distance m	
		Types 1 and 2	Types 3 and 4
(1)	(2)	(3)	(4)
i)	Residential (Group A)	30.00	22.50
ii)	Educational (Group B)	30.00	22.50
iii)	Institutional (Group C)	30.00	22.50
iv)	Assembly (Group D)	30.00	30.00
v)	Business (Group E)	30.00	30.00
vi)	Mercantile (Group F)	30.00	30.00
vii)	Industrial (Group G)		
	G-1, G-2	45.00	*See* Note 3
	G-3	22.50	
viii)	Storage (Group H)	30.00	
ix)	Hazardous (Group J)	22.50	

NOTES

1 For fully sprinklered building, the travel distance may be increased by 50 percent of the values specified.

2 Ramp shall not be counted as an exit in case of basements below the first basement in car parking.

3 Construction of Type 3 or Type 4 is not permitted.

staircases, exit passageways, external staircases and ramps.

Requirements for each are as detailed below.

4.4.2.4.1 *Doorways*

a) Every exit doorway shall open into an enclosed stairway or a horizontal exit of a corridor or passageway providing continuous and protected means of egress (*see* Fig. 7 on unaccepted arrangement of doors in a stair).

b) No exit doorway shall be less than 1 000 mm in width except assembly buildings, where door width shall be not less than 2 000 mm (*see* Fig. 8). Doorways shall be not less than 2 000 mm in height.

c) Exit doorways shall be operable from the side which they serve, without the use of a key.

d) Mirrors shall not be placed on exit doors and in exits to avoid confusion regarding the direction of exit.

e) Revolving doors can be accepted as a component in a means of egress where the following requirements are fully complied with:

1) Doors shall be capable of collapsing to a book fold position with parallel egress paths, of width not less than 1 000 mm.

2) Doors shall not be located within 3 m of the foot or top of stairs or escalators. A dispersal area shall be provided between the stairs or escalators and the doors.

3) Each revolving door shall be provided with a hinged door in the same wall within 3 m thereof, with same exiting capacity.

4) Each revolving door shall be considered as capable of exiting only 50 persons.

f) All fire rated doors and assembly shall be provided with certificate and labels prominently indicating the manufacturer's identification, door details covering door type, serial/batch number, month and year of manufacture, fire resistance rating, etc. The doors and assembly shall be certified with all prescribed hardware such as hinges, locks, panic bars, door closer, and door viewers.

g) *Access controlled doors* — Access controlled doors and electromagnetic doors shall fall under this category. These shall meet the following requirements:

1) Doors shall have fire rating as per the requirements at the location of installation.

2) Activation of the building automatic sprinkler or fire detection system, if provided, shall automatically unlock the doors in the direction of egress, and the doors shall remain unlocked until the automatic sprinkler system or fire-alarm system has been manually reset.

3) Loss of power to the part of the access control system that locks the doors shall automatically unlock the doors in the direction of egress.

4) A manual release device shall be provided in the readily accessible vicinity of the egress door with a signage 'PUSH TO EXIT' and when the same is operated, it shall result in direct interruption of power to the lock, independent of the access control system electronics.

h) *Turnstiles* — Turnstiles or similar devices that restrict travel to one direction or are used to collect fares or admission charges shall not be placed so as to obstruct any required means of egress unless door openings of required width are available within 3 m thereof.

Turnstiles or such similar devices shall also be disengaged through automatic or manual intervention to allow egress in the direction of exit.

j) Doors in folding partition shall not be treated as approved means of egress.

4.4.2.4.2 *Corridors and passageways of means of egress*

a) Corridors and passageways shall be of width not less than the calculated aggregate width

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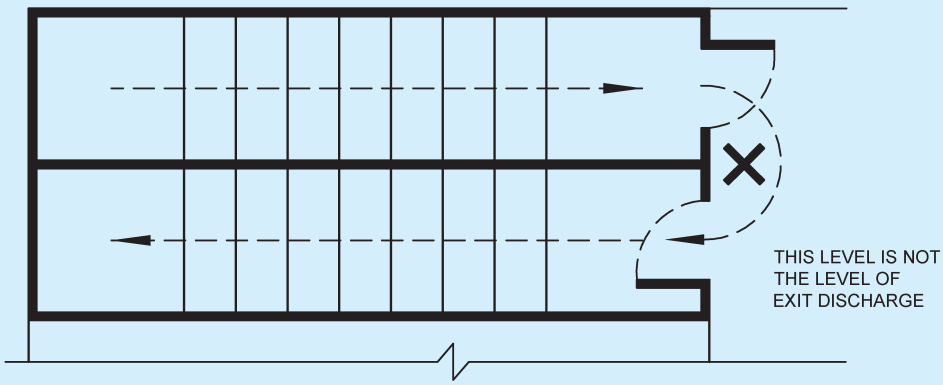


FIG. 7 UNACCEPTABLE ARRANGEMENT FOR ENCLOSING A STAIR SERVING AS A REQUIRED EXIT

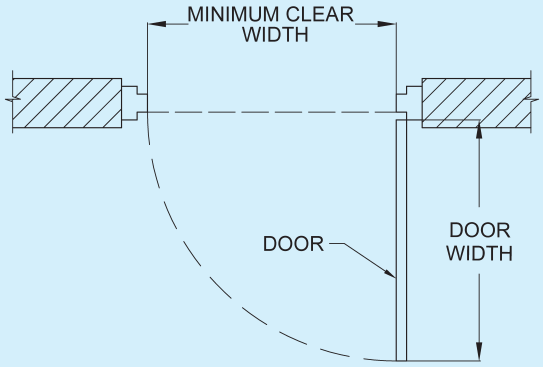


FIG. 8 MINIMUM CLEAR DOOR WIDTH

of exit doorways leading from them in the direction of travel to the exit (*see* Table 4 and Table 5).

b) In the case of buildings where there is a central corridor, which is part of exit access, the doors of rooms (except for rooms having assembly occupancy) shall open inwards to permit smooth flow of traffic in the corridor.

4.4.2.4.3 *Staircases*

4.4.2.4.3.1 *General*

The requirements of number of staircases shall supplement the requirement of different occupancies in **6.1** to **6.9**.

All buildings, as mentioned in **1.2**, shall have a minimum of two staircases. The actual number of staircases shall comply with the requirement of **4.4.2.1**.

All exit staircases shall discharge, at the level of exit discharge, to the exit discharge, either,

a) directly, or
b) through an exit passageway, or
c) through a large lobby.

At least 50 percent of the staircases shall discharge as per (a) and/or (b) above.

The minimum width of tread without nosing shall be 250 mm for staircase of residential buildings. This shall be minimum 300 mm for assembly, hotels, educational, institutional, business and other buildings. The treads shall be constructed and maintained in a manner to prevent slipping. The maximum height of riser shall be 190 mm for staircase of residential buildings (A-2) and 150 mm for other buildings. The number of risers shall be limited to 12 per flight.

The staircases may be internal staircases or external staircases.

4.4.2.4.3.2 *Internal staircases*

The internal staircases may be constructed with an external wall, or otherwise, and shall comply with the following:

a) Internal stairs shall be constructed of non-combustible materials throughout, and shall have fire resistant rating of minimum 120 min.
b) A staircase shall not be arranged round a lift shaft.
c) Exits shall not be used as a portion of a supply, return or exhaust air system serving adjoining areas. Any opening(s) shall not be permitted in walls or in doors, separating exits from adjoining areas.
d) No flue chimney, electromechanical equipment, air conditioning units, gas piping or electrical panels shall be allowed in the stairway.
e) Notwithstanding the detailed provision for exits in accordance with **4.2** and **4.3**, the following minimum width shall be provided for staircases for respective occupancies:

1) Residential (A-2) : 1.00 m

NOTE — For row housing with 2 storeys, the minimum width shall be 0.75 m.

2) Residential (A-1, A-3 and A-4) : 1.25 m

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3) Residential hotel (A-5 and A-6) : 1.50 m
4) Assembly : 2.00 m

NOTE — The width of stairs may be accepted to be 1.50 m in case of assembly occupancy having less than 150 persons.

5) Educational : 1.50 m
6) Institutional : 2.00 m
7) All other occupancies : 1.50 m

f) A handrail shall be provided on one side of the staircase of width less than 1 500 mm, and on both sides of the staircase of width 1 500 mm and more. The projection of handrail(s) in the staircase width shall not be more than 115 mm. All other requirements of handrail shall be in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

g) Handrails may project inside the measured width by not more than 90 mm.

h) The design of staircase shall also take into account the following:

1) The minimum headroom in a passage under the landing of a staircase and under the staircase shall be 2.2 m
2) Access to exit staircase shall be through a fire door of a minimum 120 min fire resistance rating.
3) No living space, store or other fire risk shall open directly into staircases.
4) The exit (including staircases) shall be continuous from refuge floors or terrace level, as applicable, to the level of exit discharge.
5) No electrical shafts/air conditioning ducts or gas pipes, etc, shall pass through or open in the staircases.
6) Lifts shall not open in staircase.
7) No combustible material shall be used for decoration/wall panelling in the staircase.
8) Beams/columns and other building features shall not reduce the head room/ width of the staircase.
9) The floor indication board, indicating the location/designated number of staircase, respective floor number and direction to exit discharge shall be placed inside the staircase, on the wall nearest to the fire door. It shall be of size not less than 300 mm × 200 mm (*see* Fig. 9).
10) Individual floors shall be prominently indicated on the wall outside the staircase and facing it.
11) All staircase shall terminate at the level of exit discharge. The access to the basement shall be by a separate staircase.
12) Scissors type staircases shall not be treated as part of exit.

4.4.2.4.3.3 *Curved stairs*

Curved stairs shall not be treated as part means of egress. However, these may be used as part of exit access provided the depth of tread is not less than 280 mm at a point 350 mm from the narrower end of the tread and the smallest radius is not less than twice the stair width.

4.4.2.4.3.4 *External staircases*

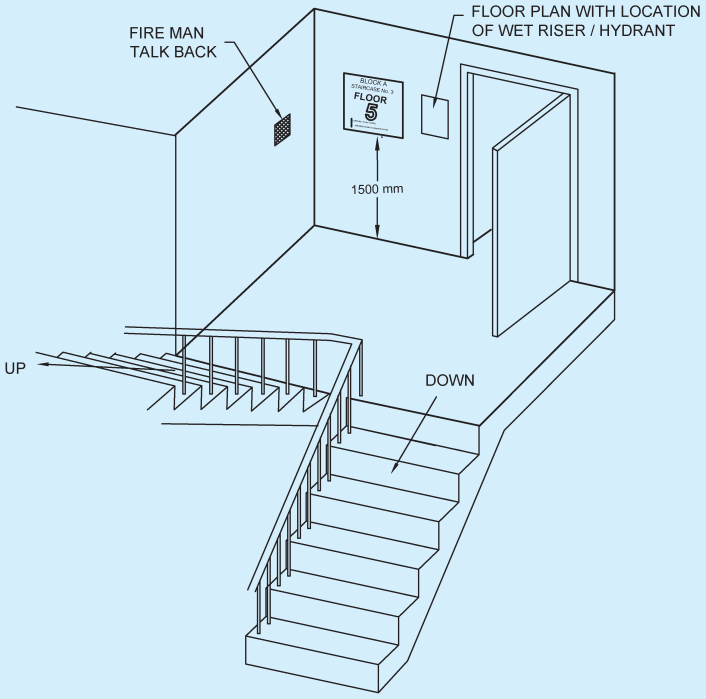
The external staircases are the staircases provided on the external wall/facade, and shall comply with the following:

a) External stairs shall always be kept in sound and usable condition.
b) All external stairs shall be directly connected to the ground.
c) Entrance to the external stairs shall be separate and remote from the internal staircase.
d) Where an external staircase is provided, it shall be ensured that the use of it at the time of fire is not prejudiced by smoke and flame from openings (for example, windows, doors) in the external face of the building. Care shall be taken to ensure that no external wall or window opening opens on to or close to an external stair. If such openings exists within 3 m from an external staircase, they shall be protected with fire rated doors/window assemblies with rating of at least 60 min (*see* Fig. 10).
e) The external stairs shall be constructed of non-combustible materials, and any doorway leading to it shall have minimum 120 min fire resistance.
f) No external staircase, shall be inclined at an angle greater than 45° from the horizontal.
g) External stairs shall have straight flight not less than 1 500 mm wide.
h) Handrails, to be provided on both sides, shall be of a height not less than 1 000 mm and not exceeding 1 200 mm. There shall be provisions of balusters with maximum gap of 150 mm.
j) The use of spiral staircase shall be limited to low occupant load and to a building not exceeding 9 m in height. A spiral staircase shall be not less than 1 500 mm in diameter and shall be designed to give adequate headroom.

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9A EXAMPLE OF A STAIRWAY MARKING SIGN
[FLOOR INDICATION BOARD]



9B STAIR SIGN PLACEMENT

NOTE — Block/Wing/Building name are to be project specific. Staircase shown as '3' is intending to show the number assigned to the staircase. All exits preferably to be assigned with number/identification enabling occupants/fire man to declare location/position.

FIG. 9 SIGN MARKING AND REQUIREMENT IN EXIT

4.4.2.4.3.5 *Ramps*

a) Ramps shall comply with all the applicable requirements for staircases regarding enclosure, capacity (*see also* Table 4) and limiting dimensions, except where specified in **6.1** to **6.9** for special uses and occupancies.

b) The slope of a ramp shall not exceed 1 in 12 (8 percent).

c) Ramp(s) shall be surfaced with approved slip resistant materials that are securely attached. No perforations are permissible on ramp floors.

d) Any changes in travel direction in ramp shall be preceded by landings of 1.5 m × 1.5 m size.

e) Ramps and intermediate landings shall continue with no decrease in width along the direction of egress travel.

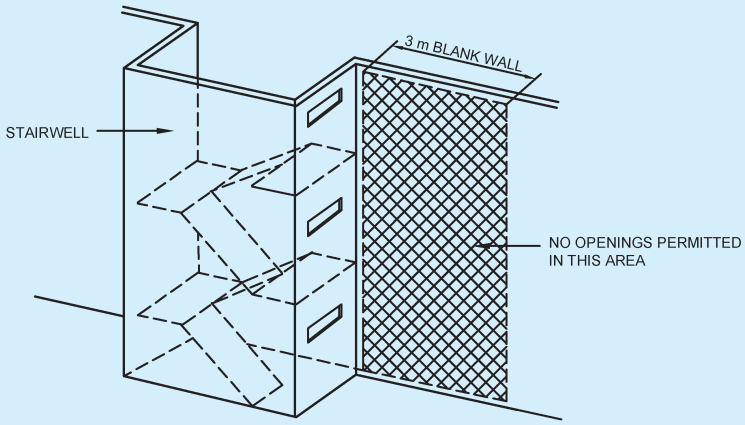
f) Outside ramps and landings shall be designed to minimise water accumulation on their surfaces.

g) Ramps shall have landings located at the top, at the bottom, and at doors opening onto the ramp.

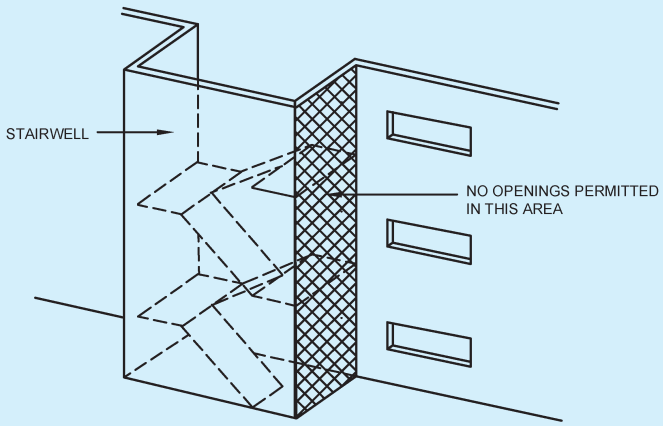
h) Every landing shall be not less than 1 500 mm long in the direction of travel.

j) Where the ramp is not part of an accessible route, the ramp landings shall not be required to exceed 1 250 mm in the direction of travel, provided that the ramp has a straight run.

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10A LIMITATIONS OF OPENINGS NEAR STAIRWELL



10B OPENING RESTRICTIONS ON STAIRWELL WALLS

FIG. 10 OPENING RESTRICTIONS

k) Handrails shall be provided on all ramps on both sides (*see* **4.4.2.4.3.4**).

NOTE — Above requirements are not applicable to basement car parking ramps

The ramps shall, in addition, comply with the requirements given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

4.4.2.5 *Smoke control of exits*

a) In building design, compartmentation plays a vital part in limiting the spread of fire and smoke. The design should ensure avoidance of spread of smoke to adjacent spaces through the various leakage openings in the compartment enclosure, such as cracks, openings around pipes ducts, airflow grills and doors. In the absence of proper sealing of all these openings, smoke and toxic gases will obstruct the free movement of occupants of the building through the exits. Pressurization of staircases is of great importance for the exclusion of smoke and toxic gases from the protected exit.

b) Pressurization is a method adopted for protecting the exits from ingress of smoke, especially in high-rise buildings. In pressurization, air is injected into the staircases, lobbies, etc, as applicable, to raise their pressure slightly above the pressure in adjacent parts of the building. As a result, ingress of smoke or toxic gases into the exits will be prevented. The pressurization of staircases and lift lobbies shall be adopted as given in Table 6.

The pressure difference for staircases shall be 50 Pa.

Pressure differences for lobbies (or corridors) shall be between 25 Pa and 30 Pa. Further, the pressure differential for enclosed staircase adjacent to such lobby (or corridors) shall be 50 Pa. For enclosed staircases adjacent to non-pressurized lobby (or corridors), the pressure differential shall be 50 Pa.

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Table 6 Pressurization of Staircases and Lift Lobbies

[*Clauses* 4.4.2.5 (b) *and* E-2]

Sl No.	Component	Height of Building		
		Less than 15 m	15 m to 30 m	More than 30 m
(1)	(2)	(3)	(4)	(5)
i)	Internal staircase not with external wall	Pressurized except for residential buildings (A-2 and A-4)	Pressurized	Pressurized
ii)	Internal staircase with external wall	Pressurized except for residential buildings (A-2 and A-4) or Naturally ventilated	Naturally ventilated or Pressurized	Cross-ventilated or Pressurized
iii)	Lift lobby	Not required at ground and above. However lift lobby segregation and pressurization is required for lift commuting from ground to basement	Naturally ventilated or Pressurized[1)]	Cross-ventilated or Pressurized[1)]

NOTES

1 The natural ventilation requirement of the staircase shall be, achieved through opening at each landing, of an area 0.5 m^2 in the external wall. A cross ventilated staircase shall have 2 such openings in opposite/adjacent walls or the same shall be cross-ventilated through the corridor.

2 Enclosed staircase leading to more than one basement shall be pressurized.

[1)] Lift lobby with fire doors (120 min) at all levels with pressurization of 25-30 Pa is required. However, if lift lobby cannot be provided at any of the levels in air conditioned buildings or in internal spaces where funnel/flue effect may be created, lift hoistway shall be pressurized at 50 Pa. For building greater than 30 m, multiple point injection air inlets to maintain desired pressurization level shall be provided. If the lift lobby, lift and staircase are part of firefighting shaft, lift lobby necessarily has to be pressurized in such case, unless naturally ventilated.

c) Equipment and ductwork for staircase pressurization shall be in accordance with one of the following:
   1) Directly connected to the stairway by ductwork enclosed in non-combustible construction.
   2) If ducts used to pressurize the system are passed through shafts and grills are provided at each level, it shall be ensured that hot gases and smoke from the building cannot ingress into the staircases under any circumstances.

d) The normal air conditioning system and the pressurization system shall be designed and interfaced to meet the requirements of emergency services. When the emergency pressurization is brought into action, the following changes in the normal air conditioning system shall be effected:
   1) Any re-circulation of air shall be stopped and all exhaust air vented to atmosphere.
   2) Any air supply to the spaces/areas other than exits shall be stopped.
   3) The exhaust system may be continued provided,
      i) the positions of the extraction grills permit a general air flow away from the means of egress;
      ii) the construction of the ductwork and fans is such that, it will not be rendered inoperable by hot gases and smoke; and
      iii) there is no danger of spread of smoke to other floors by the path of the extraction system which can be ensured by keeping the extraction fans running.

e) For pressurized stair enclosure systems, the activation of the systems shall be initiated by signalling from fire alarm panel.

f) Pressurization system shall be integrated and supervised with the automatic/manual fire alarm system for actuation.

g) Wherever pressurized staircase is to be connected to unpressurized area, the two areas shall be segregated by 120 min fire resistant wall.

h) Fresh air intake for pressurization shall be away (at least 4 m) from any of the exhaust outlets/grille.

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4.5 Compartmentation

4.5.1 *General*

a) It is important to limit the spread of a fire in any building. The usual method is to use fire barriers. In some instances these barriers need to be penetrated for ductwork, plumbing and electrical systems, and in such cases, use of passive fire protection measures shall be done so that the integrity of these barriers is not compromised.

b) Floor(s) shall be compartmented with area as given below.

4.5.2 All floors shall be compartmented/zoned with area of each compartment being not more than 750 m^2. The maximum size of the compartment shall be as follows, in case of sprinklered basement/building:

Sl No.	*Use*	*Compartmentation Area* m^2
(1)	(2)	(3)
i)	Basement car parking	3 000
ii)	Basements (other than car parking)	2 000
iii)	Institutional buildings: Subdivision C-1	1 800
iv)	Institutional buildings: Subdivision C-2 and C-3	1 125
v)	Mercantile and assembly buildings	2 000
vi)	Business buildings	3 000
vii)	All other buildings (Excluding low hazard and moderate hazard industrial buildings and storage buildings)[1)]	750

[1)] Compartmentation for low hazard and moderate hazard industrial buildings and storage buildings shall be done in consultation with local fire department.

In addition, there shall be requirement of a minimum of two compartments if the floor plate size is equal or less than the areas mentioned above. However, such requirement of minimum two compartments shall not be required, if the floor plate is less than 750 m^2.

Compartmentation shall be achieved by means of fire barrier having fire resistance rating of 120 min.

4.6 Smoke Control

4.6.1 *Smoke Exhaust and Pressurization of Areas Above Ground*

Corridors in exit access (exit access corridor) are created for meeting the requirement of use, privacy and layout in various occupancies. These are most often noted in hospitality, health care occupancies and sleeping accommodations.

Exit access corridors of guest rooms and indoor patient department/areas having patients lacking self preservation and for sleeping accommodations such as apartments, custodial, penal and mental institutions, etc, shall be provided with 60 min fire resistant wall and 20 min self-closing fire doors along with all fire stop sealing of penetrations.

Smoke exhaust system having make-up air and exhaust air system or alternatively pressurization system with supply air system for these exit access corridors shall be required.

Smoke exhaust system having make-up air and exhaust air system shall also be required for theatres/auditoria.

Such smoke exhaust system shall also be required for large lobbies and which have exit through staircase leading to exit discharge. This would enable eased exit of people through smoke controlled area to exit discharge.

All exit passageway (from exit to exit discharge) shall be pressurized or naturally ventilated. The mechanical pressurization system shall be automatic in action with manual controls in addition. All such exit passageway shall be maintained with integrity for safe means of egress and evacuation. Doors provided in such exit passageway shall be fire rated doors of 120 min rating.

Smoke exhaust system where provided, for above areas and occupancies shall have a minimum of 12 air changes per hour smoke exhaust mechanism. Pressurization system where provided shall have a minimum pressure differential of 25-30 Pa in relationship to other areas.

The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250°C for 120 min.

For naturally cross-ventilated corridors or corridors with operable windows, such smoke exhaust system or pressurization system will not be required.

4.6.2 *Smoke Exhaust and Pressurization of Areas Below Ground*

Each basement shall be separately ventilated. Vents with cross-sectional area (aggregate) not less than 2.5 percent of the floor area spread evenly round the perimeter of the basement shall be provided in the form of grills, or breakable stall board lights or pavement lights or by way of shafts.

Alternatively, a system of mechanical ventilation system may be provided with following requirements:

a) Mechanical ventilation system shall be designed to permit 12 air changes per hour in case of fire or distress call. However, for

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normal operation, air changes schedule shall be as given in Part 8 'Building Services, Section 3 Air conditioning, Heating and Mechanical Ventilation' of the Code.

b) In multi-level basements, independent air intake and smoke exhaust shafts (masonry or reinforced concrete) for respective basement levels and compartments therein shall be planned with its make-up air and exhaust air fans located on the respective level and in the respective compartment. Alternatively, in multi-level basements, common intake masonry (or reinforced cement concrete) shaft may serve respective compartments aligned at all basement levels. Similarly, common smoke exhaust/outlet masonry (or reinforced cement concrete) shafts may also be planned to serve such compartments at all basement levels. All supply air and exhaust air fans on respective levels shall be installed in fire resisting room of 120 min. Exhaust fans at the respective levels shall be provided with back draft damper connection to the common smoke exhaust shaft ensuring complete isolation and compartmentation of floor isolation to eliminate spread of fire and smoke to the other compartments/floors.

c) Due consideration shall be taken for ensuring proper drainage of such shafts to avoid insanitation condition. Inlets and extracts may be terminated at ground level with stall board or pavement lights as before. Stall board and pavement lights should be in positions easily accessible to the fire brigade and clearly marked 'AIR INLET' or 'SMOKE OUTLET' with an indication of area served at or near the opening.

d) Smoke from any fire in the basement shall not obstruct any exit serving the ground and upper floors of the building.

e) The smoke exhaust fans in the mechanical ventilation system shall be fire rated, that is, 250°C for 120 min.

f) The smoke ventilation of the basement car parking areas shall be through provision of supply and exhaust air ducts duly installed with its supports and connected to supply air and exhaust fans. Alternatively, a system of impulse fans (jet fans) may be used for meeting the requirement of smoke ventilation complying with the following:

   1) Structural aspects of beams and other down stands/services shall be taken care of in the planning and provision of the jet fans.
   2) Fans shall be fire rated, that is, 250°C for 120 min.
   3) Fans shall be adequately supported to enable operations for the duration as above.
   4) Power supply panels for the fans shall be located in fire safe zone to ensure continuity of power supply.
   5) Power supply cabling shall meet circuit integrity requirement in accordance with accepted standard [4(13)].

The smoke extraction system shall operate on actuation of flow switch actuation of sprinkler system. In addition, a local and/or remote 'manual start-stop control/switch' shall be provided for operations by the fire fighters.

Visual indication of the operation status of the fans shall also be provided with the remote control.

No system relating to smoke ventilation shall be allowed to interface or cross the transformer area, electrical switchboard, electrical rooms or exits.

Smoke exhaust system having make-up air and exhaust air system for areas other than car parking shall be required for common areas and exit access corridor in basements/underground structures and shall be completely separate and independent of car parking areas and other mechanical areas.

Supply air shall not be less than 5 m from any exhaust discharge openings.

4.7 Gas Supply

4.7.1 *Town Gas/LPG Supply Pipes*

Where gas pipes are run in buildings, the same shall be run in separate shafts exclusively for this purpose and these shall be on external walls, away from the staircases. Gas distribution pipes shall always be below the false ceiling. The length of these pipes shall be as short as possible. In the case of kitchen cooking range area, hood should have grease filters using metallic grill to trap oil vapours escaping into the fume hood

NOTE — For detailed information on gas pipe installations, reference may be made to Part 9 'Plumbing Services, Section 4 Gas Supply' of the Code.

4.7.2 *Thermal detectors*

These shall be installed into fume hoods of large kitchens for hotels, hospitals, and similar areas located in high rise buildings. Arrangements shall be made for automatic tripping of the exhaust fan in case of fire. If gas is used, the same shall be shut off. The voltage shall be 24 V or 100 V d.c. operated with external rectifier. The valve shall be of the hand re-set type and shall be located in an area segregated from cooking ranges. Valves shall be easily accessible. The hood shall have manual facility for steam or suitable hood extinguishing gas released depending on duty condition.

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4.7.3 Gas cylinders and manifold shall need to be housed in a detached location with no other occupancy within distances prescribed in good practice [4(14)] thereof. There shall be an enclosure suitably ventilated. It is desirable to provide medium velocity spray nozzles which can be operated by quick opening valve situated away from the enclosure.

4.7.4 In the case of gas cylinders, if manifold has to be installed on podium/close to podium, the same shall be away from any air intakes/smoke exhaust openings/ any windows.

4.7.5 Pressure regulating stations shall be designed and installed at critical locations for excess flow shut off valves. Seismic shut off valve at the main distribution point shall be installed for buildings in D-6 occupancy and institutional occupancy above 15 m.

4.7.6 Gas meters shall be housed in a suitably constructed metal cupboard located in a well-ventilated space, keeping in view the fact that LPG is heavier than air and town gas is lighter than air.

4.7.7 Wherever LPG reticulation/cylinders are used in buildings above 100 m, gas leak detectors shall be provided at the usage points and monitored from fire command centre. The cables used for signaling shall be circuit integrity cables.

4.7.8 The gas lines shall not be installed through any electrical shafts, escape routes, refuge areas/refuge floors.

4.7.9 Kitchens working on LPG fuel shall not be permitted in basements.

4.8 Hazardous Areas, Gaseous, Oil Storage Yard, etc

Rooms containing high pressure boilers, refrigerating machinery, transformers or other service equipment subject to possible explosion shall not be located directly under or adjacent to exits. All such rooms shall be effectively cut-off from other parts of the building and shall be provided with adequate vents to the outside air.

All rooms or areas of high hazard in additions to those hereinbefore mentioned, shall be segregated or shall be protected with fire resistant walls having fire rating of 120 min as fire, explosion or smoke therefrom is likely to interfere with safe egress from the building. Further,

a) each building shall be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas shall be as specified in Part 9 'Plumbing Services, Section 4 Gas Supply' of the Code; and

b) all exterior openings in a boiler room or rooms contain central heating equipment, if located below opening in another storey or if less than 3 m from other doors or windows of the same building shall be protected by a fire assembly as in **3.4.5**. Such assemblies shall be fixed, automatic or self-closing.

4.9 Fire Detection and Alarm

a) The requirements of fire detection and alarm systems are covered for each occupancy in Table 7 and under **6.1** to **6.9** for annunciation to occupants in view of the ensuing vulnerability and to warn occupants early of the existence of fire, so as to facilitate orderly and safe egress.

b) Fire detection and alarm systems in buildings shall be so planned and programmed so as to enable operations of various systems and equipment to facilitate requirements leading to life safety, compartmentation and fire protection. These systems and equipment may include electromechanical systems such as air handling units; pressurization systems; smoke management systems; creation of compartmentation through the release of fire barrier, hold-up fire doors, etc; and monitoring of fire water storage tanks and pumps, pressures in hydrant and sprinkler system, etc. These planning and requirements shall be based on building occupancy and other requirements on case to case basis.

c) Voice evacuation systems shall employ Hindi, English and vernacular language using pre-recorded messages and integrate with fire alarm panels for alerting the zone of fire and surrounding zones/floors as required for annunciation (*see also* Table 7 and its Note 1).

d) Appropriate visual warning arrangement through visual strobes/beacons may be considered in appropriate situations particularly in public buildings, at required locations to ensure visual as well as alarm for persons with hearing impairment.

e) For assembly buildings, institutional buildings and all buildings above 30 m in height where fire alarm system is provided in accordance to Table 7, detectors shall also be provided inside the electrical shafts, and lift machine rooms, etc, besides occupancy areas.

f) Fire alarm panels shall be connected in peer to peer network or with redundant cables, run in different shafts. Each panel shall be able to work in standalone mode and master slave architecture may be used where required.

g) The fire detection system shall be in accordance with accepted standards [4(15)].

Table 7 Minimum Requirements for Fire Fighting Installations

[*Clauses* 4.9(a), 4.9(c), 4.9(e), 5.1.1(a), 5.1.1(d), 5.1.2.1, 5.1.3(a), E-7, H-2(f) *and* Table 2]

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
RESIDENTIAL BUILDINGS (A)													
a)	**Lodging and Rooming Houses (A-1)** (*see* Note 3)												
1)	Less than 15 m in height												
	i) Up to 15 rooms	R	NR	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	5 000 (*see* Note 5)	NR	NR
	ii) More than 15 and up to 30 rooms	R	R	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	5 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	iii) More than 30 rooms	R	R	NR	NR	NR	R (*see* Note 4)	R (*see* Note 7)	NR	NR	10 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
b)	**One or two Family Private Dwellings (A-2)** (*see* Note 3)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
c)	**Dormitories (A-3) and Apartment Houses (A-4)**												
1)	Less than 15 m in height	R	R	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	5 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2)	15 m and above but not exceeding 35 m in height	R	R	NR	R	NR	R (*see* Note 4)	R (*see* Note 8)	NR	NR	25 000	NR	900
3)	Above 35 m but not exceeding 45 m in height	R	R	R	NR	NR	R (*see* Note 4 and Note 9)	R	NR	75 000	5 000	(*see* Note 10)	NR
4)	Above 45 m in height but not exceeding 60 m in height	R	R	R	NR	R	R	R	NR	150 000	10 000	(*see* Note 11)	NR
5)	Above 60 m in height	R	R	R	NR	R	R	R	R	200 000	10 000	(*see* Note 12 & Note 13)	NR
d)	**Hotels (A-5)**												
1)	Less than 15 m in height												
	i) Floor area not exceeding 300 m^2 on any of the floor	R	R	NR	NR	NR	R (*see* Note 4)	R	NR	NR	5 000 (5000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	ii) Floor area exceeding 300 m^2 but not more 1 000 m^2 on any of the floor	R	R	R (*see* Note 7)	NR	NR	R (*see* Note 4)	R	R	10 000 for every 500 m^2 floor area subject to minimum of 50 000 (*see* Note 7)	10 000 (5000) (*see* Note 6)	(*see* Note 14 in case of provision of wet riser)	450 (450) (*see* Note 6)
	iii) Floor area exceeding 1 000 m^2 on any of the floor	R	R	R (*see* Note 15)	NR	R	R	R (*see* Note 1)	R	100 000 (*see* Note 15)	10 000 (*see* Note 4)	(*see* Note 15 and Note 14)	NR

Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2)	15 m and above but not exceeding 30 m	R	R	R	NR	R	R	R	R	150 000	20 000	(*see* Note 11)	NR
3)	Above 30 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 11)	NR
e)	**Hotels (A-6)**	R	R	R	NR	R	R	R	R	250 000	20 000	(*see* Note 12)	NR
EDUCATIONAL BUILDINGS (B) (*see* Note 16)													
1)	Less than 15 m in height												
	i) Ground plus one or more storeys	R	R	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	10 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
2)	15 m and above but not exceeding 24 m in height	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	25 000	NR	900
3)	Above 24 m but not exceeding 30 m in height	R	R	R	NR	R	R (*see* Note 4)	R	NR	50 000	(5 000) (*see* Note 6)	(*see* Note 14)	NR
INSTITUTIONAL BUILDINGS (C) (*see* Note 16)													
a)	**Hospitals, Sanatoria and Nursing Homes (C-1)**												
1)	Less than 15 m in height with plot area up to 1 000 m^2												
	i) Up to ground plus one storey, with no beds	R	NR	NR	NR	NR	R (*see* Note 4)	R	NR	NR	(5 000) (*see* Note 6)	NR	(450) (*see* Note 6)

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	ii) Up to ground plus one storey with beds	R	R	NR	NR	NR	R (*see* Note 4)	R	NR	NR	5 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	iii) Ground plus two or more storeys, with no beds	R	R	NR	R	NR	R (*see* Note 4)	R	R	NR	10 000 (5 000) (*see* Note 6)	NR	900 (450) (*see* Note 6)
	iv) Ground plus two or more storeys, with beds	R	R	R	NR	NR	R	R (*see* Note 1)	R	75 000	10 000	(*see* Note 14)	NR
2)	Less than 15 m in height with plot area more than 1 000 m^2	R	R	R	NR	R	R	R (*see* Note 1)	R	1 00 000	10 000	(*see* Note 14)	NR
3)	15 m and above but not exceeding 24 m in height	R	R	R	NR	R	R	R	R	150 000	20 000	(*see* Note 10)	NR
4)	Above 24 m and not exceeding 45 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 11)	NR
b)	**Custodial (C-2), and Penal and Mental (C-3)**												
1)	Less than 10 m in height												
	i) Up to 300 persons	R	R	NR	NR	NR	R (*see* Note 4)	R	NR	NR	10 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	ii) More than 300 persons	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	15 000 (5 000) (*see* Note 6)	NR	900 (450) (*see* Note 6)

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
2)	10 m and above but not exceeding 15 m in height	R	R	R	NR	R	R (*see* Note 4)	R	R	100 000	5 000 (5 000) (*see* Note 6)	(*see* Note 10)	NR
3)	15 m and above but not exceeding 24 m in height	R	R	R	NR	R	R	R	R	150 000	10 000	(*see* Note 11)	NR
4)	24 m and above but not exceeding 30 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 11)	NR
ASSEMBLY BUILDINGS (D) (*see* Note 16)													
a)	**Buildings (D-1 to D-5)**												
1)	Less than 10 m in height												
	i) Up to 300 persons	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	20 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	ii) More than 300 persons	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	25 000 (5 000) (*see* Note 6)	NR	900 (450) (*see* Note 6)
2)	Above 10 m but not exceeding 15 m in height	R	R	R	NR	NR	R (*see* Note 4)	R (*see* Note 1)	R	100 000	5 000 (5 000) (*see* Note 6)	(*see* Note 10)	450 (450) (*see* Note 6)
3)	Above 15 m but not exceeding 24 m in height	R	R	R	NR	R	R	R	R	150 000	10 000	(*see* Note 10)	NR
4)	Above 24 m but not exceeding 30 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 11)	NR
b)	**D-6**	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 12)	NR
c)	**D-7**	For details *see* **6.4.4**											

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
BUSINESS BUILDINGS (E)													
1)	Less than 10 m in height	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	10 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
2)	Above 10 m but not exceeding 15 m in height	R	R	R	NR	NR	R (*see* Note 4)	R	R	50 000	5 000 (5 000) (*see* Note 6)	(*see* Note 14)	450 (450) (*see* Note 6)
3)	Above 15 m and up to 24 m in height	R	R	R	NR	R	R	R	R	100 000	10 000	(*see* Note 10)	NR
4)	Above 24 m and up to 30 m in height	R	R	R	NR	R	R	R	R	150 000	20 000	(*see* Note 11)	NR
5)	Above 30 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 12)	NR
MERCANTILE BUILDINGS (F)													
a)	**F-1 and F-2** (*see* Note 16)												
1)	Less than 15 m in height												
	i) Ground plus one storey, with total of all floor area not exceeding 500 m^2	R	R	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	5 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)

Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	ii) Ground plus one storey and total of all floor area exceeding 500 m^2	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	20 000 (5 000) (*see* Note 6)	NR	900 (450) (*see* Note 6)
	iii) More than ground plus one storey	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	25 000 (5 000) (*see* Note 6)	NR	900 (450) (*see* Note 6)
2)	Above 15 m but not exceeding 24 m in height	R	R	R	NR	R	R	R	R	100 000	10 000	(*see* Note 10)	NR
3)	Above 24 m but not exceeding 30 m in height	R	R	R	NR	R	R	R	R	200 000	20 000	(*see* Note 11)	NR
b)	**Underground shopping complex (F-3)**	R	R	R	NR	R	R	R	R	150 000	10 000	(*see* Note 11)	NR
INDUSTRIAL BUILDINGS (G) (*see* Note 17)													
a)	**Low Hazard (G-1)** (*see* Note 18)												
	i) Covered area up to 100 m^2	R	NR	NR	NR	NR	R (*see* Note 4)	NR	NR	NR	5 000 (*see* Note 5)	NR	450 (*see* Note 5)
	ii) Covered area more than 100 m^2 and up to 500 m^2	R	R	NR	R (*see* Note 8)	NR	R (*see* Note 4)	NR	NR	NR	20 000 (5 000) (*see* Note 6)	NR	450 (450) (*see* Note 6)

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	iii) Covered area more than 500 m^2 (for building height up to 15 m)	R	R	NR	R	NR	R (*see* Note 4)	R	NR	NR	20 000 (5000) (*see* Note 6)	NR	450 (450) (*see* Note 6)
	iv) Covered area more than 500 m^2 (for building height above 15 m)	R	R	R	NR	R	R (*see* Note 4)	R	R	75 000	5 000 (*see* Note 6)	(*see* Note 14)	NR
b)	**Moderate Hazard (G-2)** (*see* Note **18**)												
	i) Covered area up to 100 m^2	R	R	NR	NR	NR	R	NR	NR	NR	10 000	NR	450
	ii) Covered area more than 100 m^2 and up to 500 m^2	R	R	NR	NR	NR	R	NR	NR	NR	20 000	NR	900
	iii) Covered area more than 500 m^2 and up to 1000 m^2 (for height up to 15 m)	R	R	NR	R	NR	R	R	R	NR	50 000	NR	900
	iv) Covered area more than 500 m^2 and up to 1000 m^2 (for height above 15 m)	R	R	R	NR	R	R	R	R	100 000	10 000	(*see* Note 14)	NR
	v) Covered area more than 1000 m^2	R	R	R	NR	R	R	R	R	150 000	20 000	(*see* Note 11)	NR

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation								Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Exting-uisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
c)	**High Hazard (G-3)** (*see* Note 19)												
	i) Covered area up to 50 m^2	R	R	NR	NR	NR	R	NR	NR	NR	10 000	NR	900
	ii) Covered area more than 50 m^2 and up to 150 m^2	R	R	NR	NR	NR	R	R	R	NR	25 000	NR	900
	iii) Covered area more than 150 m^2 and up to 300 m^2	R	R	R	NR	NR	R	R	R	50 000	10 000	(*see* Note 14)	NR
	iv) Covered area more than 300 m^2 and up to 500 m^2	R	R	R	NR	R	R	R	R	100 000	20 000	(*see* Note 10)	NR
	v) Covered area more than 500 m^2	R	R	R	NR	R	R	R	R	150 000	20 000	(*see* Note 11)	NR
STORAGE BUILDINGS (H) (*see* Note 20)													
1)	Below 15 m in height and covered area less than 250 m^2	R	R	NR	NR	NR	R	NR	NR	NR	25 000	NR	900
2)	Below 15 m in height and covered area more than 250 m^2												
	i) Ground floor only	R	R	R	NR	R	R	R	R	50 000	10 000	(*see* Note 14)	450
	ii) Ground plus one floor	R	R	R	NR	R	R	R	R	75 000	10 000	(*see* Note 10)	450

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Table 7 — (*Continued*)

Sl No.	Type of Building Occupancy	Type of Installation							Water Supply (litre)		Pump Capacity (litre/min)	
		Fire Extinguisher	First Aid Hose Reel	Wet Riser	Down Comer	Yard Hydrant	Automatic Sprinkler System	Manually Operated Electronic Fire Alarm Systems (*see* Note 1)	Automatic Detection and Alarm System (*see* Note 2)	Under-ground Static Water Storage Tank Combined Capacity for Wet Riser, Yard Hydrant and Sprinklers per Set of Pumps	Terrace Tank over Respective Tower Terrace	Pump Near Underground Static Water Storage Tank (Fire Pump) with Minimum Pressure of 3.5 kg/cm^2 at Remotest Location	At the Terrace Tank Level with Minimum Pressure of 3.5 kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	iii) More than ground plus one floor	R	R	R	NR	R	R	R	R	100 000	10 000	(*see* Note 10)	450
3)	Multi-Level Car Parking (MLCP)	R	R	R	NR	R	R	R	NR	150 000	10 000	(*see* Note 11)	900
HAZARDOUS BUILDINGS (J) (*see* Note 20)													
1)	Up to 15 m in height												
	i) Single Storey Building	R	R	R	NR	R	R	R	R	Minimum 240 min firefighting requirements	NR	(*see* Note 21)	NR
	ii) More than one floor building but not exceeding 15 m	R	R	R	R	R	R	R	R	Minimum 240 min firefighting requirements	50 000	(*see* Note 21)	900

R – Required
NR – Not Required

NOTES

1 MOEFA System shall also include talk-back system and public address system for the occupancies given in the table for (d) (1) (iii) under A-5, (a) (1) (iv) and (a) (2) under C-1, and (a) (2) under D-1 to D-5, in all buildings 15 m and above in height, except for A-3 and A-4 occupancies where these shall be provided for buildings of height 24 m and above. These shall also be provided in car parking areas more than 300 m^2 and in multi-level car parking irrespective of their areas.

2 Automatic detection and alarm system is not required to be provided in car parking area. Such detection system shall however be required in other areas of car parking such as electrical rooms, cabins and other areas.

3 Buildings above 15 m in height are not to be permitted for occupancies A-1 and A-2.

4 Required to be installed in basement, if area of basement exceeds 200 m^2.

5 Required to be provided if basement area exceeds 200 m^2.

Table 7 — (*Concluded*)

6 Additional value given in parenthesis shall be added if basement area exceeds 200 m^2.
7 Required to be provided for buildings with more than two storeys (Ground + One).
8 Required to be provided for buildings with height above 15 m and above.
9 Sprinklers shall be fed water from both underground static water storage tank and terrace tank.
10 Provide required number of sets of pumps each consisting of one electric and one diesel pump (stand by) of capacity 2 280 litre/min and one electric pump of capacity 180 litre/min (*see* Fig. 11) (*see also* notes 22 and 23).
11 Provide required number of sets of pumps each consisting of two electric and one diesel pump (stand by) of capacity 2 280 litre/min and two electric pump of capacity 180 litre/min (*see* Fig. 12) (*see also* Notes 22 and 23).
12 Provide required number of sets of pumps each consisting of two electric and one diesel pump (stand by) of capacity 2 850 litre/min and two electric pump of capacity 180 litre/min (*see* Fig. 12) (*see also* Notes 22 and 23).
13 Lower levels in high rise buildings 60 m or above in height are likely to experience high pressure and therefore, it is recommended to consider multi-stage, multi-outlet pumps (creating pressure zones) or variable frequency drive pumps or any other equivalent arrangement.
14 Provide required number of sets of pumps each consisting of one electric and one diesel pump (stand by) of capacity 1 620 litre/min and one electric pump of capacity 180 litre/min (*see* Fig. 11) (*see also* Notes 22 and 23).
15 Required to be provided for buildings with more than one storey.
16 Buildings above 30 m in height not to be permitted for Group B, Group C, Group D and Group F occupancies.
17 The requirements given in this table for Group G Industrial Buildings are for small scale industry units. For other industries the requirements will have to be worked out on the basis of relevant Indian Standards and also in consultation with the local fire authorities.
18 Buildings above 18 m in height not to be permitted for G-1 and G-2 occupancies.
19 Buildings above 15 m in height not to be permitted for G-3 occupancies.
20 Buildings above 15 m in height not to be permitted for Group H and Group J occupancies. However, buildings above 45 m in height shall not be permitted for multi-level car parking (MLCP) occupancy.
21 Pump capacity shall be based on the covered area of the building.
22 One set of pumps shall be provided for each 100 hydrants or part thereof, with a maximum of two sets. In case of more than one pump set installation, both pump sets shall be interconnected at their delivery headers.
23 Alternative to provisions of additional set of pumps, the objective can be met by providing additional diesel pump of the same capacity and doubling the water tank capacity as required for one set of pumps.
24 As per the requirement of local authority dry riser may be used in hilly areas, industrial areas or as required.

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Guidelines for selection of various types of fire detectors for different occupancies and their installation and maintenance shall be in accordance with good practice [4(16)] and the Part 12 'Asset and Facility Management' of the Code.

h) In buildings where automatic fire alarm system is provided, the following shall be monitored from fire alarm panel:

1) Water level in all tanks.
2) Hydrant and sprinkler pressures of respective zones as provided.
3) Pump 'ON/OFF' status.
4) All isolation valves, wherever provided with supervisory switch (non-padlock valves).
5) Other requirements to meet electro-mechanical services interface.

4.10 Fire Officer

4.10.1 A qualified Fire Officer with experience of not less than 3 years shall be appointed who will be available on the premises, for large educational complexes, business buildings with height 30 m and above, residential building with height 60 m and above, institutional buildings of 15 m and above, starred hotels and D-6 occupancy.

4.10.2 The Fire Officer shall,

a) maintain the firefighting equipment in good working condition at all times.
b) prepare fire orders and fire operational plans and get them promulgated.
c) impart regular training to the occupants of the buildings in the use of firefighting equipment provided on the premises and keep them informed about the fire emergency evacuation plan.
d) keep proper liaison with the city fire brigade.
e) ensure that all fire precautionary measures are observed at the times.

NOTE — Competent authority having jurisdiction may insist on compliance of the above rules in case of buildings having very large areas even if the height is less than 30 m.

4.11 Fire Drills and Fire Orders

Fire notices/orders shall be prepared to fulfil the requirements of firefighting and evacuation from the buildings in the event of fire and other emergency. The occupants shall be made thoroughly conversant with their action in the event of emergency, by displaying fire notices at vantage points and also through regular training. Such notices should be displayed prominently in bold lettering.

For guidelines for fire drills and evacuation procedures for high rise buildings, *see* Annex D.

5 FIRE PROTECTION

5.1 Fire Extinguishers/Fixed Firefighting Installations

5.1.1 All buildings depending upon the occupancy use and height shall be protected by fire extinguishers, hose reels, wet riser, down-comer, yard hydrants, automatic sprinkler installation, deluge system, high/medium velocity water spray, foam, water mist systems, gaseous or dry powder system, manual/automatic fire alarm system, etc, in accordance with the provisions of various clauses given below, as applicable:

a) These fire extinguishing equipment and their installation shall be in accordance with accepted standards [4(17)]. The extinguishers shall be mounted at a convenient height to enable its quick access and efficient use by all in the event of a fire incidence. The requirements of fire extinguishers/yard hydrant systems/wet riser/down-comer installation and capacity of water storage tanks and fire pumps, etc, shall be as specified in Table 7. The requirements regarding size of mains/risers shall be as given in Table 8. The typical arrangements of down-comer and wet riser installations are shown in Fig. 13. The wet riser shall be designed for zonal distribution ensuring that unduly high pressures are not developed in risers and hose-pipes.
b) First-aid firefighting appliances shall be provided and installed in accordance with good practice [4(18)]. The firefighting equipment and accessories to be installed in buildings for use in firefighting shall also be in accordance with the accepted standard [4(17)] and shall be maintained periodically so as to ensure their perfect serviceability at all times.
c) Valves in fixed firefighting installations shall have supervisory switch with its signalling to fire alarm panel or to have chain(s), pad lock(s), label and tamper-proof security tag(s) with serial number to prevent tampering/unauthorized operation. These valves shall be kept in their intended 'open' position.
d) In addition to wet riser or down-comer, first-aid hose reels shall be installed in buildings (where required under Table 7) on all the floors, in accordance with accepted standard [4(19)]. The first-aid hose reel shall be

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connected directly to the riser/down-comer main and diameter of the hose reel shall not be less than 19 mm.

e) Wet risers shall be interconnected at terrace level to form a ring and cut-off shall be provided for each connection to enable repair/ maintenance without affecting rest of the system.

f) Pressure at the hydraulically remote hydrant and at the highest hydrant shall not be less than 3.5 bar. The pressure at the hydrants shall however not exceed 7.0 bar, considering the safety of operators. It may be planned to provide orifice plates for landing valves to control pressure to desired limit especially at lower levels; this could also be achieved through other suitable means of pressure reducing devices such as pressure controlled hydrant valves.

g) Hydrants for firefighting and hose reels shall be located in the lobby in firefighting shaft. Those hydrants planned to be provided near fire exit staircase on the floor shall be within 5 m from exit door in exit access. Such hydrant cabinet may finish with doors to meet interior finishes with requirement of glass panel to provide visibility to the installations inside and inscribed with the word: 'FIRE HOSE CABINET' of letter size 75 mm in height and 12 mm in width. Such door of the fire hose cabinet need not be fire resistant rated. The location of such cabinets shall be shown on floor plan and duly displayed in the landing of the respective fire exit staircase.

5.1.2 *Static Water Storage Tanks and Pump House*

5.1.2.1 *Static water storage tanks*

A satisfactory supply of water for the purpose of firefighting shall always be available in the form of underground/terrace level static storage tank with capacity specified for each building with arrangements or replenishment.

Water for the hydrant services shall be stored in an easily accessible surface/underground lined reservoir or above ground tanks of steel, concrete or masonry. The effective capacity of the reservoir above the top of the pump casing (flooded suction) for various types of occupancies shall be as indicated in Table 7.

Water for firefighting shall be stored in two or more interconnected compartments of equal size to facilitate cleaning and maintenance of the tanks without interrupting the water availability for firefighting.

To prevent stagnation of water in the static water storage tank, the suction tank of the domestic water supply shall be fed only through an overflow arrangement from the fire water storage tanks to maintain the level therein at the minimum specified capacity.

Alternatively, domestic and fire water can be stored in two interconnected compartments as mentioned above. The suction inlet(s) for the domestic water pumps shall be so located at an elevation that minimum water requirements for firefighting as stated in Table 7 will be always available for fire pumps.

The static storage water supply required for the above mentioned purpose shall entirely be accessible to the fire engines of the local fire service. Suitable number of manholes shall be provided for inspection, repairs, insertion of suction hose, etc. As an alternative to the arrangement of manholes to allow access from the top, suitable arrangement to enable efficient access to the tank by the firemen from the adjoining fire pump room having direct access from the ground level, shall be made. The underground fire water storage tank(s) shall not be more than 7 m in depth from the level having fire brigade draw-out connection, while the draw-out connection shall not be more than 5 m away from the tank wall.

The covering slab shall be able to withstand a total vehicular load of 45 t (or as applicable) equally divided as a four-point load when the slab forms a part of pathway/driveway.

The static water storage tank shall be provided with a fire brigade collecting head with 4 number 63 mm diameter (2 number 63 mm diameter for pump with capacity 1 400 litre/min) instantaneous male inlets arranged in a valve box at a suitable point at street level. The same shall be connected to the static tank by a suitable fixed galvanized iron pipe not less than 150 mm in diameter to discharge water into the tank when required at the rate of 2 250 litre/min, if tank is in the basement or not approachable for the fire engines.

Each of the static water storage tanks shall also be provided with a fire brigade draw out collecting head with 63 mm diameter instantaneous male draw out arranged in a valve box at a suitable point at street level. This draw out shall be connected to galvanized iron pipe of 100 mm diameter with foot valve arrangement in the tank.

5.1.2.2 *Firefighting pump house*

The requirements shall be as given below:

a) It is preferable to install the pump house at ground level. Pump house shall be situated so as to be directly accessible from the surrounding ground level.

b) Pump house shall be installed not lower than the second basement. When installed in the

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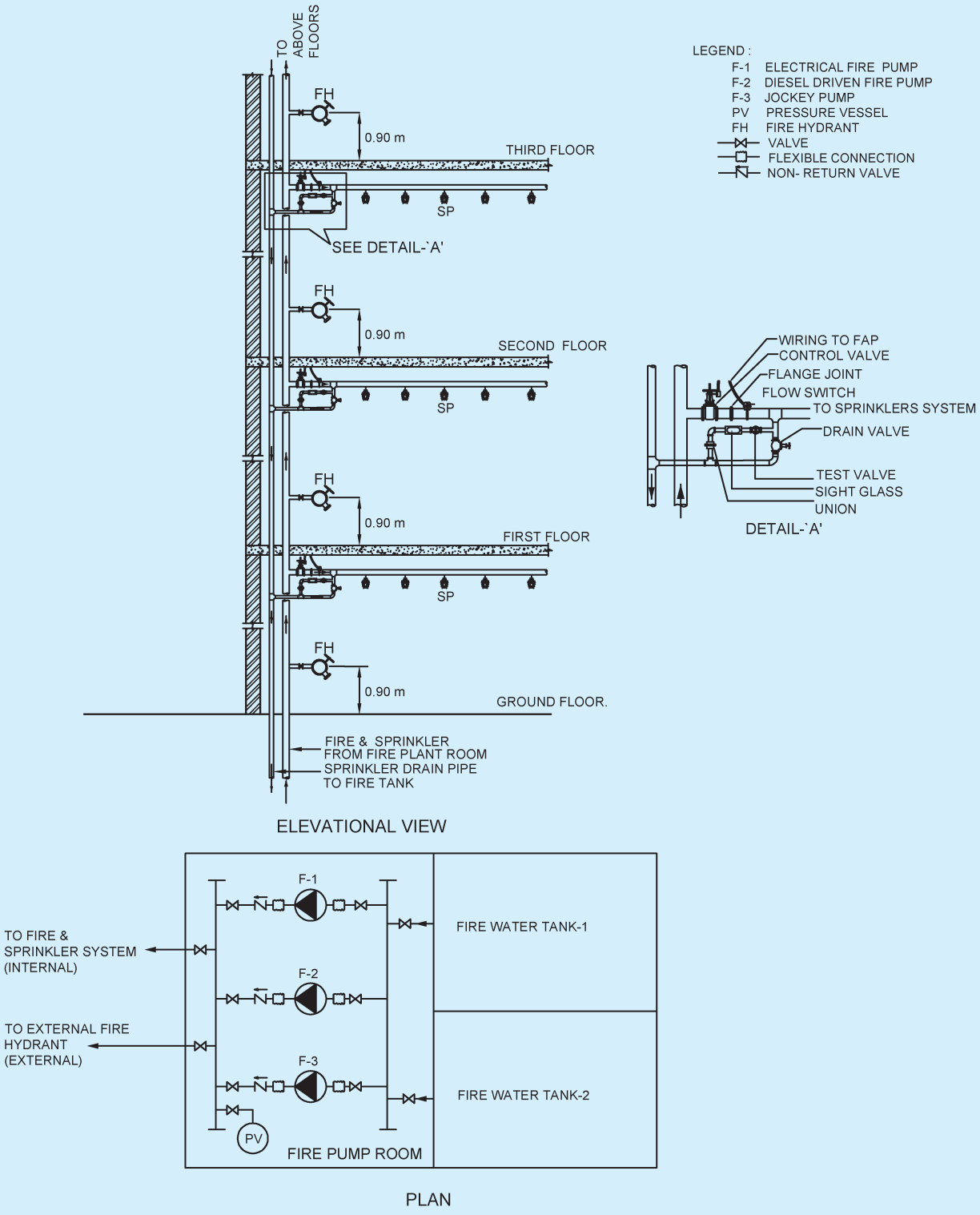


FIG. 11 TYPICAL SYSTEM OF PUMPING WITH ONE ELECTRIC, ONE DIESEL FIRE PUMP

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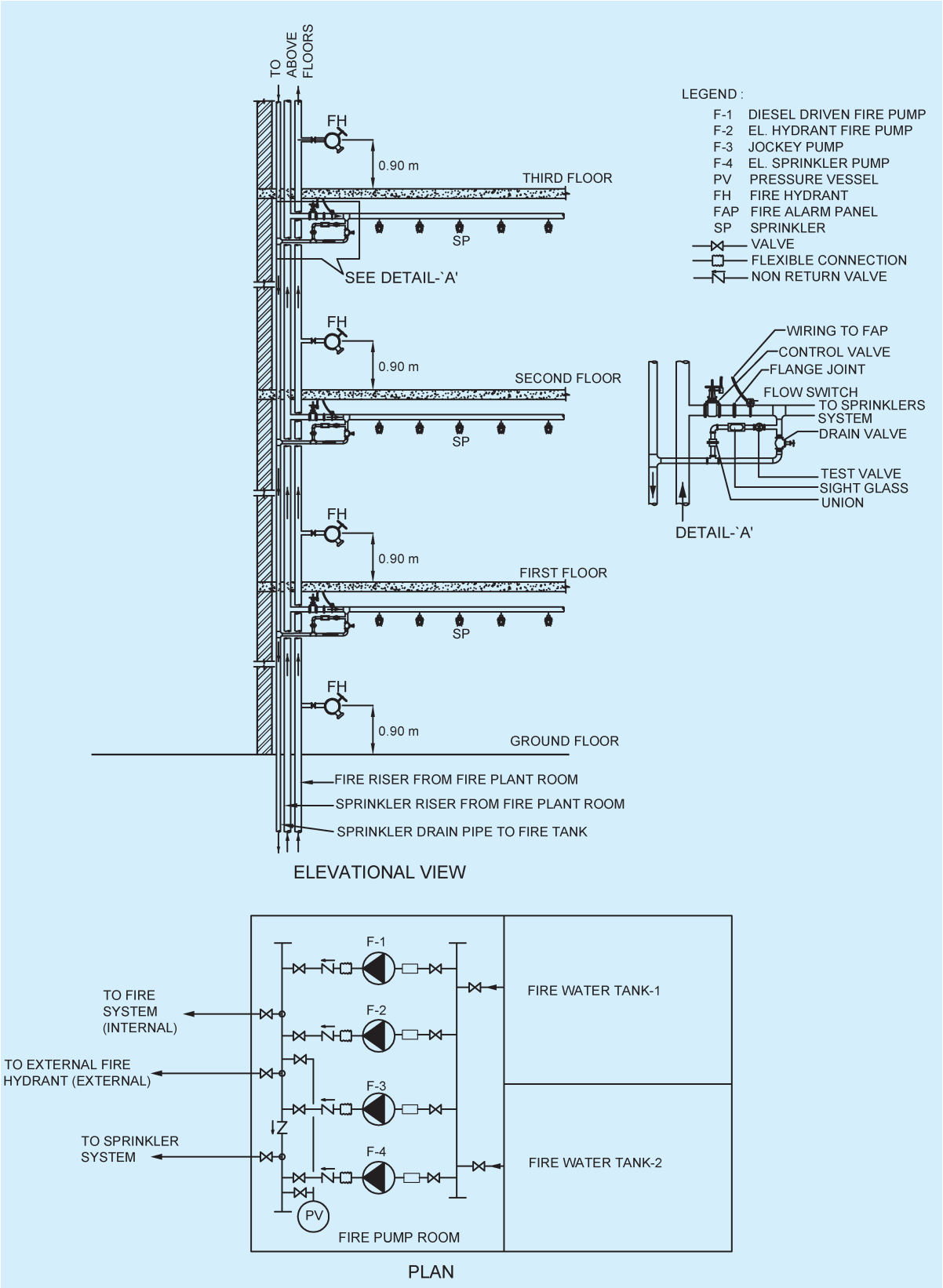


FIG. 12 TYPICAL SYSTEM OF PUMPING WITH TWO ELECTRIC, ONE DIESEL FIRE PUMP

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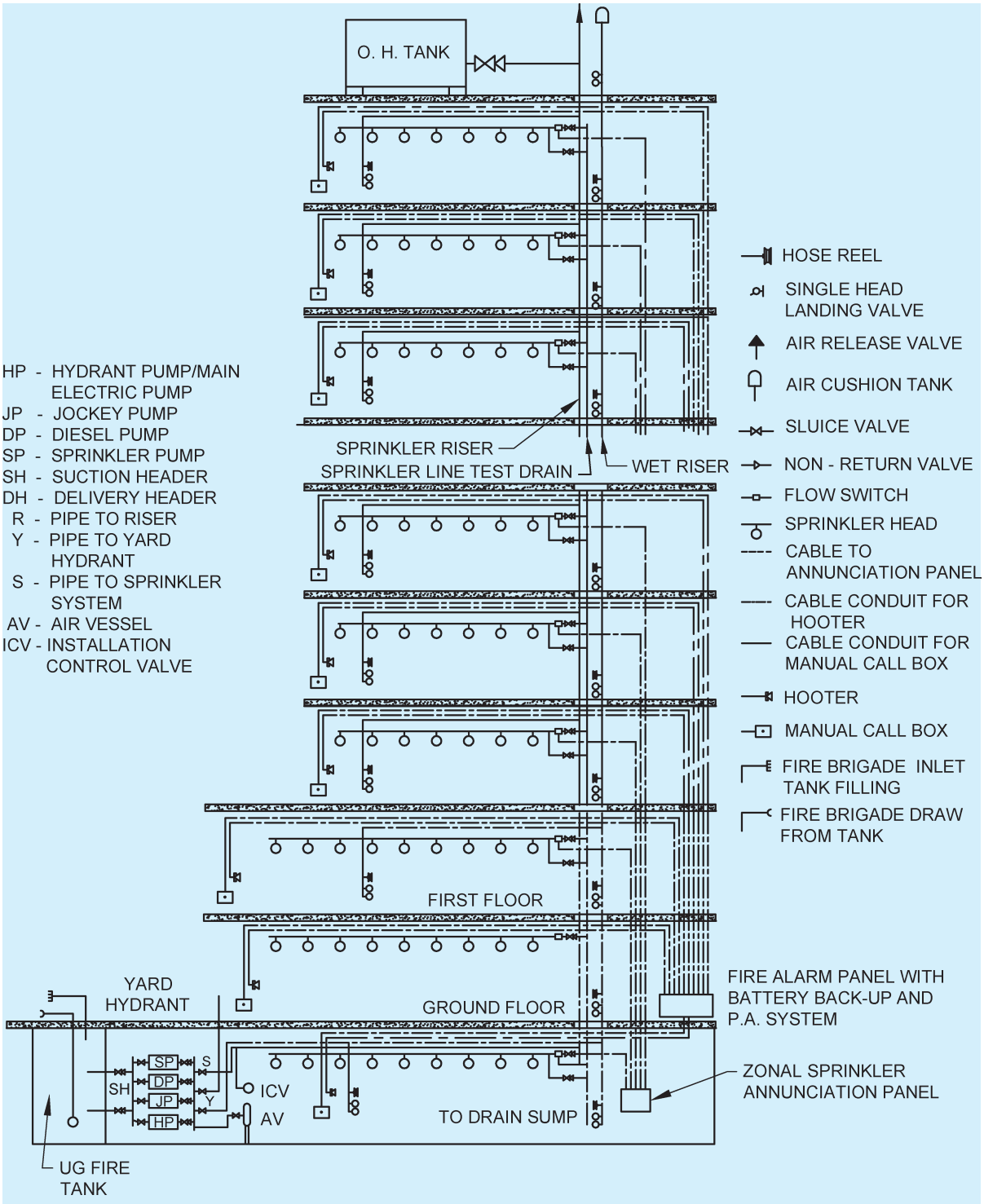


FIG. 13 TYPICAL ARRANGEMENT OF WET RISER AND TOTAL SPRINKLER SYSTEM OF BUILDING

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Table 8 Size of Mains
[*Clause* 5.1.1(a)]

Sl No.	Size of the Mains mm	Type of Building	Remarks
(1)	(2)	(3)	(4)
i)	100 mm with single outlet landing valves	a) Residential building (A):	
		1) Dormitories	—
		2) Apartments	—
		3) Hotels	Up to 45 m height
		b) Educational buildings (B)	—
		c) Institutional buildings (C)	Up to 30 m height
		d) Assembly buildings (D)	—
		e) Business buildings (E)	Up to 45 m height
		f) Mercantile buildings (F)	—
		g) Industrial buildings (G)	Up to 15 m height
ii)	150 mm with single outlet landing valves	a) Hotels	Above 45 m height
		b) Starred hotels	—
		c) Institutional buildings (C)	Above 30 m height
		d) Business buildings (E)	Above 45 m height
		e) Industrial buildings (G)	Above 15 m height
		f) Storage buildings (H)	Up to 15 m height
		g) Hazardous buildings (J)	Up to 15 m height

basement, staircase with direct accessibility (or through enclosed passageway with 120 min fire rating) from the ground, shall be provided. Access to the pump room shall not require to negotiate through other occupancies within the basement.

c) Pump house shall be separated by fire walls all around and doors shall be protected by fire doors (120 min rating).

d) Pump house shall be well ventilated and due care shall be taken to avoid water stagnation.

e) No other utility equipment shall be installed inside fire pump room.

f) Insertions like flexible couplings, bellows, etc, in the suction and delivery piping shall be suitably planned and installed.

g) Installation of negative suction arrangement and submersible pumps shall not be allowed.

h) Pump house shall be sufficiently large to accommodate all pumps, and their accessories like PRVs, installation control valve, valves, diesel tank and electrical panel.

j) Battery of diesel engine operated fire pump shall have separate charger from emergency power supply circuit.

k) Exhaust pipe of diesel engine shall be insulated as per best engineering practice and taken to a safe location at ground level, considering the back pressure.

m) Fire pumps shall be provided with soft starter or variable frequency drive starter.

5.1.3 *Automatic Sprinkler Installation*

The requirements shall be as given below:

a) Automatic sprinklers shall be installed wherever required in terms of Table 7 throughout the building in accordance with good practice [4(20)].

b) If selective sprinklering is adopted, there is a real danger of a fire starting in one of the unsprinklered area gathering momentum spreading to other areas and reaching the sprinklered areas as a fully developed fire. In such an event, the sprinklers can be rendered useless or ineffective.

c) Automatic sprinklers shall be installed in false ceiling voids exceeding 800 mm in height.

d) Installation of sprinklers may be excluded in any area to be used for substation and DG set.

e) In areas having height 17 m or above such as in *atria*, sprinkler installations may be rendered ineffective and hence may be avoided.

f) Pressure in sprinkler system shall not exceed 12 bar or else high pressure sprinkler to be installed for above 12 bar operations.

g) The maximum floor area on any one floor to be protected by sprinklers supplied by any one sprinkler system riser from an installation control valve shall be based on system protection area limitations considering maximum floor area on any one floor to be 4 500 m^2 for all occupancies except industrial and hazardous occupancies, where Authorities

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shall be consulted for advice based on type and nature of risk.

h) Sprinkler installation control valves, shall be installed inside the fire pump room.

j) For industrial buildings, such installation control valves may be installed outside the building and Authorities shall be consulted in situations where it is not possible to locate them inside the buildings. It is advisable to provide electrically operated siren for each valve outside the buildings in addition to water gongs in such case.

k) The sprinkler flow switches provided shall be monitored by fire alarm panel.

m) It is essential to make provisions for avoiding water from sprinkler/hydrant operation entering lifts and electrical rooms.

n) Ramps at all levels shall be protected with sprinklers.

5.1.4 *Automatic High Velocity and Medium Velocity Water Spray Systems*

Automatic high velocity water spray or emulsifying system shall be provided for protection of outdoor and/or indoor oil-cooled transformers as applicable in accordance with good practice [4(21)] where applicable (*see* Annex E). Also, medium velocity water spray system shall be provided for tankage (where applicable), conveyors, cable galleries and other occupancies listed in good practice [4(21)].

5.1.5 *Fixed Foam Installation*

Fixed foam generating system shall be provided for protection of oil storage area for boilers with its ancillary storage of furnace oils in basement. Fixed foam installations can be low, medium or high expansion types, which can be provided based on the type of fire hazards identified in the facility. High expansion foams are used for cable tunnels and other confined areas. Design and installation of foam systems shall be governed by good practice [4(22)].

5.1.6 *Gas Based Suppression System*

Gas based fire extinguishing installation shall be provided in accordance with good practice on premises where water or foam cannot be used for fire extinguishing because of the special nature of the contents of the buildings/areas to be protected where either the building(s) have very limited manpower or unmanned. The protection design for fixed carbon dioxide fire extinguishing system shall conform to good practice [4(23)] in all respects. For some special fire risk/essential applications, carbon dioxide may not be suitable and alternate provisions shall be made as per relevant standards (*see* **5.1.9**).

5.1.7 Firefighting equipment shall be suitably located and clearly marked by luminous signs.

5.1.8 *Automatic Water Mist Systems*

These systems involve the use of fine water sprays for the efficient extinguishment of fires. These systems may be provided to protect areas in buildings for the uses as specified in good practice [4(24)].

5.1.9 *Extinguishing Systems with Clean Agents*

Alternative systems for halon gas protection systems shall be provided where necessary as prescribed in this Part. These shall be in accordance with the accepted standards [4(25)].

5.2 Fire Detection and Alarm System

See **4.9**.

5.3 The fixed firefighting installations and systems shall be maintained in accordance with good practice [4(26)] and the Part 12 'Asset and Facility Management' of the Code.

6 ADDITIONAL OCCUPANCY WISE REQUIREMENTS

In addition to the general requirements on fire prevention given in **3**, the life safety requirements given in **4**, and the fire protection requirements given in **5**, the following additional requirements shall also be complied with for each type of occupancy.

For additional requirements for high rise buildings, the provisions as given in Annex E shall apply.

Atriums in building occupancies shall comply with the provisions as given in Annex F.

For fire protection requirements of commercial kitchen, cooking facilities with or without restaurants, the provisions of Annex G shall be referred.

6.1 Residential Buildings (Group A)

6.1.1 *Life Safety*

6.1.1.1 *Subdivision A–1*

a) All locking devices, which would impede or prohibit exit, such as chain type bolts, limited opening sliding type locks and burglar locks, which are not disengaged easily by quick-releasing catches, shall be prohibited.

b) All bathroom door locks or fasteners shall be designed to permit the opening of the locked or closed door from the outside in an emergency without the use of a special key.

c) No lodging or rooming house shall have its sole means of egress pass through any non-residential occupancy in the same building.

d) Rooming and lodging houses having floor area of 500 m^2 on any one or more floors shall have access to minimum two separate means of exits, at least one of which shall be so arranged as to have direct exit discharge.

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6.1.1.2 *Subdivision A-3*

a) Requirements of **6.1.1.1** shall be applicable.

b) All sleeping rooms having occupancy of more than 10 persons shall have two separate and distinct exit access in different directions.

6.1.1.3 *Subdivision A-4*

In case of high rise apartments, of the minimum exits as specified in **4.4.2.4.3.1**, the naturally ventilated exit staircases may not require the provision of fire door. However, fire door shall be provided for all other staircases and pressurized staircases.

6.1.1.4 *Subdivision A-5*

a) Panic bars shall be provided in the fire exits. Panic bars shall be located at a height between 865 mm and 1 220 mm from the floor level.

b) All guest rooms and suites shall be protected by extended throw, quick response type sprinklers only. Also these areas shall be provided with audio-based detectors, having a sound level of at least 75 dB.

c) Horizontal-sliding doors shall not be used for door openings across corridors.

6.1.2 *Additional Precautions*

a) Flammable liquids for household purposes shall be kept in tightly stoppered or sealed containers. For the limits of quantities of flammable liquids to be allowed in various occupancies, reference may be made to appropriate regulations.

b) No stove or combustion heater shall be located directly under or immediately at the foot of stairs or otherwise so located as to block escape in case of malfunctioning of the stove or heater.

c) All kitchen exhaust fans, where provided, shall be fixed to an outside wall or to a duct of non-combustible material, which leads directly to the outside. The ducts shall not pass through areas having combustible materials. However, in case of centralized ducting, the duct shall be provided with adequate protection to limit the spread of fire.

d) Stores, engineering workshops, areas of high hazard, etc used for storage of substantial amount of flammable liquids shall be of 120 min fire resistance rating wall. Such areas shall be provided with fire doors, to be kept closed and shall be posted with a sign on each side of the door in 25 mm high block letters stating — 'FIREDOOR — KEEP CLOSED'.

6.2 Educational Buildings (Group B)

6.2.1 *Fire Prevention*

a) Buildings intended for educational occupancy shall not be used for storage of any hazardous material.

b) Gymnasiums, indoor stadiums and similar occupancies are permitted to have floors/ running tracks of wood, cinder, synthetic or the like.

6.2.2 *Life Safety*

a) Every room with a capacity of over 45 persons in area shall have at least two doorways. Exit doors shall be operated by panic bars except that doors leading from classrooms directly to the outside may be equipped with the same type of lock as is used on classroom doors leading to corridor, with no provision whatsoever for locking against egress from the classroom.

b) A building, which will have only the first floor and is accessible to not more than 20 pupils at any time, may be used for school purposes with the following exceptions:

1) Exterior walls or parts of walls which are less than 900 mm from adjacent property lines shall have no openings therein.

2) Classrooms may have only one exit not less than 900 mm wide.

c) Rooms or areas for use by the preschool, kindergarten, Class/Grade 1 students shall be located on ground floor/level of exit discharge. Rooms or areas occupied by Class/Grade II students shall be located not above one floor higher than ground floor/level of exit discharge.

d) Of the minimum exits as specified in **4.4.2.4.3.1**, the naturally ventilated exit staircases, may not require provision of fire door. However, fire door shall be provided for all other staircases and pressurized staircases.

6.2.3 *Additional Precautions*

a) Storage of volatile flammable liquids shall be prohibited and the handling of such liquids shall be restricted to science laboratories only.

b) All exterior openings in a boiler room or rooms containing central heating equipment,

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if located below an opening in another storey or if less than 3 m from other doors or windows of the same building, shall be protected by a fire assembly as in **3.4.5**. Such assemblies shall be of fixed, automatic or self-closing type.

6.3 Institutional Buildings (Group C)

6.3.1 *Fire Prevention*

No combustible material of any kind shall be stored or used in any building or section thereof used for institutional occupancy, except as necessary to normal occupancy and use of the building.

6.3.2 *Life Safety*

a) The common path of travel shall be 30 m. The maximum dead end of corridor distance shall not exceed 6 m.

b) Principle of progressive horizontal evacuation is of paramount consideration for hospital patients particularly those lacking self-preservation. This calls for moving occupants from a fire affected area to an adjoining area at the same level through a fire resistant wall, to protect them from the immediate dangers of fire and smoke (*see* Fig. 14).

c) Progressive horizontal evacuation operates on the basis of evacuation from compartment to compartment and on use of adjacent compartments as temporary means of refuge. All compartments shall be divided with self-closing (door closers) fire doors with electromagnetic hold open. A coordinator shall be provided to sequence the closing of double leaf in case of emergency.

d) Doors in fire resistant walls shall be so installed that these may normally be kept in open position, but will close automatically. Corridor door openings shall be not less than 2.0 m in width of double swing double leaf type door. A coordinator shall be provided as above, for closing of double leaf in case of emergency.

e) Exits and other features for penal and mental institutions, and custodial institutions shall be the same as specified for hospitals [*see* **6.3.2** (g)], in so far as applicable. Reliable means shall be provided to permit the prompt release of inmates from any locked section in case of fire or other emergency.

f) All buildings or sections of buildings in penal and mental institution used for manufacturing, storage or office purposes shall have exits in accordance with the provisions of the Code for those occupancies.

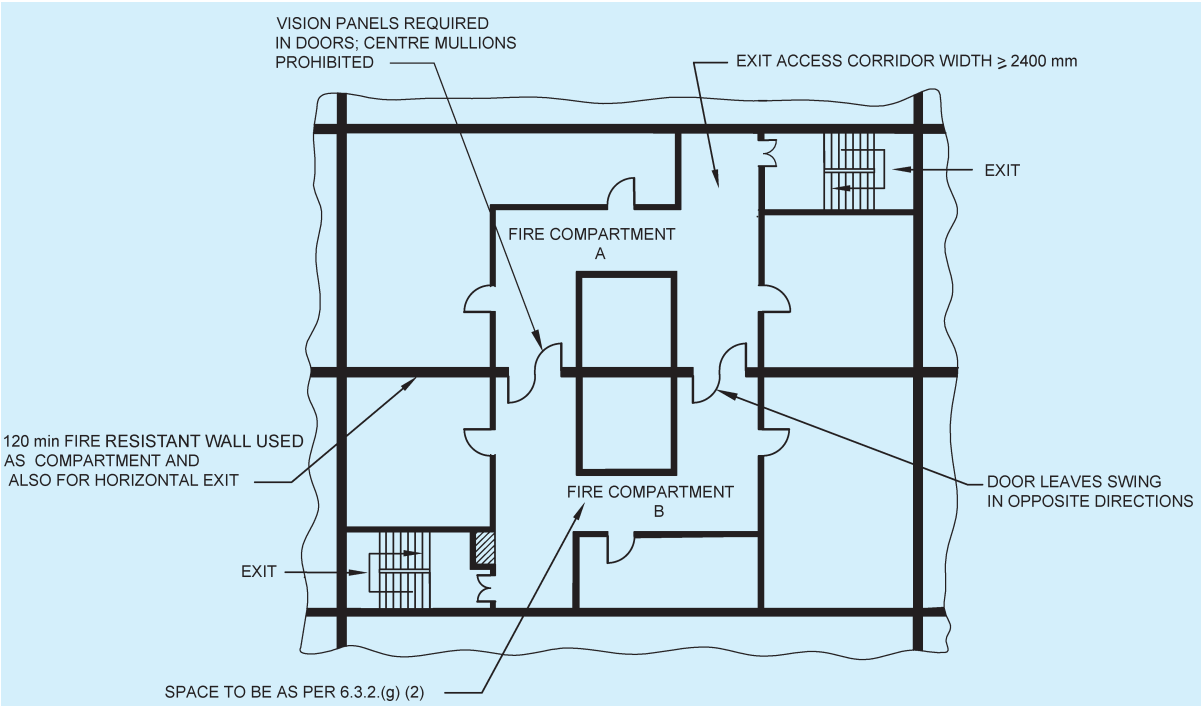


FIG. 14 PART PLAN INDICATING CONCEPT OF HORIZONTAL EXIT IN HOSPITAL

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g) For hospitals (Subdivision C-1), the following shall also be complied with:

1) Compartmentation shall meet the requirement as per **4.5.2**.
2) Each compartment (*see* **4.5.2**) shall be able to accommodate, in addition to its own, the patients from adjoining compartment also considering 3.5 m^2 per person. If patients are not bed-ridden, a factor of 0.6 m^2 per person is recommended.
3) All critical patients and those incapable of self-preservation and having physical impairment shall be housed within 30 m height.
4) Other types of patients and occupancies incidental to the hospitals such as consultation rooms, nurses' stations, medical shops, canteens, etc may be housed at heights beyond 30 m but not more than 45 m.
5) Basement shall not be used to store flammables or for pathological or other laboratories particularly those involving usage of chemicals.
6) Operation theatres, delivery rooms, Intensive care units, recovery rooms, etc, that containing patients lacking self-preservation in case of emergencies shall be fire/smoke separated (120 min minimum rating) from all the adjoining areas.
7) Aisles, corridors, ramps, etc, through which patients are moved, shall have a minimum width of 2.4 m throughout. Aisles, corridors, and ramps in other areas not intended for the housing, treatment, or use of inpatients shall be not less than 1.5 m in width.
8) All exits from hospital or infirmary sections shall be not less than 2.0 m in width.
9) Minimum width of door of single or double occupancy patient room shall be 1.25 m while for the wards for 3 to 5 patient beds shall be 1.50 m, to permit movement of patients. The minimum width of door for wards for more than 5 patient beds and for areas necessarily requiring patient evacuation on bed (such as ICU, recovery units, delivery rooms, etc), shall have door width of 2.0 m. The width of 2.0 m may be reduced to minimum of 1.5 m where two such doors are provided in such areas.
10) Any sleeping accommodation or suite exceeding 100 m^2 in area shall have at least two doorways leading to the exit access corridors.
11) Floor surface of corridors shall not be inclined at a gradient steeper than 1 in 12 to the horizontal.
12) Exit access corridors from a compartment to another compartment shall be divided at the compartment intersection by a fire door of 120 min fire rating in the fire compartment wall.
13) Rooms designated for laboratory and the like shall not exceed 100 m^2 in area and if additional space is required, fire separation of 120 min shall be provided.
14) Storage of flammable liquids in laboratories or in any other area shall be not more than 3 litre for every 10 m^2 area.
15) Disposal of any equipment and other (particularly hazardous) materials shall be accomplished in the premises by a disposal specialist or at a safe location away from the health care facility by competent personnel using procedures established in concurrence with the safe practices.
16) A stretcher lift in a lift bank shall also act as fireman's lift meeting the requirements of Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks, Subsection 5A Lifts' of the Code.

h) *Progressive evacuation strategy — See* Fig. 15, in which, as an example, the exit calculations at two locations shall be based on requirements of total occupancy for area (A, B and C) divided by 2 considering progressive evacuation strategy.

6.3.3 *Exception and Deviation*

It is recognized that in institutions or part of buildings housing various types of psychiatric patients, or used as mental institutions and penal institutions, it is necessary to maintain locked doors and barred windows; and to such extent the necessary provision in other sections of the code requiring the keeping of exits unlocked may be waived. It is also recognized that certain type of psychiatric patients are not capable of seeking safety without adequate guidance. In buildings where this situation prevails, reliable means for the rapid release of occupants shall be provided, such as remote control of locks, or by keying all locks to keys commonly used by attendants.

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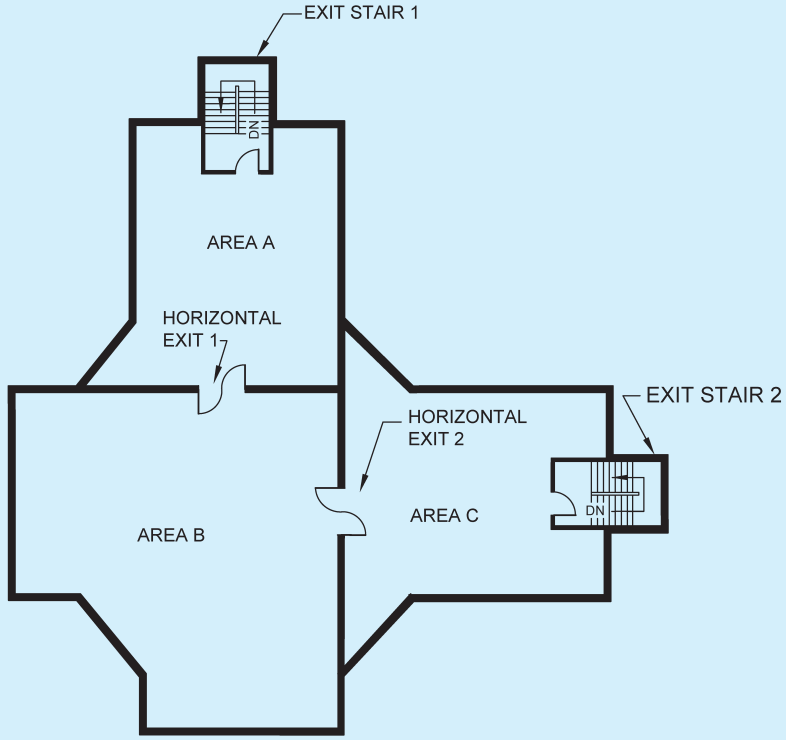


FIG. 15 MINIMUM OF TWO EXITS ACCESSIBLE FROM ALL PARTS OF FLOOR

6.4 Assembly Buildings (Group D)

6.4.1 *Fire Prevention*

6.4.1.1 The following shall be applicable:

a) Decorations of places of assembly shall be of non-flammable materials. Fabrics and papers used for such purpose shall be treated with an effective flame-retardant material. Stage settings made of combustible materials shall likewise be treated with fire retardant materials of Class 1 flame spread.

b) Gymnasiums, indoor stadiums and similar occupancies are permitted to have floors/ running tracks of wood, cinder, synthetic or the like.

6.4.1.2 *Additional fire prevention requirements for D-6 occupancy*

Building having D-6 mixed use assembly/mercantile occupancy will limit the height of the assembly/ mercantile occupancy portion of the buildings to 30 m. Above this height the buildings may be used for business or residential occupancies with 240 min separation. Independent exits shall be provided for such occupancy above 30 m and shall not interface with exits of assembly/mercantile occupancy.

6.4.2 *Life Safety*

6.4.2.1 The following shall be applicable:

a) Exit door width for assembly buildings shall not be less than 2.0 m.

b) Every place of assembly of sub-division D-1 shall have at least four separate exits as remote from each other as practicable.

c) Every place of assembly of sub-division D-2 shall have at least two separate exits as remote from each other as practicable and if of capacity over 600, at least three exits shall be provided with each exit not less than of 2.0 m width.

d) Clear aisles not less than 1.2 m in width shall be formed at right angles to the line of seating in such number and manner that no seat shall be more than seven seats away from an aisle. Rows of seats opening on to an aisle at one end only shall have not more than seven seats. Under the conditions, where all these aisles do not directly meet the exit doors, cross-aisles shall be provided parallel to the line of seating so as to provide direct access to the exit, provided that not less than one cross aisle for every 10 rows shall be required. The width of cross-aisles shall be minimum of 1 m. Steps shall not be placed in aisles to overcome differences in levels, unless the gradient exceeds 1 in 10.

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e) The fascia of boxes, balconies and galleries shall have substantial railings not less than 1 000 mm high above the floor. The railings at the end of aisles extending to the fascia shall be not less than 1 100 mm high for the width of the aisle or 1.2 m high at the foot of steps.

f) Cross-aisles, except where the backs of seats on the front of the aisle project 600 mm or more above the floor of the aisle, shall be provided with railings not less than 900 mm high.

g) No turnstiles or other devices to restrict the movement of persons shall be installed in any place of assembly in such a manner as to interfere in any way with the required exit facilities.

h) In theatres and similar places of public assembly where persons are admitted to the building at a time when seats are not available for them and are allowed to wait in a lobby or similar space until seats are available, such use of lobby or similar space shall not encroach upon the required clear width of exits. Such waiting shall be restricted to areas separated from the required exit ways by substantial permanent partitions or fixed rigid railing not less than 1 050 mm high. Exits shall be provided for such waiting spaces on the basis of one person for each 0.3 m^2 of waiting space area. Such exits shall be in addition to the exits specified for the main auditorium area and shall conform in construction and arrangement to the general rules of exits given above.

j) No display or exhibit shall be so installed or operated as to interfere in any way with access to any required exit, or with any required exit sign.

k) All displays or exhibits of combustible material or construction and all booths and temporary construction in connection therewith shall be so limited in combustibility or protected as to avoid any undue hazard of fire which might endanger occupants before they have opportunity to use the available exits, as determined by the authority.

m) Places of assembly in buildings of other occupancy may use exits common to the place of assembly and the other occupancy, provided the assembly area and the other occupancy are considered separately, and each has exits sufficient to meet the requirements of the Code.

n) Exits shall be sufficient for simultaneous occupancy of both the places of assembly and other parts of the building.

p) For detailed information regarding cinema buildings, reference may be made to good practice [4(27)].

q) Seats in places of public assembly, accommodating more than 300 persons, shall be securely fastened to the floor, except as permitted in (r) below. All seats in balconies and galleries shall be securely fastened to the floor, except that in nailed-in enclosures, boxes with level floors and having not more than 14 seats, the seats need not be fastened.

r) Chairs not secured to the floor may be permitted in restaurants, night clubs and other occupancies where the fastening of seats to the floor may not be practicable, provided that in the area used for seating, excluding dance floor, stage, etc, there shall be not more than one seat for each 1.4 m^2 of floor area and adequate aisles to reach exits shall be maintained at all times. The arrangements shall be as follows in general:

   1) Rows of seats between aisles shall have not more than 14 seats.
   2) Rows of seats opening on to an aisle at one end only shall have not more than 7 seats.
   3) Seats without dividing arms shall have their capacity determined by allowing 450 mm per person.

s) The spacing of rows of seats from back to back shall be neither less than 850 mm nor less than 700 mm plus the sum of the thickness of the back and inclination of the back. There shall be a space of not less than 350 mm between the back of one seat and the front of the seat immediately behind it as measured between plumb lines.

t) *Lighting* — No open flame lighting devices shall be used in any place of assembly, except in the following cases:

   1) Where necessary for ceremonial purposes, the enforcing Authority may permit open flame lighting under such restrictions as are necessary to avoid danger of ignition of combustible materials or injury to occupants.
   2) Candles may be used on restaurant tables if securely supported on non-combustible bases and so located as to avoid danger of ignition of combustible materials.
   3) Open flame devices may be used on stages where they are a necessary part of

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theatrical performance, provided adequate precautions, satisfactory to the Authority aretaken to prevent ignition of combustible materials.

6.4.2.2 *Life safety provisions for D-6 occupancy*

The following additional requirements shall be applicable:

a) Assembly occupancies of theatres, cinema halls and multiplexes shall be so located in the mall building that their exits will be separate and lead the occupant directly to exit discharge.

b) The common path of travel shall be 30 m. The maximum dead end of corridor distance shall not exceed 6 m.

c) The minimum width of an exit passageway shall be 2.0 m.

d) Where wheeled carts or buggies are used by customers, adequate provision shall be made for the transit and parking of such carts to minimise the possibility that they might obstruct means of egress. Any other storage or hindrances causing obstruction in exits shall be avoided.

e) Car parking facilities shall comply with Annex H. Car parking areas at upper levels adjacent to shops, food courts or multiplex shall be separated by 120 min fire rated construction and building elements.

f) 50 percent lifts in common areas in D-6 shall be with features and requirement of fireman's lift.

g) The manual call points shall be break glass and not pull stations.

h) Photoluminescent markings shall be done along the width and length of treads in all enclosed exits staircases. Exit directional arrow on the wall (in the direction of egress) shall be 175 mm × 50 mm.

j) Refuge area to be provided on the floor at or immediately above 18 m shall be not less than 10 percent of gross area of floor. Next refuge area to be at/on the floor immediately above 24 m. The refuge area shall be 10 percent of the respective floor, which may be divided into two or more separate refuge areas at each of the respective floors, with each being not less than 100 m^2. Refuge area shall also meet all the requirements of life safety as per **4**.

6.4.3 *Fire Protection*

a) Every stage equipped with fly galleries, grid irons and rigging for movable theatre type scenery, shall have a system of automatic sprinklers over and under such stage areas or spaces and auxiliary spaces, such as dressing rooms, store rooms and workshops, and the proscenium opening shall be provided with a fire resisting curtain, capable of withstanding a lateral pressure of 4 kN/m^2 over the entire area. The curtain shall have an emergency closing device capable of causing the curtain to close without the use of power and when so closed, it shall be reasonably tight against the passage of smoke.

b) The stage roof of every theatre using movable scenery or having a motion picture screen of highly combustible construction shall have a ventilator or ventilators in or above it, openable from the stage floor by hand and also opening by fusible links or some other approved automatic heat/smoke actuated device, to give a free opening equal to at least one-eighth the area of the floor of the stage.

c) The proscenium wall of every theatre using movable scenery of decorations shall have, exclusive of the proscenium opening, not more than two openings entering the stage, each not to exceed 2 m^2 and fitted with self-closing fire resistant doors.

d) Every place of assembly in which projection of motion pictures by light is made shall have the projection apparatus enclosed in a fire resisting fixed booth in accordance with good practice [4(27)], except that such booth shall not be required where no nitrocellulose motion picture film is used.

6.4.4 *Fire Protection and Firefighting System for Metro Stations* (*D-7 Occupancy*)

Fire and life safety requirements for metro stations and metro trainways shall be in accordance with Annex J and Annex K, respectively.

6.5 Business Buildings (Group E)

6.5.1 *Life Safety*

Not less than two exits shall be provided for every floor, including basements occupied for office purposes or uses incidental thereto.

6.5.2 *Fire Protection*

a) For Subdivision E-2, the requirement shall be provision of automatic fire detection alarm system, while for fire protection, CO_2 and/or foam based installation to be planned based on the requirements.

b) For Subdivision E-3, E-4 and E-5, the requirement shall be provision of automatic

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fire detection alarm system, while for fire protection, any or combination of clean agents, mist technologies, hypoxic air technology, etc, may be planned for appropriate/special situations/locations. Electrical panels may be provided with CO_2/inert gas flooding system based on the requirement and reliability of power for the functional requirement and performance.

6.6 Mercantile Buildings (Group F)

6.6.1 *Life Safety*

6.6.1.1 Open air mercantile operations, such as open air markets, petrol filling stations, roadside stands for the sale of a farm produce and other outdoor mercantile operations shall be so arranged and conducted as to maintain free and unobstructed ways of travel at all times to permit prompt escape from any point of danger in case of fire or other emergency, but no dead-ends in which persons might be trapped due to display stands, adjoining buildings, fences, vehicles or other obstructions.

6.6.1.2 If such mercantile operations are conducted in roofed-over areas, these shall be treated as mercantile buildings, provided canopies over individual small stands to protect merchandise from the weather shall not be construed to constitute buildings for the purpose of the Code.

6.6.2 *Exception and Deviation*

Any mercantile occupancy, where goods of a highly hazardous nature are predominant, shall be considered under Group J occupancy for the purpose of the Code.

6.7 Industrial Buildings (Group G)

6.7.1 *Fire Prevention*

6.7.1.1 *Fire separating walls, fire separating floors and fire partitions*

Fire separating walls shall be provided between two buildings or between two blocks inside a building, having different fire hazards in accordance with the provisions of this Part. The areas having storage, manufacturing, hazardous activities such as paint store, oil storage, spray booths, etc, shall be separated from non-hazardous areas like administrative office, staff canteen, etc by fire rated walls/doors of 120 min fire resistance rating. The fire resistance rating of high hazardous areas like petrochemical, explosives shall be 240 min.

The fire separating wall where provided shall comply with the following requirements:

a) The separating wall shall be carried through the roof. This portion of the wall extending above the roof, known as 'screen wall' shall be of such a height (in no case less than 600 mm) that the horizontal distance at the level of the top of the screen wall between the roofs of the buildings/compartments being segregated is at least 6 m.

b) The screen wall shall be of not less than 230 mm in thickness if it is an extension of a masonry wall, and not less than 150 mm in thickness if it is an extension of a reinforced concrete wall.

c) The separating wall need not be extended as a screen wall if the roof of one or both of the buildings/blocks being segregated is of reinforced concrete construction (RCC).

d) In the case of buildings of unequal height, windows or other openings in the wall of the higher building overlooking the roof of the lower building and within 6 m, thereof, shall be protected by fire resistant glass assembly or by approved type fire doors unless the roof of the lower building is of reinforced concrete.

e) In case the eaves of the higher building fall within 6 m of the roof of the lower building such eaves should be cut-off and the screen wall raised as a parapet, 600 mm high over the roof of the higher building, unless the roof of the lower building is of RCC construction.

f) Fire separating walls shall also be extended outwards on both sides by at least 450 mm.

g) Doors and window openings in external walls within 3 m of the fire separating walls shall be protected by fire doors having a rating of at least 60 min and window openings may be protected by fire resistant glass assembly having same fire rating.

h) In the case of buildings/compartments having north-light roofs when a separating wall runs parallel to the axis of the north-light opening, the screen wall shall be carried through and 600 mm above the ridge of the north light. If, however, the separating wall is at right angles to the axis of the north-light opening, the saw tooth gaps shall be bricked up and the screen wall extended 600 mm above the ridge of the north light as well as beyond the extreme north-light opening.

j) Similarly, the thickness of the floor slabs in case of buildings having upper levels shall be designed to provide fire rating as mentioned above.

k) Storage areas shall be separated from the remainder of the building/block by fire walls.

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m) Moderate and high hazard areas in industries to have two fire doors each having 180 min fire resistance rating.

6.7.2 *Life Safety*

6.7.2.1 In buildings used for aircraft assembly or other occupancy requiring undivided floor areas so large that the distances from points within the area to the nearest outside walls where exit doors could be provided are in excess of 45 m, requirements for distance to exits may be satisfied by providing stairs leading to exit tunnels or to overhead passageways. In cases where such arrangements are not practicable, the Authority may, by special ruling, permit other exit arrangements for single storeyed buildings with distances in excess of the maximum distances specified in **4**, if completely automatic sprinkler protection is provided and if the heights of ceiling curtain boards and roof ventilation are such as to minimise the possibility that employees will be overtaken by the spread of fire or smoke within 1.8 m of the floor level before they have time to reach exits, provided, however, that in no case may the distance of travel to reach the nearest exit exceed 65 m where smoke venting is required as a condition for permitting distances of travel to exits in excess of the maximum otherwise allowed.

6.7.2.2 The following shall apply to special purpose industrial occupancies:

a) Exits need be provided only for the persons actually employed; spaces not subject to human occupancy because of the presence of machinery or equipment may be excluded from consideration.

b) Where unprotected vertical openings are necessary to manufacturing operations, these may be permitted beyond the limits specified for industrial occupancy, provided every floor level has direct access to one or more enclosed stairways or other exits protected against obstruction by any fire in the open areas connected by the unprotected vertical openings or smoke therefrom.

6.7.2.3 The following shall apply to high hazard industrial occupancies:

a) From every point in every floor area, there shall be at least two exits accessible in different directions; where floor areas are divided into rooms, there shall be at least two ways of escape from every room, however small rooms, except toilet rooms, so located that the points of access thereto are out of or suitably shielded from areas of high hazard.

b) In addition to types of exits for upper floors specified for Group G occupancies, slide escapes may be used as required exits for both new and existing buildings.

NOTE — All high hazard industrial occupancies shall have automatic sprinkler protection or such other protection as may be appropriate to the particular hazard, including explosion venting for any area subject to explosion hazard, designed to minimise danger to occupants in case of fire or other emergency before they have time to utilize exits to escape.

6.7.3 *Additional Precautions*

a) In any room in which volatile flammable substances are used or stored, no device generating a glow or flame capable of igniting flammable vapour shall be installed or used, such a room shall be provided with a suitably designed exhaust ventilation system (*see* Annex M).

b) For detailed information on fire safety of certain individual (specific) industrial occupancies, reference may be made to good practice [4(28)].

c) Fire protection considerations for venting industrial occupancies shall be as in Annex M.

6.8 Storage Buildings (Group H)

6.8.1 *Life Safety*

6.8.1.1 Every area used for the storage of hazardous commodities shall have an exit within 22.5 m of any point in the area where persons may be present or 35 m where automatic sprinkler protection is provided.

6.8.1.2 Every storage area or space exceeding 1 400 m^2 gross area, or where more than 10 persons may be normally present shall have at least two exit access doors leading to the corridors in exit access, which can be readily opened. This shall not be subject to locking so long as any persons are inside and shall not depend on power operation. Exits in such cases shall be as remote from each other as practicable.

For warehouses, natural draft smoke venting shall utilize roof vents or vents in walls at or near the ceiling level; such vents shall be normally open, or, if closed, shall be designed for automatic opening in case of fire, by release of smoke sensitive devices.

6.8.1.3 The following special provisions shall apply to aircraft hangers:

a) Exits from aircraft hangers (storage or servicing areas) shall be provided at intervals of not more than 45 m on all exterior walls of aircraft hangers. There shall be a minimum of two exits serving each aircraft storage or servicing areas. Horizontal exits through interior fire walls shall be provided at intervals of not more than 30 m. 'Dwarf' or 'smash'

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doors accommodating aircraft may be used to comply with these requirements. All doors designated as exits shall be kept unlocked in the direction of exit travel while the area is occupied.

b) Exits from mezzanine floors in aircraft storage or servicing areas shall be so arranged that the maximum travel to reach the nearest exits from any point on the mezzanine shall not exceed 22.5 m. Such exits shall lead directly to a properly enclosed stairwell discharging directly to the exterior or to a suitably cut-off area or to outside fire escape stairs.

6.8.1.4 The following special provisions shall apply to grain elevators:

a) There shall be at least one stair tower from basement to first floor and from the first floor to the top floor of workhouse which is enclosed in a dust tight non-combustible shaft.

b) Non-combustible doors of self-closing type shall be provided at each floor landing.

c) An exterior fire escape of the stair or basket ladder type shall be provided from the roof of the workshop to ground level or the roof of an adjoining annexe with access from all floors above the first.

d) An exterior fire escape of either the stair or basket ladder type shall be provided from the roof of each storage annexe to ground level.

6.8.1.5 For provisions relating to car parking facilities, *see* Annex H.

6.8.2 *Additional Precautions*

Requirements specified in **6.7.3** (a) shall apply to Group H occupancies also.

6.9 Hazardous Uses (Group J)

6.9.1 *Life Safety*

Requirements specified in **6.7.2.3** shall apply to Group J occupancies also.

6.9.2 *Additional Precautions*

The following requirements shall apply to all Group J occupancies, as applicable:

a) Hazardous buildings shall have vapour/flame/ember/spark detectors and explosion suppression systems depending on the type of fire hazard involved.

b) Each building where gas is employed for any purpose shall be provided with an approved outside gas shut-off valve conspicuously marked. The detailed requirements regarding safe use of gas shall be as specified in Part 9 'Plumbing Services, Section 4 Gas Supply' of the Code.

c) Each boiler room or room containing a heating plant shall be separated from the rest of the building by a separating wall.

d) In any room in which volatile flammable substances are used or stored, no device generating a spark, or glow flame capable of igniting flammable vapour shall be installed or permitted unless it is enclosed in a flameproof enclosure.

e) The use, handling, storage and sale of gasoline, fuel oil and other flammable liquids shall not be permitted in Group J occupancies unless such use, handling, storage and sale is in accordance with appropriate legislation in force.

f) All openings in exterior walls except wall vents shall be protected by a fire stop assembly as in **4** and they shall be fixed, automatic or self-closing. Wall vents having an area of not less than 100 cm^2 each shall be placed in the exterior walls near the floor line, not more than 1 800 mm apart horizontally. Each building shall be provided with a power driven fan exhaust system of ventilation which shall be arranged and operated so as to produce a complete change of air in each room every 3 min.

g) Each machine in dry-cleaning establishments which uses flammable liquid shall have an adequate steam line or any other suitable extinguishing agent directly connected to it, so arranged as to have the agent automatically released to the inside of each machine should an explosion occur in the machine.

h) Equipment or machinery which generates or emits combustible or explosive dust or fibres shall be provided with an adequate dust collecting and exhaust system.

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ANNEX A

(*Clause* 3.1.8)

CALORIFIC VALUES OF COMMON MATERIALS

A-1 The calorific values of some common materials are given in Table 9 for guidance.

Table 9 Calorific Values of Common Materials
(*Clause* A-1)

Sl No.	Material	Calorific Value ($\times 10^3$ kJ/kg)[1)]	Wood Equivalent (kg/kg)
(1)	(2)	(3)	(4)
i)	Solid Fuels		
	a) Anthracite	28.6	1.66
	b) Bituminous coal	30.8	1.75
	c) Charcoal	28.4	1.61
	d) Coke (average)	27.5	1.56
	e) Peat	20.9	1.19
	f) Sub-bituminous coal	22.0	1.25
	g) Woods (hard or softwood)	17.6	1.00
ii)	Hydrocarbons		
	a) Benzene	39.6	2.25
	b) Butane	47.1	2.68
	c) Ethane	49.1	2.79
	d) Ethylene	47.7	2.71
	e) Fuel oil	41.6	2.36
	f) Gas oil	42.9	2.44
	g) Hexane	44.9	2.55
	h) Methane (natural gas)	52.8	3.00
	j) Octane	45.3	2.58
	k) Paraffin	39.6-44.0	2.3-2.5
	m) Pentane	46.0	2.61
	n) Propane	47.3	2.69
	p) Propylene	46.2	2.63
iii)	Alcohols		
	a) Ethyl alcohol	28.4	1.61
	b) Methyl alcohol	21.1	1.20
	c) Propyl alcohol	31.9	1.81
iv)	Polymers		
	a) Casein	23.1	1.31
	b) Cellulose	16.5	0.94
	c) Cellulose acetate	17.8	1.01
	d) Polyethylene	48.4	2.75
	e) Polypropylene	48.4	2.75
	f) Polystyrene	41.8	2.38
	g) Polyvinylchloride	20.9	1.19
	h) Polymethyl methacrylate	24.6	1.40
	j) Polyurethane	35.2	2.00
	k) Polyamide (nylon)	22.0	1.25
	m) Polyester	22.0	1.25
v)	Common Solids		
	a) Asphalt	38.3	2.13
	b) Bitumen	33.4	1.90
	c) Carbon	32.1	1.83
	d) Cotton (dry)	15.8	0.90
	e) Flax	14.3	0.81
	f) Furs and skins	18.7	1.06
	g) Hair (animal)	20.9	1.19
	h) Leather	17.6	1.00
	j) Ozokerite (wax)	43.3	2.46
	k) Paper (average)	15.4	0.88
	m) Paraffin wax	40.9	2.33
	n) Pitch	33.0	1.88
	p) Rubber	37.4	2.13
	q) Straw	13.2	0.75
	r) Tallows	37.6	2.14
	s) Tan bark	20.9	1.19
	t) Tar (bituminous)	35.2	2.00
	u) Wool (raw)	21.6	1.23
	w) Wool (scoured)	19.6	1.11
vi)	Foodstuffs		
	a) Barley	14.1	0.80
	b) Bran	11.0	0.63
	c) Bread	9.9	0.56
	d) Butter	29.5	1.68
	e) Cheese (cheddar)	18.1	1.03
	f) Corn meal	14.1	0.80
	g) Flour	14.1	0.80
	h) Margarine	29.5	1.68
	j) Oatmeal	15.8	0.90
	k) Rice	13.9	0.79
	m) Soya been flour	16.1	0.91
	n) Sugar	15.4	0.88
	p) Whole wheat	14.3	0.81
vii)	Miscellaneous		
	a) Acetone	29.7	1.69
	b) Acetaldehyde	25.1	1.43
	c) Formaldehyde	17.6	1.00
	d) Hydrogen	134.2	7.63
	e) Magnesium	24.0	1.36

[1)] 1 kJ is approximately equal to 1 Btu so the figures in the tables are also equivalent to Btu/kg.

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ANNEX B

(*Clause* 3.1.8)

BROAD CLASSIFICATION OF INDUSTRIAL OCCUPANCIES INTO DIFFERENT DEGREE OF HAZARD

Light Hazard	Moderate Hazard	High Hazard
Abrasive Manufacturing Premises	Aluminium Factories	**SUB-CATEGORY (A)**
Aerated Water Factories	*Atta* and Cereal Grinding	Aircraft Hangers
Agarbatti Manufacturing	Bakeries and Biscuit Factories	Aluminium/Magnesium Powder Plants
Areca Nut Slicing and/or Betel nut Factories	*Beedi* Factories	Bituminised Paper and/or Hessian Cloth/Tar Felt Manufacturing
Analytical and/or Quality Control Laboratories	Bobbin Factories	Cotton Waste Factories
Asbestos Steam Packing and Lagging Manufacturing	Bookbinders, Envelopes and Paper Bag Manufacturing	Celluloid Goods Manufacturing
Battery Charging/Battery Service Stations	Cable Manufacturing	Chemical Manufacturing using raw materials having flash points below 23°C
Battery Manufacturing	Camphor Boiling	Cigarette Filter Manufacturing
Breweries	Candle Works	Cinema Films and T.V. Production Studios
Brick Works	Carbon Paper/Typewriter Ribbon Manufacturing	Coal and/or Coke and/or Charcoal Ball and Briquettes Manufacturing
Canning Factories	Cardboard Box Manufacturing	Collieries
Cardamom Factories	Carpenters, Wood Wool and Furniture Manufacturing	Cotton Seed Cleaning or De-linting Factories.
Cement Factories and/or Asbestos or Concrete Products Manufacturing	Carpet and Durries Factories	Distilleries
Ceramic Factories and	Cashewnut Factories	Duplicating/Stencil Paper Manufacturing
Crockery and Stoneware Pipe Manufacturing	Chemical Manufacturing using raw materials having flash points above 23°C	Fire-works Manufacturing.
Clay Works	Cigar and Cigarette Factories	Foam Plastics Manufacturing and/or Converting Plants.
Clock and Watch Manufacturing	Coir Factories	Godowns and Warehouses (Storing Combustible/Flammable Goods).
Coffee Curing Roasting and Grinding Premises	Coir Carpets, Rugs, Tobacco, Hides and Skin Presses	Grass, Hay, Fodder and *Bhoosa* (chaff) Pressing Factories
Condensed Milk Factories, Milk Pasteurising Plant and Dairies	Cold Storage Premises	Industrial Gas Manufacturing (Other than Inert/Halogenated Hydrocarbon Gases)
Confectionery Manufacturing	Cork Products Manufacturing	Jute Mills and Jute Presses
Electric Generating Houses (Hydro electric)	Dry Cleaning, Dyeing and Laundries.	Linoleum Factories
Electric Lamps (Incandescent and Fluorescent) and TV Picture Tube Manufacturing	Electric Substations/Distribution Stations	LPG Bottling Plants (Mini)
Electro Plating Works	Electric Generating Stations (Other than Underground Power houses)	Man Made Fibres (Acrylic Fibres/yarn Manufacturing)
Engineering Workshops	Enamelware Factories	Match Factories
	Filter and Wax Paper Manufacturing	
	Flour Mills	

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Light Hazard	Moderate Hazard	High Hazard
Fruits and Vegetables Dehydrating and Drying Factories	Garages	Mattress and Pillow Making
Fruit Products and Condiment Factories	Garment Makers	Metal or Tin Printers (where more than 50 Percent of floor area is occupied as Engineering Workshop; this may be taken as ordinary hazard risk)
Glass and Glass Fibre Manufacturing	Ghee Factories (Other than Vegetable)	Oil Mills
Godowns and Warehouses Storing Non-combustible Goods only	Godowns and Warehouses (Other than those Under Light and High Hazard A Categories)	Oil Extraction Plants
Green Houses	Grain and/or Seeds Disintegrating and/or Crushing Factories	Oil Terminals/Depots handling flammable Liquids having flash point of 23° C and Below
Gold Thread/Gilding Factories	Grease Manufacturing	Paints and Varnish Factories
Gum and/or Glue and Gelatine Manufacturing	Hosiery, Lace, Embroidery and Thread Factories	Paper and Cardboard Mills having raw material yards
Ice, Ice Candy and Ice-cream Manufacturing	Incandescent Gas Mantle Manufacturing	Piers, Wharves and Jetties – Handling Extra Hazardous Materials
Ink (Excluding Printing Ink) Factories	Industrial Gas Manufacturing (Inert/Halogenated hydrocarbon gases)	Printing Ink Manufacturing.
Mica Products Manufacturing	Man-made Yarn/Fibre Manufacturing (Other than Acrylic Fibres/Yarn Manufacturing)	Rosin Lamp-Black and Turpentine Factories
Pottery Works	Manure and Fertilizer Works (Blending, Mixing and granulating)	Saw Mills
Poultry Farms	Mineral Oil Blending and Processing	Sponge Iron Steel Plants (Gas Based)
Salt Crushing Factories and Refineries	Oil and Leather Cloth Factories	Surgical Cotton Manufacturing
Stables	Oil Terminals/Depots Other than those Categorised under High Hazard A	Tarpaulin and Canvas Proofing Factories
Sugar Candy Manufacturing	Open storage of Flammable Liquids in Drums, Cans, etc	Turpentine and Rosin Distilleries
Sugar Factories and Refineries	Oxygen Plants	Tyre Retreading and Resoling Factories
Tanneries/Leather Goods Manufacturers	Paper and Cardboard Mills. without Raw Material Yards	**SUB-CATEGORY (B)**
Umbrella Assembling Factories	Piers, Wharves, Jetties and Dockyards other than those Categorized Under High Hazard A	Ammonia and Urea Synthesis Plants
Vermicelli Factories	Plastic Goods Manufacturing	CNG Compressing and Bottling Plants
Water Treatment/Filtration Plants and Water Pump Houses	Plywood/Wood Veneering Factories	Coal Based Methane Plants
Zinc/Copper Factories	Printing Press Premises	Explosive Factories
		NOTE — In case of complexes having separate plants having varying degrees of hazard, authority having jurisdiction shall be consulted to decide on level of protection to be provided.

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Light Hazard	Moderate Hazard	High Hazard
	Pulverising and Crushing Mills	
	Rice Mills	
	Rope Works	
	Rubber Goods Manufacturing	
	Rubber Tyres and Tubes Manufacturing	
	Shellac Factories	
	Silk Filiatures	
	Soaps and Glycerine Factories	
	Spray Painting	
	Starch Factories	
	Tea Factories	
	Textile Mills	
	Tobacco (Chewing) and Pan-Masala Making	
	Tobacco Grinding and Crushing	
	Tobacco Redrying Factories	
	Woollen Mills	

NOTE — Any occupancy that is not covered in this annex shall be classified in the most appropriate class which resembles the proposed occupancy.

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ANNEX C

(*Clauses* 3.3.2 *and* 3.3.3)

AVAILABLE DATA REGARDING FIRE RESISTANCE RATING OF VARIOUS BUILDING COMPONENTS

Table 10 Masonry Walls: Solid (Required to Resist Fire from One Side at a Time)

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (min) of									
		Load Bearing					Non-load Bearing				
		60	90	120	180	240	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	Reinforced cement concrete[1)]	120 (25)[2)]	140 (25)[2)]	160 (25)[2)]	200 (25)[2)]	240 (25)[2)]	—	—	—	—	—
ii)	Unreinforced cement concrete	150	175	—	—	—	—	—	—	—	—
iii)	No-fines concrete with:										
	a) 13 mm cement/sand or gypsum/sand	—	—	—	—	—	150	150	150	150	150
	b) 13 mm light weight aggregate gypsum plaster	—	—	—	—	—	150	150	150	150	150
iv)	Bricks of clay:										
	a) Without finish	90	100	100	170	170	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
v)	Bricks of sand lime:										
	a) Without finish	90	100	100	190	190	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	90	90	90	100
vi)	Blocks of concrete:										
	a) Without finish	90	100	100	—	—	75	90	100	140	150
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	75	75	75	90	100
	c) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	75	90	90	100	140
vii)	Blocks of lightweight concrete:										
	a) Without finish	90	100	100	140	150	75	75	75	125	140
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	90	100	100	50	63	75	75	75
	c) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	75	75	75	90	100
viii)	Blocks of aerated concrete:										
	a) Without finish	90	100	100	140	180	50	63	63	75	100
	b) With 13 mm lightweight aggregate gypsum plaster	90	90	100	100	150	—	—	—	—	—

[1)] Walls containing at least 1 percent of vertical reinforcement.

[2)] Minimum thickness of actual cover to reinforcement.

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Table 11 Masonry Walls: Hollow (Required to Resist Fire from One Side at a Time)
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm), Excluding any Finish for a Fire Resistance (Min) of										
		Load Bearing					Non-load Bearing					
		60	90	120	180	240	30	60	90	120	180	240
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	Bricks of clay:											
	a) Without finish	170	170	170	200	200	75	75	90	100	170	170
	b) With 13 mm lightweight aggregate gypsum plaster	100	100	170	170	170	75	75	90	90	90	100
ii)	Blocks of concrete:											
	a) Without finish	—	—	—	—	—	90	125	125	140	140	150
	b) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	90	125	125	140	140	140
	c) With 13 mm lightweight aggregate gypsum plaster	190	200	200	—	—	75	90	90	100	125	125
iii)	Blocks of lightweight concrete:											
	a) Without finish	100	100	100	—	—	75	90	90	100	140	150
	b) With 13 mm cement/sand or gypsum/sand	—	—	—	—	—	75	75	75	100	140	140
	c) With 13 mm lightweight aggregate gypsum plaster	—	—	—	—	—	63	63	63	75	90	100

Table 12 Framed Construction, Load Bearing (Required to Resist Fire from One Side at a Time)
(*Clause* C-1)

Sl No.	Nature of Construction and Materials/Timber Studs at Centres not Exceeding 600 mm, Faced on Each Side with	Minimum Thickness (mm) of Protection for a Fire Resistance of 60 min
(1)	(2)	(3)
i)	Plasterboard layers with joints staggered, joints in outer layer taped and filled – Total thickness for each face	25
ii)	One layer of 12.7 mm plasterboard with a finish of lightweight aggregate gypsum plaster	13
iii)	Metal lath and plaster, thickness of plaster:	
	a) Sanded gypsum plaster (metal lathing grade)	22
	b) Lightweight aggregate gypsum plaster	13

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Table 13 Framed Construction, Non-Load Bearing (Required to Resist Fire from One Side at a Time)
(*Clause* C-1)

Sl No.	Nature of Construction and Materials/Steel or Timber Frame at Centres not Exceeding 600 mm, Facings on Both Sides of	Stud Construction	Minimum Thickness (mm) of Protection for a Fire Resistance of			
			30 min	60 min	90 min	120 min
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Dry lining with materials fixed direct to studs, without plaster finish:					
	a) One layer of plasterboard with taped and filled joints	Timber or steel	12.7	—	—	—
	b) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled – Total thickness for each face	Timber or steel	19	25	—	—
	c) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	Timber or steel	9	12	—	—
	d) One layer of wood wool slabs	Timber	25	—	—	—
	e) One layer of chipboard or of plywood	Timber or steel	18	—	—	—
ii)	Lining with materials fixed direct to suds, with plaster finish:					
	a) Plasterboard of thickness:					
	1) With not less than 5 mm gypsum plaster finish	Timber or steel	9.5	—	—	—
	2) With not less than 13 mm gypsum plaster finish	Timber or steel	—	12.7	—	—
iii)	Wet finish:					
	a) Metal lath and plaster, thickness of plaster:					
	1) Sanded gypsum plaster	Timber or steel	13	—	—	—
	2) Lightweight aggregate gypsum plaster	Timber	—	13	19	25
		Steel	—	13	—	—

Table 14 Framed External Walls Load Bearing
(Required to Resist Fire from One Side at a Time)
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 60 min
(1)	(2)	(3)
i)	Timber studs at centres not exceeding 600 mm with internal linings of: Plasterboard layers with joints in outer layer taped and filled, total thickness of plasterboard	31

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Table 15 Framed External Walls Non-Load Bearing [Required to Resist Fire from Inside the Building (A)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of					
		30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Steel frame with an external cladding of non-combustible sheets (excluding sheet steel), with a steel supporting framework and internal lining of:						
	a) Metal lath and plaster, thickness of plaster:						
	1) Sanded gypsum plaster (metal lathing grade)	13	13	—	—	—	—
	2) Lightweight aggregate gypsum plaster	10	13	15	15	15	19
	b) Two layer of plasterboard with joints staggered joints in outer layer taped and filled – Total thickness	21	32	—	—	—	—
	c) Plasterboard of thickness:						
	1) With not less than 5 mm gypsum plaster finish	12.7	—	—	—	—	—
	2) With not less than 13 mm gypsum plaster finish	9.5	—	—	—	—	—
	3) With not less than 10 mm lightweight aggregate gypsum plaster	9.5	—	—	—	—	—
	d) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9	9	12	12	12	12
	e) One layer of wood/wool slabs without finish	—	50	—	—	—	—
	f) One layer of compressed straw building slabs:						
	1) Without finish	50	—	—	—	—	—
	2) With not less than 5 mm gypsum plaster finish	—	50	—	—	—	—
	g) Aerated concrete blocks	50	50	63	63	75	100
	h) Bricks of clay:						
	1) Without finish	75	75	90	90	100	100
	2) With not less than 13 mm lightweight aggregate gypsum plaster	—	—	75	75	90	90

Table 16 Framed External Walls Non-Load Bearing [Required to Resist Fire from Inside the Building (B)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection to provide Sufficient Insulation to Achieve a Modified Fire Resistance of Up to 240 min
(1)	(2)	(3)
i)	Steel frame with an external cladding of sheet steel fully lapped, steel bolted and fixed to steel sheeting rails, with timber or steel supporting framework and internal lining of:	
	a) Metal lath and plaster, thickness of plaster:	
	1) Sanded gypsum plaster (metal lathing grade)	13
	2) Lightweight aggregate gypsum plaster	10
	b) One layer of plasterboard with joints taped and filled	12.7
	c) Plasterboard of thickness with not less than 5 mm gypsum plaster finish	9.5
	d) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick, or by timber	9
	e) One layer of wood/wool slabs	25
	f) One layer of compressed straw building slabs	50
	g) One layer of chipboard or of plywood	18
	h) Aerated concrete blocks	50
	j) Bricks of clay	75
	k) Any internal decorative lining with a cavity fill independently supported and retained in position of mineral fibre insulating material (excluding glass) at a density of 48 kg/m^3	50

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Table 17 Framed Walls Non-Load Bearing [Required to Resist Fire from Inside the Building (C)]

(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of 90 min
(1)	(2)	(3)
i)	Timber frame with external cladding of weather boarding or external plywood, 9.5 mm with an internal lining of :	
	a) Plasterboard not less than 9.5 mm thick, finished with:	
	1) Gypsum plaster	13
	2) Lightweight aggregate gypsum plaster	10
	b) Plasterboard not less than 12.7 mm thick, finished with:	
	1) Gypsum plaster	10
	2) Lightweight aggregate gypsum plaster	10
	c) One layer of asbestos insulating board with transverse joints backed by fillers of asbestos insulating board not less than 9 mm thick,	9
	or by timber	12

Table 18 Reinforced Concrete Columns

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Fully exposed	a) Width	150	200	250	300	400	450
		b) Cover	40	40	40	40	40	40
ii)	50 percent exposed	a) Width	125	160	200	200	300	350
		b) Cover	40	40	40	40	40	40
iii)	One face exposed	a) Thickness	100	120	140	160	200	240
		b) Cover	40	40	40	40	40	40

Table 19 Concrete Beams

(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Width	200	200	200	200	240	280
		b) Cover	20	20	20	40	60[1)]	70[1)]
ii)	Reinforced concrete (continuous)	a) Width	200	200	200	200	240	280
		b) Cover	20	20	20	30	40	50[1)]
iii)	Prestressed concrete (simply supported	a) Width	100	120	150	200	240	280
		b) Cover	25	40	55[1)]	70[1)]	80[1)]	90[1)]
iv)	Prestressed concrete (continuous)	a) Width	80	100	120	150	200	240
		b) Cover	20	30	40	55[1)]	70[1)]	80[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

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Table 20 Concrete Floors
(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Thickness	75	95	110	125	150	170
		b) Cover	20	20	25	35	45[1)]	55[1)]
ii)	Reinforced concrete (continuous)	a) Thickness	75	95	110	125	150	170
		b) Cover	20	20	20	25	35	45[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 21 Concrete Floors: Ribbed Open Soffit
(*Clause* C-1)

Sl No.	Nature of Construction and Materials		Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of					
			30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Reinforced concrete (simply supported)	a) Thickness of floor	75	95	110	125	150	170
		b) Rib width	125	125	125	125	150	175
		c) Cover	20	20	35	45[1)]	55[1)]	65[1)]
ii)	Reinforced concrete (continuous)	a) Thickness of floor	75	95	110	125	150	170
		b) Rib width	125	125	125	125	150	175
		c) Cover	20	20	20	35	45[1)]	55[1)]

[1)] Require attention to the additional measures necessary to reduce the risk of spalling.

Table 22 Encased Steel Columns, 203 mm × 203 mm
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Dimensions (mm) Excluding any Finish, for a Fire Resistance of				
		60 min	90 min	120 min	180 min	240 min
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Hollow protection (without an air cavity over the flanges):					
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster[1)]	13	15	20	32	—
	b) Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:					
	1) 9.5 mm plaster board	10	15	—	—	—
	2) 19 mm plaster board	10	13	20	—	—
	c) Asbestos insulating boards, thickness of board:					
	1) Single thickness of board, with 6 mm cover fillets at transverse joints	—	19	25	—	—
	2) Two layers, of total thickness	—	—	—	38	50
	d) Solid bricks of clay, composition or sand lime, reinforced in every horizontal joint, unplastered	50	50	50	75	100
	e) Aerated concrete blocks	60	60	60	—	—
	f) Solid blocks of lightweight concrete	50	50	50	60	75
	Hollow protection (with an air cavity over the flanges)					

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Table 22 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
ii)	Asbestos insulating board screwed to 25 mm asbestos battens	12	19	—	—	—
iii)	Solid protections:					
	a) Concrete, not leaner than 1:2:4 mix (unplastered):					
	1) Concrete not assumed to be load bearing, reinforced[2)]	25	25	25	50	75
	2) Concrete assumed to be load bearing	50	50	50	75	75
	b) Lightweight concrete, not leaner than 1:2:4 mix (unplastered): concrete not assumed to be load bearing, reinforced[2)]	25	25	25	40	60

[1)] So fixed or designed, as to allow full penetration for mechanical bond.
[2)] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

Table 23 Encased Steel Beams, 406 mm × 176 mm (Protection Applied on Three Sides)
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of					
		30 min	60 min	90 min	120 min	180 min	240 min
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Hollow protection (without an air cavity beneath the lower flange):						
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster[1)]	13	13	15	20	25	—
	b) Plasterboard with 1.6 mm wire binding[2)] at 100 mm pitch, finished with lightweight aggregate gypsum plaster not less than the thickness specified:						
	1) 9.5 mm plaster board	10	10	15	—	—	—
	2) 19 mm plaster board	10	10	13	20	—	—
	c) Asbestos insulating boards, thickness of board :						
	1) Single thickness of board, with 6 mm cover fillets at transverse joints	—	—	19	25	—	—
	2) Two layers, of total thickness	—	—	—	—	38	50
ii)	Hollow protection (with an air cavity below the lower flange):						
	a) Asbestos insulating board screwed to 25 mm asbestos battens	9	12	—	—	—	—
iii)	Solid protection :						
	a) Concrete, not leaner than 1:2:4 mix (unplastered):						
	1) Concrete not assumed to be load bearing, reinforced[3)]	25	25	25	25	50	75
	2) Concrete assumed to be load bearing	50	50	50	50	75	75
	b) Lightweight concrete[4)], not leaner than 1:2:4 (mix) unplastered	25	25	25	25	40	60

[1)] So fixed or designed, as to allow full penetration for mechanical bond.
[2)] Where wire binding cannot be used, expert advice should be sought regarding alternative methods of support to enable the lower edges of the plasterboard to be fixed together and to the lower flange, and for the top edge of the plasterboard to be held in position.
[3)] Reinforcement shall consist of steel binding wire not less than 2.3 mm in thickness or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.
[4)] Concrete not assumed to be load bearing, reinforced.

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Table 24 Timber Floors – Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 21 mm Finished Thickness
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection, for a Fire Resistance of		
		30 min	60 min	120 min
(1)	(2)	(3)	(4)	(5)
i)	37 mm (minimum) timber joists with a ceiling of:			
	a) Timber lathing and plaster, plaster of thickness	15	—	—
	b) Metal lathing and plaster, thickness of plaster:			
	1) Sanded gypsum plaster (metal lathing grade)	15	—	—
	2) Lightweight aggregate gypsum plaster	13	13	25
	c) One layer of plasterboard with taped and filled joints	12.7	—	—
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	19	31	—
	e) One layer of plasterboard not less than 9.5 mm thick, finished with:			
	1) Gypsum plaster	5	—	—
	2) Sanded gypsum plaster	13	—	—
	3) Lightweight aggregate gypsum plaster	13	—	—
	f) One layer of plasterboard not less than 12.7 mm thick, finished with:			
	1) Gypsum plaster	5	—	—
	2) Lightweight aggregate gypsum plaster	10	—	—
	g) One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12	—

Table 25 Timber Floors – Tongued and Grooved Boarding, or Sheets of Tongued and Grooved Plywood or Wood Chipboard, of not Less than 15 mm Finished Thickness
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection for a Fire Resistance of		
		30 min	60 min	120 min
(1)	(2)	(3)	(4)	(5)
i)	37 mm (minimum) timber joists with a ceiling of:			
	a) Timber lathing and plaster, plaster of thickness	15	—	—
	b) Metal lathing and plaster, thickness of plaster for:			
	1) Sanded gypsum plaster (metal lathing grade)	15	—	—
	2) Lightweight aggregate gypsum plaster	13	13	25
	c) One layer of plasterboard with taped and filled joints	12.7	—	—
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	22	31	—
	e) One layer of plasterboard not less than 9.5 mm thick, finish with:			
	1) Gypsum plaster	5	—	—
	2) Sanded gypsum plaster	15	—	—
	3) Lightweight aggregate gypsum plaster	13	—	—
	f) One layer of plasterboard not less than 12.7 mm thick, finished with:			
	1) Gypsum plaster	5	—	—
	2) Lightweight aggregate gypsum plaster	10	—	—
	g) One layer of asbestos insulating board, with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	9	12[1)]	—

[1)] Finished on top with 25 mm minimum thick glass fibre or mineral wool laid between joints.

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Table 26 Timber Floors – Any Structurally Suitable Flooring of Timber or Lignocelluloses Boards
(*Clause* C-1)

Sl No.	Nature of Construction and Materials	Minimum Thickness (mm) of Protection, for a Fire Resistance of	
		30 min	60 min
(1)	(2)	(3)	(4)
i)	37 mm (minimum) timber joists with a ceiling of:		
	a) Timber lathing and plaster, plaster of thickness	15	—
	b) Metal lathing and plaster, thickness of plaster for :		
	1) Sanded gypsum plaster (metal lathing grade)	15	—
	2) Lightweight aggregate gypsum plaster	13	19
	c) One layer of plasterboard with joints taped and filled and backed by timber	12.7	—
	d) Two layers of plasterboard with joints staggered, joints in outer layer taped and filled total thickness	25	—
	e) Two layers of plasterboard, each not less than 9.5 mm thick, joints between boards staggered and outer layer finished with gypsum plaster	5	—
	f) One layer of plasterboard not less than 9.5 mm thick, finish with :		
	1) Sanded gypsum plaster	13	—
	2) Lightweight aggregate gypsum plaster	15	—
	g) One layer of plasterboard not less than 12.7 mm thick, finished with :		
	1) Sanded gypsum plaster	15	—
	2) Lightweight aggregate gypsum plaster	13	—
	h) One layer of asbestos insulating board with any transverse joints backed by fillets of asbestos insulating board not less than 9 mm thick, or by timber	12	—

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ANNEX D

(*Clause* 4.11)

GUIDELINES FOR FIRE DRILL AND EVACUATION PROCEDURES FOR HIGH RISE BUILDINGS

D-1 INTRODUCTION

In case of fire in a high rise building, safe evacuation of its occupants may present serious problems unless a plan for orderly and systematic evacuation is prepared in advance and all occupants are well drilled in the operation of such plan. These guidelines are intended to assist them in this task.

D-2 ALARMS

Any person discovering fire, heat or smoke shall immediately report such condition to the fire brigade, unless he has personal knowledge that such a report has been made. No person shall make, issue, post or maintain any regulation or order, written or verbal, that would require any person to take any unnecessary delaying action prior to reporting such condition to the fire brigade.

D-3 DRILLS

D-3.1 Fire drills shall be conducted, in accordance with the Fire Safety Plan, at least once every three months for buildings during the first two years. Thereafter, fire drills shall be conducted at least once every six months.

D-3.2 All occupants of the building shall participate in the fire drill. However, occupants of the building, other than building service employees, are not required to leave the floor or use the exits during the drill.

D-3.3 A written record of such drills shall be kept on the premises for a three years period and shall be readily available for fire brigade inspection.

D-4 SIGNS AND PLANS

D-4.1 Signs at Lift Landings

A sign shall be posted and maintained in a conspicuous place on every floor at or near the lift landing in accordance with the requirements, indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall contain a diagram showing the location of the stairways except that such diagram may be omitted, provided signs containing such diagram are posted in conspicuous places on the respective floor.

A sign shall read 'IN CASE OF FIRE, USE STAIRS UNLESS INSTRUCTED OTHERWISE'. The lettering shall be at least 12.5 mm block letters in red and white background. Such lettering shall be properly spaced to provide good legibility. The sign shall be at least 250 mm × 300 mm, where the diagram is also incorporated in it and 62.5 mm × 250 mm where the diagram is omitted. In the latter case, the diagram sign shall be at least 200 mm × 300 mm. The sign shall be located directly above the call-button and squarely attached to the wall or partition. The top of the sign shall not be above 2 m from the floor level.

D-4.2 Floor Numbering Signs

A sign shall be posted and maintained within each stair enclosure on every floor, indicating the number of the floor, in accordance with the requirements given below.

The numerals shall be of bold type and at least 75 mm high. The numerals and background shall be in contrasting colours. The sign shall be securely attached to the stair side of the door.

D-4.3 Stair and Lifts Identification Signs

Each stairway and each lift bank shall be identified by an alphabetical letter. A sign indicating the letter of identification shall be posted and maintained at each lift landing and on the side of the stairway door from which egress is to be made, in accordance with the requirements given in **4.4.2.4.3.2**(h)(9).

D-4.4 Stair Re-entry Signs

A sign shall be posted and maintained on each floor within each stairway and on the occupancy side of the stairway where required, indicating whether re-entry is provided into the building and the floor where such re-entry is provided, in accordance with the requirements given below.

The lettering and numerals of the signs shall be at least 12.5 mm high of bold type. The lettering and background shall be of contrasting colours and the signs shall be securely attached approximately 1.5 m above the floor level.

D-5 FIRE SAFETY PLAN

D-5.1 A format for the Fire Safety Plan shall be as given in **D-9.10.**

D-5.2 The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Authority.

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D-5.3 The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

D-5.4 In the event there are changes from conditions existing at the time the Fire Safety Plan for the building was approved, and the changes are such so as to require amending the Fire Safety Plan, within 30 days after such changes, an amended Fire Safety Plan shall be submitted to the fire brigade for approval.

D-6 FIRE COMMAND CENTRE

A Fire Command Centre shall be established in the building (*see* **3.4.12**).

D-7 COMMUNICATIONS AND FIRE ALARM

A means of communication and fire alarm for use during fire emergencies shall be provided and maintained by the owner or person in charge of the building.

D-8 FIRE SAFETY PLAN FORMAT

D-8.1 Building Address

Street and Pin Code Number……

Telephone Number……..

D-8.2 Purpose and Objective

D-8.2.1 *Purpose*

To establish method of systematic, safe and orderly evacuation of an area or building by and of its occupants in case of fire or other emergency, in the least possible time, to a safe area by the nearest safe means of egress; also the use of such available fire appliances (including sounding of alarms) as may have been provided for controlling or extinguishing fire and safeguarding of human life.

D-8.2.2 *Objective*

To provide proper education as a part of continuing employee indoctrination and through a continuing written programme for all occupants, to ensure prompt reporting of fire, the response of fire alarms as designated, and the immediate initiation of fire safety procedures to safeguard life and contain fire until the arrival of the fire brigade.

D-8.3 Fire Safety Director

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Fire Safety Director (*see* **D-9.1**)

D-8.4 Deputy Fire Safety Director

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Deputy Fire Safety Director (*see* **D-9.2**)

D-8.5 Fire Wardens and Deputy Fire Wardens

a) Are their names on organization charts for each floor and/or tenancy?
b) Submit typical completed organization chart for Fire Drill and Evacuation Assignment.
c) Duties of Fire Wardens and Deputy Fire Wardens (*see* **D-9.3**).

D-8.6 Building Evacuation Supervisor

a) Name
b) Regularly assigned employment — Title
c) Regularly assigned location
d) How is he notified when at regular location ?
e) How is he notified when not at regular location?
f) Normal working hours
g) Duties of Building Evacuation Supervisor (*see* **D-9.4**).

D-8.7 Fire Party

a) Submit a completed organization chart for Fire Parties naming person in charge, and his title in the building.
b) Indicate standards of selection from building employees based on background and availability.
c) How are they notified?
d) How are they notified when they are not at their regular locations?
e) Means of responding
f) Duties of each member of Fire Party (*see* **D-9.5**).

D-8.8 Occupants Instructions

Distribution of instructions of all tenants, tenants' employees and building employees (*see* **D-9.6**).

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D-8.9 Evacuation Drills

a) Frequency of drills
b) How conducted?
c) Participation? Who participated? How?
d) Controls and supervision
e) Recording of details of drills

D-8.10 Fire Command Station

a) Location
b) Requirements:
   1) Adequate illumination
   2) Adequate communication to mechanical equipment room and lifts control room on each floor
   3) Copy of Fire Safety Plan
   4) Copy of Building Information Form
   5) Representative floor plans showing location of signs, floor remote station, communications, etc

D-8.11 Signs

a) Signs at lifts landings, Floor diagrams
b) Floor numbering
c) Stairway identification
d) Lifts identification
e) Stair re-entry

D-8.12 Fire Prevention and Fire Protection Programme

See **D-9.7**.

D-8.13 Building Information Form

see **D-9.8**

D-8.14 Representative Floor Plan

See **D-9.9**

D-8.15 Fire Safety Plan Prepared by

See **D-9.10**

a) Date when prepared, and
b) Date when revised

D-9 DUTIES

D-9.1 Fire Safety Director's Duties

D-9.1.1 Be familiar with the written Fire Safety Plan providing for fire drill and evacuation procedure in accordance with orders on the subject.

D-9.1.2 Select qualified building service employees for a Fire Party and organize, train and supervise such fire brigade.

D-9.1.3 Be responsible for the availability and state of readiness of the Fire Party.

D-9.1.4 Conduct fire and evacuation drills.

D-9.1.5 Be responsible for the designation and training of a Fire Warden for each floor, and sufficient Deputy Fire Wardens for each tenancy in accordance with orders on the subject.

D-9.1.6 Be responsible for a daily check for the availability of the Fire Wardens, and see that up-to-date organization charts are posted.

NOTE — If the number of Fire Wardens and Deputy Fire Wardens in the building is such that it is impractical to individually contact each one daily, a suggested method to satisfy the requirements is to make provisions for the Fire Warden, or a Deputy Fire Warden in the absence of the Fire Warden, to notify the Fire Safety Director when the Fire Warden or required number of Deputy Fire Wardens are not available. In order to determine the compliance by the Fire Warden and Deputy Fire Wardens, when this method is used, the Fire Safety Director shall make a spot check of several different floors each day.

D-9.1.7 Notify the owner or some other person having charge of the building when any designated individual is neglecting his responsibilities contained in Fire Safety Plan. The owner or the other person in-charge of the building shall bring the matter to the attention of the firm employing the individual. If the firm fails to correct the condition, the fire department shall be notified by the owner/person in charge of the building.

D-9.1.8 In the event of fire, shall report to the fire command centre to supervise, provide for and coordinate with respect to the following:

a) Ensuring that the fire department has been notified of any fire or fire alarm.
b) Manning of the fire command station.
c) Direction of evacuating procedures as provided in the Fire Safety Plan.
d) Report on conditions on fire floor for information of fire department on their arrival.
e) Advising the fire department officer in-charge in the operation of the Fire Command Centre.

D-9.1.9 Be responsible for the training and activities of the Building Evacuation Supervisor.

D-9.2 Deputy Fire Safety Director's Duties

a) He is the subordinate to the Fire Safety Director.
b) He shall perform duties of Fire Safety Director in his absence.

D-9.3 Fire Warden's and Deputy Fire Warden's Duties

The tenant or tenants of each floor shall, upon request of the owner or person in charge of buildings, make responsible and dependable employees available for

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designation by the Fire Safety Director as Fire Warden and Deputy Fire Wardens.

D-9.3.1 Each floor of a building shall be under the direction of a designated Fire Warden for the evacuation of occupants in the event of fire. He shall be assisted in his duties by the Deputy Fire Wardens. A Deputy Fire Warden shall be provided for each tenancy. When the floor area of a tenancy exceeds 700 m^2 of occupiable space, a Deputy Fire Warden shall be assigned for each 700 m^2 or part thereof.

D-9.3.2 Each Fire Warden and Deputy Fire Warden shall be familiar with the fire safety plan, the location of exits and the location and operation of any available fire alarm system.

D-9.3.3 In the event of fire, or fire alarm the Fire Warden shall ascertain the location of the fire, and direct evacuation of the floor in accordance with directions received and the following guidelines:

a) The most critical areas for immediate evacuation are the fire floor and floors immediately above. Evacuation from the other floors shall be instituted when instructions from the fire Command Centre or conditions indicate such action. Evacuation shall be *via* uncontaminated stairs. The Fire Warden shall try to avoid stairs being used by the Fire department. If this is not possible, he shall try to attract the attention of the Fire department personnel before such personnel open the door to the fire floor.

b) Evacuation to two or more levels below the fire floor is generally adequate. He shall keep the fire command station informed regarding his location.

c) Fire Wardens and their deputies shall see that all occupants are notified of the fire, and that they proceed immediately to execute the Fire Safety Plan.

d) The Fire Warden on the fire floor shall, as soon as practicable, notify the Fire Command Centre of the particulars.

e) Fire Wardens on floors above the fire shall, after executing the Fire Safety Plan, notify the Fire command station of the means being used for evacuation and any other particulars.

f) In the event that stairways serving fire floor and/or floors above are unusable due to contamination or cut-off by fire and/or smoke or that several floors above fire involve large numbers of occupants who must be evacuated, consideration may be given to using lifts in accordance with the following:

   1) If the lifts servicing his floor also service the fire floor, they shall not be used. However, lifts may be used if there is more than one bank of lifts, and he is informed from the Fire Command Centre that one bank is unaffected by the fire.
   2) If lifts do not service the fire floor and their shafts have no openings on the fire floor, they may be used, unless directed otherwise.
   3) Lifts manned by trained building personnel or firemen may also be used.
   4) In the absence of a serviceable lift, the Fire Warden shall select the safest stairway to use for evacuation on the basis of the location of the fire and any information received from the Fire Command Centre. The Fire Warden shall check the environment in the stairs prior to entry for evacuation. If it is affected by smoke, alternative stair shall be selected, and the Fire Command Centre notified.
   5) The Fire Warden shall keep the Fire Command Centre informed of the means being employed for evacuation by the occupants of his floor.

g) Ensure that an alarm has been transmitted.

D-9.3.4 *Organization Chart for Fire Drill and Evacuation Assignment*

A chart designating employees and their assignments shall be prepared and posted in a conspicuous place in each tenancy and on each floor of a tenancy that occupies more than one floor and a copy shall be in the possession of the Fire Safety Director.

D-9.3.5 Keep available an updated listing of all personnel with physical disabilities who cannot use stairs unaided. Make arrangements to have these occupants assisted in moving down the stairs to two or more levels below fire floor. If it is necessary to move such occupants to a still lower level during the fire, move them down the stairs to the uppermost floor served by an uninvolved lifts bank and then evacuate them to the street floor by lifts. Where assistance is required for such evacuation, notify Fire Safety Director.

D-9.3.6 Provide for Fire Warden identification during fire drills and fires, such as using armband, etc.

D-9.3.7 Ensure that all persons on the floor are notified of fire and all are evacuated to safe areas. A search must be conducted in the lavatories to ensure all are out. Personnel assigned as searchers can promptly and efficiently perform this duty.

D-9.3.8 Check availability of applicable personnel on organization chart and provide for a substitute when the position on a chart is not covered.

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D-9.3.9 After evacuation, perform a head count to ensure that all regular occupants known to have occupied the floor have been evacuated.

D-9.3.10 When alarm is received, the Fire Warden shall remain at a selected position in the vicinity of the communication station on the floor, in order to maintain communication with the Fire Command Centre and to receive and give instructions.

D-9.4 Building Evacuation Supervisor's Duties

A Building Evacuation Supervisor is required at all times other than normal working or business hours when there are occupants in the building and there is no Fire Safety Director on duty in the building.

D-9.4.1 He should be capable of directing the evacuation of the occupants as provided by the Fire Safety Plan.

D-9.4.2 During fire emergencies, the primary responsibility of the Building Evacuation Supervisor shall be to man the Fire Command Centre, and the direction and execution of the evacuation as provided in the Fire Safety Plan. The Building Evacuation Supervisor's training and related activities shall be under the direction of the Fire Safety Director in accordance with these rules, and the Fire Safety Plan. Such activities shall be subject to fire department control.

D-9.5 Fire Party Duties

On receipt of an alarm for fire, the Fire Party shall,

a) report to the floor below the fire to assist in evacuation and provide information to the Fire Command Centre.

b) after evacuations of fire floor, endeavour to control spread of fire by closing doors, etc.

c) attempt to control the fire until arrival of the fire department, if the fire is small and conditions do not pose a personal threat.

d) leave one member on the floor below the fire to direct the fire department to the fire location and to inform them of conditions.

e) on arrival of the fire department, the Fire Party shall report to the Fire Command Centre for additional instructions.

f) have a member designated as runner, who shall know the location of the nearest telephone, and be instructed in its use. Such member shall immediately upon receipt of information that there is a fire or evidence of fire, go to the telephone, transmit an alarm and await the arrival of the fire department and direct them to the location of the fire.

NOTE — A chart designating employees and their assignments shall be prepared.

D-9.6 Occupant's Instructions

a) The applicable parts of the approved Fire Safety Plan shall be distributed to all tenants of the building by the building management when the Fire Safety Plan has been approved by the Fire Commissioner.

b) The applicable parts of the approved Fire Safety Plan shall then be distributed by the tenants to all their employees and by the building management to all their building employees.

c) All occupants of the building shall participate and cooperate in carrying out the provisions of the Fire Safety Plan.

D-9.7 Fire Prevention and Fire Protection Programme

a) A plan for periodic formal inspections of each floor area, including exit facilities, fire extinguishers and housekeeping shall be developed. A copy of such plan be submitted.

b) Provision shall be made for the monthly testing of communication and alarm systems.

D-9.8 Building Information Form

It shall include the following information:

a) Building address……Pin Code…..

b) Owner or person in-charge of building — Name, Address and Telephone Number.

c) Fire Safety Director and Deputy Fire Safety Director's Name and Telephone Number.

d) Certificate of occupancy. Location where posted, or duplicate attached.

e) Height, area, class of construction.

f) Number type and location of fire stairs and/ or firefighting shaft.

g) Number, type and location of horizontal exits or other areas of refuge.

h) Number, type, location and operation of lifts and escalators.

j) Interior fire alarms, or alarms to central stations.

k) Communications systems and/or walkie-talkie, telephones, etc.

m) Standpipe system; size and location of risers, gravity or pressure tank, fire pump, location of siamese connections, name of employee with certificate of qualification and number of certificate.

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n) Sprinkler system; name of employee with Certificate of Fitness and certificate number. Primary and secondary water supply, fire pump and areas protected.

p) Special extinguishing system, if any, components and operation.

q) Average number of persons normally employed in building (Daytime and night time).

r) Average number of persons with disabilities in building and their location (Daytime and night time).

s) Number of persons normally visiting the building (Daytime and night time).

t) Service equipment such as:
   1) Electric power, primary, auxiliary;
   2) Lighting, normal, emergency, type and location;
   3) Heating, type, fuel, location of heating unit;
   4) *Ventilation* — with fixed windows, emergency means of exhausting heat and smoke;
   5) *Air conditioning systems* — Brief description of the system, including ducts and floors serviced;
   6) Refuse storage and disposal;
   7) Firefighting equipment and appliances, other than standpipe and sprinkler system; and
   8) Other pertinent building equipment.

u) Alternations and repair operations, if any, and the protective and preventive measures necessary to safeguard such operations with attention to torch operations.

w) Storage and use of flammable solids, liquids and/or gases.

y) Special occupancies in the building and the proper protection and maintenance thereof. Places of public assembly, studios, and theatrical occupancies.

D-9.9 Representative Floor Plan

A floor plan, representative of the majority or the floor designs of the entire building, shall be at the Command Post, in the main lobby, under the authority of the Fire Safety Director. One copy of a representative floor plan shall be submitted to the Fire department with the Fire Safety Plan.

D-9.10 Fire Safety Plan

In planning, evaluate the individual floor layouts, the population of floors, the number and kinds of exits, the zoning of the floor by area and occupants. Determine the movement of traffic by the most expeditious route to an appropriate exit and alternative route for each zone, since under fire conditions one or more exits may not be usable. This format should be used in the preparation of the Fire Safety Plan. Nothing contained in this Fire Safety Plan format shall be construed as all inclusive. All rules and other requirements shall be fully complied with.

D-9.11 Personal Fire Instruction Card

All the occupants of the building shall be given a Personal Fire Instruction Card giving the details of the floor plan and exit routes along with the instruction to be followed in the event of fire. A typical Personal Fire Instruction Card shall be as follows:

PERSONAL FIRE INSTRUCTION CARD

SEAL

NAME OF THE ORGANIZATION

ADDRESS OF THE ORGANIZATION

NAME:_____

DESIGNATION:_____

FLOOR NO. : _____

DATE : _____

FIRE WARDEN

INSTRUCTIONS

FOR YOUR OWN SAFETY YOU SHOULD KNOW

1. Two push button fire alarm boxes are provided per floor. You should read the operating instructions.
2. You should read the operating instructions on the body of the fire extinguishers provided on your floor.
3. The nearest exit from your table.
4. Your assembly point on ground floor (check with your Fire/Deputy Fire Warden).
5. FOR YOUR OWN PROTECTION YOU SHOULD REPORT TO YOUR FIRE/ DEPUTY FIRE WARDEN
   a) If any exit door/route is obstructed by loose materials, goods, boxes, etc.
   b) If any staircase door, lift lobby door does not close automatically, or does not close completely.
   c) If any push button fire alarm point, or fire extinguisher is obstructed, damaged or apparently out of order.

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IF YOU DISCOVER A FIRE

1) Break the glass of the nearest push button fire alarm and push the button.
2) Attack the fire with extinguishers provided on your floor. Take guidance from your Wardens.
3) Evacuate, if your Warden asks you to do so.

IF YOU HEAR EVACUATION INSTRUCTIONS

1) Leave the floor immediately by the nearest staircase as directed.
2) Report to your Warden, at your predetermined assembly point outside the building.
3) Do not try to use lifts.
4) Do not go to cloakroom.
5) Do not run or shout.
6) Do not stop to collect personal belongings.
7) Keep the lift lobby and staircase doors shut.

YOUR ASSEMBLY POINT IS …….

ANNEX E

(*Clauses* 5.1.4 *and* 6)

ADDITIONAL REQUIREMENTS FOR HIGH RISE BUILDINGS

E-1 GENERAL

High rise buildings (15 m and above in height) shall receive special attention with respect to fire and life safety particularly with regard to planning, design, execution, maintenance and training so that the intended provisions of this Code are well implemented. These get further accentuated as the buildings go taller; some of the key aspects are as follows:

a) Staging and evacuation requirements of occupants.
b) Stack effect posing challenges towards pressurization and smoke exhaust.
c) Zoning of firefighting system to meet functional requirements of hydraulic pressure and flow.
d) Challenges experienced by fire personnel in reaching the place of fire and towards evacuation.

Aspects to mitigate these challenges require innovative approach, interaction with local fire authorities and meaningful strategic planning towards maintenance and fire drills.

E-2 EGRESS AND EVACUATION STRATEGY

One firefighting shall be planned for each residential building/tower, in an educational building/ block, and for each compartment of institutional, assembly, business and mercantile occupancy types. For other occupancy types, requirement of firefighting shaft shall be ascertained in consultation with the local fire authority. The firefighting shaft shall necessarily have connectivity directly to exit discharge or through exit passageway (having 120 min fire resistance walls) to exit discharge.

Staircase and fire lift lobby of a firefighting shaft shall be smoke controlled as per **4.4.2.5** and Table 6.

It is recommended that the pressurization requirement for staircase in firefighting shaft and for other fire exit staircases in buildings greater than 60 m in height be evaluated to limit the force required to operate the door assembly (in the direction of door opening) to not more than 133 N to set the door leaf in motion. The aspect of pressurization, door area/width and door closure shall be planned in consideration to the above.

E-3 FIRE SAFETY REQUIREMENTS FOR LIFTS

The provisions as given in **7.1** to **7.2.4** under fire safety requirements of lifts in high rise buildings in Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks, Subsection 5A Lifts' of the Code shall be applicable.

E-4 HORIZONTAL EXITS/REFUGE AREA

A horizontal exit shall be through a fire door of 120 min rating in a fire resistant wall. Horizontal exit require separation with the refuge area or adjoining compartment through 120 min fire barrier. The adjoining compartment of the horizontal exit should allow unlocked and ease of egress and exits for the occupants using defend in place strategy.

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Requirements of horizontal exits are as under:

a) Width of horizontal exit doorway shall be suitable to meet the occupant load factor for egress.

b) Doors in horizontal exits shall be openable at all times from both sides.

c) All doors shall swing in the direction of exit travel. For horizontal exits, if a double leaf door is used, the right hand door leaf shall swing in the direction of exit travel.

d) Refuge area shall be provided in buildings of height more than 24 m. Refuge area provided shall be planned to accommodate the occupants of two consecutive floors (this shall consider occupants of the floor where refuge is provided and occupants of floor above) by considering area of 0.3 m^2 per person for the calculated number of occupants and shall include additionally to accommodate one wheelchair space of an area of 0.9 m^2 for every 200 occupants, portion thereof, based on the occupant load served by the area of refuge or a minimum of 15 m^2, whichever is higher, shall be provided as under:

   1) The refuge area shall be provided on the periphery of the floor and open to air at least on one side protected with suitable railings.

   2) Refuge area(s) shall be provided at/or immediately above 24 m and thereafter at every 15 m or so.

   The above refuge area requirement for D-6 occupancy requirement shall however be in accordance with **6.4.2.2.**

e) A prominent sign bearing the words 'REFUGE AREA' shall be installed at the entry of the refuge area, having height of letters of minimum 75 mm and also containing information about the location of refuge areas on the floors above and below this floor. The same signage shall also be conspicuously located within the refuge area.

f) Each refuge area shall be ventilated and provided with first aid box, fire extinguishers, public address speaker, fire man talk back, and adequate emergency lighting as well as drinking water facility.

g) Refuge areas shall be approachable from the space they serve by an accessible means of egress.

h) Refuge areas shall connect to firefighting shaft (comprising fireman's lift, lobby and staircase) without having the occupants requiring to return to the building spaces through which travel to the area of refuge occurred.

j) The refuge area shall always be kept clear. No storage of combustible products and materials, electrical and mechanical equipment, etc shall be allowed in such areas.

k) Refuge area shall be provided with adequate drainage facility to maintain efficient storm water disposal.

m) Entire refuge area shall be provided with sprinklers.

n) Where there is a difference in level between connected areas for horizontal exits, ramps of slope not steeper than 1 in 12 shall be provided (and steps should be avoided).

NOTE — Refuge area provided in excess of the requirements shall be counted towards FAR.

High rise apartment buildings with apartments having balcony, need not be provided with refuge area; however apartment buildings without balcony shall provide refuge area as given above. Refuge areas for apartment buildings of height above 60 m while having balconies shall be provided at 60 m and thereafter at every 30 m. The refuge area shall be an area equivalent to 0.3 m^2 per person for accommodating occupants of two consecutive floors, where occupant load shall be derived on basis of 12.5 m^2 of gross floor area and additionally 0.9 m^2 for accommodating wheel chair requirement or shall be 15 m^2, whichever is higher.

E-5 ELECTRICAL SERVICES

The specific requirements for electrical installations in multi-storeyed buildings given in Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code and Section 7 of National Electrical Code 2011 shall be followed.

Wherever transformers are planned at higher floors, the HT cables shall be routed through a separate shaft having its own fire resistance rating of 120 min. Wherever HT generators are planned centrally at ground or first basement level, redundant transformers and HT cables shall be planned for buildings above 60 m in height.

E-6 FIRE PROTECTION

For residential occupancies above 120 m in height and other occupancies above 60 m in height, the sprinklers shall be fed from the main and an alternate/standby riser with suitable isolation valves. The entire sprinkler system shall be designed in accordance with good practice [4(20)].

Where the height of the building exceeds 150 m to 175 m, fire water static storage and pumps shall be required to be provided at 160 m to 180 m and thereafter at intermediate floors at higher levels enabling efficient and functional firefighting installations. The static fire

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water storage tanks located at such levels shall have capacity at minimum half of the storage of underground static water storage tank prescribed in Table 7. Such tanks shall be supplemented with water supplies through one working and one standby pump of capacity 2 850 litre/min with two risers at alternate locations feeding to such fire water static storage tanks. The fire pump's requirement and capacity shall also be derived for occupancy type as per Table 7 substituting the diesel pump with electrical pump. The fire pump room at such level shall have dedicated connectivity through passageway (with 120 min integrity) from the firefighting shaft. Such fire pump room shall have 120 min fire resisting wall and provided with adequate ventilation with talk-back connectivity to the main fire pump room and Fire Command Centre.

For high rise buildings, seismic bracings shall be considered for firefighting installations depending on seismic vulnerability of the region and the type of occupancy.

E-7 FIRE AND LIFE SAFETY AUDIT

a) Fire and life safety audit shall be carried out for all buildings having a height of more than 15 m.

b) Such audits shall preferably be conducted by a third party auditor having requisite experience in fire and life safety inspections.

c) Frequency of such audits shall be once in two years.

E-8 HELIPAD

For high rise buildings above 200 m in height, provision for helipad is recommended for specific requirements like landing of fire equipment, and support facilities or other emergencies.

ANNEX F

(*Clause* 6)

ATRIUM

F-1 ATRIUM REQUIREMENTS

a) In order for an atrium to be permitted in buildings, the following shall be complied:

   1) Atrium shall be permitted in buildings of Type 1 and Type 2 construction only.

   2) The use of combustible furnishings and decorations on the floor of the atrium shall be limited and sparsely distributed.

b) Smoke detectors shall be provided on the underside of each floor protruding into the atrium, at the atrium roof and adjacent to each return air intake from the atrium. Within atrium space, beam type or aspirating type smoke detectors shall be used to ensure detection of smoke, considering factors such as stratification of smoke.

c) Where the ceiling of the atrium is more than 17 m above the floor, water based protection (automatic sprinklers) at the ceiling of atrium is not required.

d) Hydrants shall be available at the floor of the atrium and also at the adjoining upper spaces/floors of the atrium.

   Sprinklers are required to be installed for coverage of glass areas of retail, tenant and other areas adjoining the exit access corridor and atrium. Sprinklers shall be at a distance of 450 mm to 600 mm enabling cooling of such glass and limiting the extent of fire and smoke to the atrium (*see* Fig. 16). This provision does not allow similar sprinkler installation arrangement to offset fire compartmentation requirements, in which case fire barrier is required as per relevant provisions of this Part.

e) Atrium in business occupancy shall be planned with 6 air changes per hour (ACPH) while atrium in hotels and assembly occupancy shall be planned with 8 ACPH smoke extraction system.

   Such air changes shall be planned in atrium for a height of 15 m from the top.

f) Smoke exhaust fans shall be capable of operating effectively at 250°C for 120 min.

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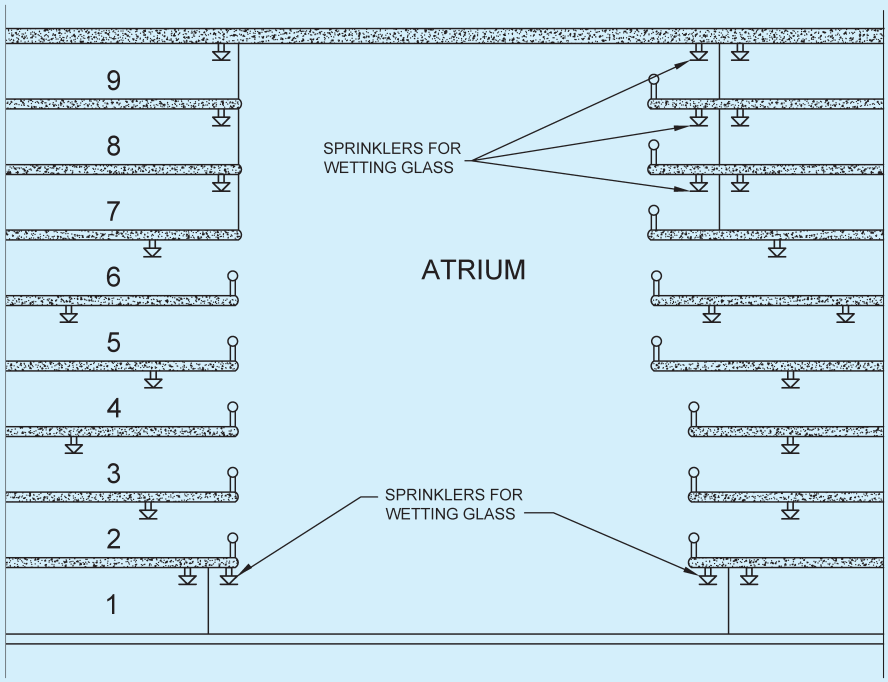


FIG. 16 SPRINKLER PROTECTION OF GLASS FOR FLOOR OPEN TO ATRIUM

g) Makeup air supply points shall be located beneath the smoke layer and on the lower levels connected by the atrium.

h) Makeup air shall be provided by fans, openings to outside to allow infiltration, or the combination thereof.

j) It is recommended that makeup air be designed at 85 percent to 95 percent of the exhaust flow rate, not including the leakage through these small paths.

k) The makeup air shall not cause door-opening force to exceed allowable limits.

m) The makeup air velocity shall not exceed 1.02 m/s where the makeup air could come into contact with the plume unless a higher makeup air velocity is supported by engineering analysis.

n) Atrium smoke management system fans shall be provided with emergency power.

p) If so required by the Authority, an engineering analysis should be performed which demonstrates that the smoke system for the atrium is designed to keep the smoke layer interface 1 800 mm above the highest occupied floor level of exit access, open to the atrium, for a period equal to 1.5 times the calculated egress time or 20 min, whichever is greater.

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ANNEX G

(*Clause* 6)

COMMERCIAL KITCHENS

G-0 GENERAL

The provisions given herein are applicable to those commercial kitchens serving in centrally air conditioned buildings such as kitchens of starred hotels, food courts, malls, banquet halls and restaurants.

Electricity, gas and in some cases solid fuels such as wood or charcoal are the energy sources used to power a commercial kitchen.

The potential hazards posed by the commercial cooking facilities are as follows:

a) *On cooking appliances using oil as fuel* — The oil can self-ignite due to overheating of the cooking appliances or through open flames.

b) Full grease residues trapped in the hoods due to non-cleaning of filters and dusts periodically and exhaust ventilation system can ignite through overheated air flues or open flames.

c) Faulty electrical equipment and electrical installation are more likely to spark, and failure of thermostat and safety switches that may lead to overheat and consequent fire.

d) Flammable materials in the vicinity of open flames or heat sources

G-1 TERMS ASSOCIATED WITH COOKING OPERATIONS

a) *Types of restaurants/food preparation facilities* — Buffet restaurants, cafeterias, coffee shops, entertainment facilities (nightclubs, dinner theatres), and ethnic, fast food, speciality and traditional restaurants, corporate canteens, casinos, educational facilities, schools and universities, hospitals, care homes, mental homes and prisons.

b) *Ventilation/grease extraction equipment* — Exhaust hoods, grease removal devices, exhaust ductwork, exhaust fans, dampers and other ancillary components or systems that are involved in the capture, containment, and control of grease-laden cooking effluent.

c) *Cooking appliances* — Ranges, deep fat fryers, microwave ovens, griddles, grills, pressurized fryers, potato chip fryers, woks, broilers, doughnut fryers, barbecue/smokers, ovens, *Tandoors*, steam kettles, appliances initializing grease and cooking oils, etc.

G-2 FIRE PROTECTION SYSTEMS

a) A kitchen fire suppression system needs to be installed whenever cooking appliances are using LPG/PNG/oil/electricity and/or dry fuel like wood or charcoal for cooking and/or can ignite the exhaust or fat for cooking and/or can ignite the ventilation system. Cooking equipment that produces grease-laden vapours and that might be a source of ignition of grease in the hood, grease removal device, or duct shall be protected by fire-suppression equipment.

b) The initial fire hazard is the cooking appliance itself. However, once the exhaust ventilation system is involved in fire due to propagation from the appliances, the exhaust system becomes the more severe hazard due to the potential of fire propagation outside the cooking space.

c) The requirement for kitchen fire suppression systems shall be directly linked to measurements that actually represent the risk. Some other contributory factors could be but not necessarily — connected load (kW), area occupied by kitchen equipment, volume of cooking oil and other flammables, inter distances between equipment, cooking media, etc.

d) Grease laden hoods can be ignited by heat penetrating the outside of the kitchen hood. Any penetration to the outside of a hood, shall be either welded or fitted with an approved sealing device so as not to allow cooking grease and oil to migrate to the outer portion of the hood.

e) If sprinkler protection is specified for a building, it needs careful consideration of the likely consequences if certain portion of the building is omitted from the scope of protection, for example, no water should get on the cooking appliances (especially the fryer). Removing this protection from a high hazard area logically requires this area to be protected by a more suitable solution, dedicated to this special hazard.

G-3 FIRE SEPARATION REQUIREMENTS

a) Where a kitchen is required for the preparation of food and/or where 'open flame' cooking appliances are used and/or where fryers

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(with no open flames) are used, the kitchen shall be separated from other parts of the same building by compartment wall and floor having fire resistance of at least 60 min.

b) Food serving areas shall be fire separated from the kitchens/cooking areas by fire rated elements having a resistance of at least 60 min. Doors shall have fire resistance of 60 min rating and fitted with automatic self-closing device.

c) In open type kitchen cooking area, sitting area needs to be segregated by 60 min fire rated glass or drop fire curtains [*see also* **G-3**(d) and **G-5.2**(b)].

d) Where the flue or exhaust duct passes through the compartment wall or floor, the flue or duct shall be encased by non-combustible construction and no damper shall be permitted to be installed in such flue or duct. Also such flue or ductwork shall be clear from combustible materials.

e) If the commercial kitchen/cooking is situated in a building that is not sprinkler protected, the floor area of the kitchen/cooking shall not exceed 50 m^2.

f) Commercial kitchen/cooking using LPG as fuel for the 'open flame' cooking activities shall not be allowed to be located at the basements. As regards LPG cylinder storage, attention is drawn to good practice [4(14)] and Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code for compliance requirements

g) It is advisable to locate the kitchen/cooking operations on the external periphery of the building so that in the event of mechanical ventilation failure, it can be naturally ventilated.

G-4 Life safety and egress requirements shall be governed by the requirements under life safety (*see* **4**). In case the requirements under this annex differs from those under **4**, this annex shall take precedence.

G-5 FIRE SAFETY REQUIREMENTS

G-5.1 General

a) The following equipment must always be kept in working condition:

1) Cooking equipment,
2) Hoods,
3) Exhaust ducts (if provided),
4) Fans,
5) Fire extinguishing systems,
6) Fire detection and alarm system, and
7) Gas leakage detectors (if gas is used as fuel).

b) An automatic fixed suppression system shall be installed to protect all cooking equipment producing grease laden vapours and that might be a source of ignition of grease in the hood, grease removal device.

c) Fire-suppression equipment shall be provided for the protection of grease removal devices, hood exhaust plenums, and exhaust duct systems.

d) All fire suppression systems and components installed shall be in accordance with relevant Indian and/or International Standards.

G-5.2 Protection of Cooking Equipment (General)

a) Cooking equipment shall be protected with the following:

1) Automatic wet chemical fire suppression system for the protection of hoods (OR) other equivalent approved systems like water mist applications for kitchen fires.
2) Automatic sprinkler system for non-cooking areas (not in the vicinity of cooking areas or inside hoods).
3) Exhaust ducts shall be protected by automatic high temperature sprinklers designed as per good practice [4(20)].

b) Due diligence shall be exercised before considering protection with sprinkler/water mist installation particularly for the protection of fryers. No sprinklers shall be provided within 3 m of cooking equipment and kitchen hoods. Area sensitive to sprinklers shall be protected with wet chemical suppression systems or other approved systems for the type of protection. Water mist systems, if approved for use for the type of application (that is, commercial cooking equipment) by fire tests, may also be considered.

c) Kitchen hoods independent suppression systems shall discharge wet chemicals to all areas of a kitchen range extract hood that is potentially coated in grease. The system shall also discharge over deep fat cooking pans or other potential fire source. The system shall be activated by heat detectors located above the appliances/within hoods and in the entrance to exhaust duct. Additional detectors behind equipment in the duct may be

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necessary. These may be of fusible link type. Extinguishing systems shall also incorporate manually actuating devices which shall be located in easily accessible locations in the means of egress.

d) The operational sequence shall be as follows:
   1) On detection of fire in the hood and upon actuation of fire suppression system, any power or gas supplies serving the kitchen equipment must be cut-off and isolated automatically.
   2) Pressure regulating stations shall be designed and installed at critical locations for excess flow shut off valves.
   3) Seismic shut off valve at the main distribution point shall also be provided.
   4) The exhaust fan shall not stop and continue operating, even after activation of the system. The supply fan shall switch off.
   5) Gas leakage detectors shall be provided in all kitchens that link to a gas solenoid valve for emergency shut off. Suitable gas detection system (based on type of gas used LPG or PNG) integrated with fire detection and alarm system must be provided in addition to heat/multi-criteria detectors and sprinklers.
   6) Manually operating devices shall immediately activate fire suppression system, which in turn shall shut off other systems like fuel supply/power supply, etc. Manual system shall operate mechanically and not rely on electrical power for activation, unless this is from an emergency power source as described in this Code.
   7) In the event of the kitchen hood system being activated, an alarm should be sounded. The system must also be interfaced with the fire detection and alarm system.

e) Fire extinguishers in the vicinity of cooking area and the hoods shall be suitable for the type of fire.

G-5.3 Cooking Equipment Exhaust Ventilation

a) Hoods/ducts containing automatic fire suppression systems are protected areas; therefore, these hoods are not considered obstructions to overhead sprinkler systems and shall not require floor coverage underneath thereof.

b) Sprinkler installation shall comply with various provisions contained in accepted standard [4(28)]. The temperature rating of sprinklers shall be so selected that it is 30°C above the anticipated maximum temperature within cooking/kitchen areas. Sprinklers provided inside the exhaust ducts shall be of 141°C temperature.

c) Provision of cleaning of the kitchen exhaust every six months to ensure that the carbon soot accumulated in the exhaust duct is cleaned to avoid the chances of outbreak of fire shall be made.

d) Independent exhaust ducts shall be provided for equipment using dry fuel like wood/ charcoal which produce spark and are likely to ignite the grease which might have accumulated in the common duct. Alternatively, approved spark arrestors may be provided before the duct from equipment using dry fuel meets the main duct. These spark arrestors shall be so provided that these are easily accessible and removable for cleaning.

G-5.4 Cooking Equipment

a) Cooking equipment (such as deep fat fryers, rangers, griddles, and broilers) that may be a source of ignition shall be provided in accordance with the provision of **G-5.2**(a).

b) The operation of any sprinkler within the kitchen or cooking area shall automatically shut off all sources of fuel and heat to all equipment requiring protection. Any gas appliance not requiring protection but located under ventilating equipment shall also be shut off. All shutdown devices shall be of the type that requires manual resetting prior to fuel or power being restored.

c) An approved indicating valve (flow indicating switch) shall be installed in the water supply line feeding to the sprinklers protecting the cooking and extraction ventilating system.

d) A system test connection shall be provided to verify proper operation of equipment specified in item **G-5.2**(d)(4).

e) Sprinklers shall be inspected at least twice in a year and cleaned, if found coated with grease and other particles during their use and thus their thermal sensing elements desensitized.

f) Any penetrations to the outside of a hood, be either welded or fit with a sealing device (certified by national/international approval bodies) to not allow cooking grease, oil to migrate to the outer portion of the hood. The fitment arrangements shall be of approved type. Gaskets for the panels shall be certified to withstand a temperature of 815.6°C (1 500°F).

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g) Grease strip shall be readily available for efficient and regular cleaning of concrete or paved floors of kitchen and restaurant and also the drainage areas.

h) The hood or that portion of a primary collection means designed for collecting cooking vapours and residues shall be constructed of and be supported by steel not less than 1.09 mm (No. 18 MSG) in thickness or stainless steel not less than 0.94 mm (No. 20 MSG) in thickness or other approved material of equivalent strength and fire and corrosion resistance.

j) All seams, joint, and penetrations of the hood enclosure that direct and capture grease-laden vapours and exhaust gases shall have a liquid tight continuous external weld to the hood's lower outermost perimeter.

k) Grease filters shall be of steel rigid construction that will not distort or crush under normal operation handling and cleaning conditions. They shall be so arranged that all exhaust air passes through the grease filters. Filters shall be easily accessible and removable for periodic cleaning.

m) Grease filters shall be installed at an angle not less than 45° from the horizontal.

n) Grease filters shall be equipped with a grease drip tray beneath their lower edges and shall have a suitable minimum depth needed to collect grease. The grease drip trays shall be pitched to drain into an enclosed metal container having a capacity not exceeding 3.8 litre.

p) The exhaust ducts shall be constructed of and supported by carbon steel not less than 1.37 mm (No. 16 MSG) in thickness or stainless steel not less than 1.09 mm (No. 18 MSG) in thickness.

G-5.5 Rooftop Terminations — Exhaust Systems

a) The exhaust system shall terminate either outside the building with a fan or duct or through the roof or to the roof from outside with minimum 3 m of horizontal clearance from the outlet to the adjacent buildings, property lines and air intakes.

b) There shall be a minimum of 1.5 m of horizontal clearance from the outlet (fan housing) to any combustible structure.

c) There shall be a vertical separation of 1.0 m below any exhaust outlets for air intakes within 3.0 m of the exhaust outlet.

ANNEX H

[*Clauses* 6.4.2.2 *and* 6.8.1.5]

CAR PARKING FACILITIES

H-1 The provisions given in **H-2** to **H-5** shall apply to parking structures of the closed or open type, within buildings above or below grade.

H-2 GENERAL

a) Where both parking and repair operations are conducted in the same building, the entire building shall comply with the requirements for Group G occupancies, unless the parking and repair sections are effectively separated by separation walls of 120 min.

b) Floor surfaces shall be non-combustible, sloping towards drains to remove accumulation of water.

c) Those parts of parking structures located within, immediately above or below, attached to, or less than 3 m away from a building used for any other purpose shall be separated by fire resistant walls and floors having fire resistance rating of not less than 120 min. This shall exclude those incidental spaces which are occupied by cashier, attendant booth or those spaces used for toilets, with a total area not exceeding 200 m^2.

d) Vehicle ramps shall not be considered as exits unless pedestrian facilities are provided.

e) Other occupancies like fuel dispensing, shall not be allowed in the building. Car repair facilities, if provided, shall be separated by 120 min fire resistant construction.

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f) In addition to fire protection requirements as per Table 7, appropriate fire detection and suppressions systems shall be provided for the protection of hydraulic oil tank and pumps located below ground level for operation of car lifts.

g) Means of egress shall meet the requirements specified in **4**.

H-3 OPEN PARKING STRUCTURES (INCLUDING MULTI-LEVEL PARKING AND STILT PARKING)

a) The term open parking structure specifies the degree to which the structure's exterior walls must have openings. Parking structures that meet the definition of the term open parking structure provide sufficient area in exterior walls to vent the products of combustion to a greater degree than an enclosed parking structure.

b) A parking structure having each parking level wall openings open to the atmosphere, for an area of not less than 0.4 m^2 for each linear metre of its exterior perimeter shall be construed as open parking structure. Such openings shall be distributed over 40 percent of the building perimeter or uniformly over two opposing sides. Interior wall lines shall be at least 20 percent open, with openings distributed to provide ventilation, else, the structure shall be deemed as enclosed parking structures.

NOTE — A car park located at the stilt level of a building (not open to sky) can be considered an open or an unenclosed car park if any part of the car park is within 30 m of a permanent natural ventilation opening and any one of the following is complied with towards the permanent natural ventilation requirement:

i) 50 percent of the car park perimeter shall be open to permanent natural ventilation.

ii) At least 75 percent of the car park perimeter is having the 50 percent natural ventilation opening.

c) All stilt parking are required to be provided with sprinkler system where such buildings are required to be sprinklered.

d) Open parking structures are not required to be provided with compartmentation.

e) Open car parking (open to sky) within building complex having fire hydrant system shall also need to be protected with yard hydrant installation system in accordance with good practice [4(29)].

H-4 ENCLOSED PARKING STRUCTURES

a) Those car parking structures which are enclosed on all sides and on top, not falling within the definition of open car parking [*see* **H-3**(b)] and also those situated in the basements shall be known as enclosed car parking structures.

b) All sprinklers in car parking shall be standard response type with minimum K-Factor of 80, area coverage of 9 m^2 and designed as per good practice [4(20)].

c) For basement car parking, compartmentation can be achieved, with fire barrier or with water curtain nozzle (K-23) or with combination thereof. Automatic deluge system comprising deluge valve, piping, nozzles, etc shall be used to zone the compartment in case of water curtain system. In case of water curtain, existing water storage shall be supplemented by water demand for water curtain nozzles for 60 min considering the largest compartment's perimeter out of all compartments of car parking in any of the basements.

d) The water supply for the water curtain nozzles shall be through independent electric pump of adequate capacity (flow and head) with piping/riser for the water supply to the nozzles.

e) The water curtain shall be operated by the actuation of flow switch actuating sprinkler system.

f) For smoke ventilation requirement of car parking, *see* **4.6.2**.

g) All fire exit doors from the car parking to exits shall be painted green and shall display exit signage.

H-5 AUTOMATED CAR PARKING UTILIZING MECHANICAL OR COMPUTERIZED/ ROBOTIC MEANS

a) Automated car parking structure can be of open parking type or enclosed types.

b) Automated car parking facilities pose more hazard compared to manual parking due to following reasons:

1) High density of cars due to close stacking-one over another.

2) Lack of provision on fire separation/ compartmentation-horizontal or vertical leading to rapid fire spread.

3) Non-availability of any person to notice/ control the fire in initial stages.

4) Limited access to firefighting personnel.

5) Extensive height and depth involved with highly combustible load.

c) Fire escape staircases, at least 1 250 mm wide shall be provided at appropriate locations so

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that no place is more than 45 m from the nearest staircase. Horizontal walkways, at least 1 000 mm wide for access to all the areas shall be provided at every parking level.

d) Travel distance and means of egress shall be governed by the respective sections of this Code.

e) The hazardous areas like DG sets, transformers, HT/LT panels for the parking lot shall be suitably segregated from other areas as per requirements given in this Code and all such areas shall be protected by suitable automatic fire suppressions systems.

ANNEX J

(*Clause* 6.4.4)

FIRE AND LIFE SAFETY REQUIREMENTS FOR METRO STATIONS

J-1 APPLICATION AND SCOPE

The provisions of this annex relates to the buildings constructed as part of the metro stations/metro rail systems.

J-2 TERMINOLOGY ASSOCIATED WITH METRO FACILITIES

For the purpose of this annex, the terminologies given at **2.43** shall apply.

J-3 GENERAL

J-3.1 Classification

Metro stations can be classified under 'Assembly occupancies'. These shall include any station building or part thereof, permanent or temporary, through which people transit for the duration of time required to enter the building and board the train to depart the station platform or to alight from the train and depart from the station building.

J-3.2 Sub-classification

Metro stations can be further classified under the following headings:

a) Elevated and enclosed stations,

b) Elevated and open stations, and

c) Underground stations.

NOTE — The above shall include all open and enclosed Metro Stations along with their associated ancillary structures and train depots. Elevated shall mean to include 'at-grade' stations as well.

J-3.3 Fire Zones

Metro stations, that is, mass rapid transit may be constructed within Fire Zone No. 1, 2 or 3, as per the transportation requirement.

J-3.4 Type of Construction

Metro stations shall conform to Type 1 or Type 2 or combinations of Types 1 and 2 non-combustible constructions, as defined in **3.3**.

J-4 LIFE SAFETY REQUIREMENTS

J-4.1 Occupant Load

a) Main occupant load in a transit station is the platform occupant load, on which basis the life safety provisions of transit stations are designed. Occupant loads in transit stations are mainly a function of the train carrying capacities rather than the areas of a station.

b) For calculating platform occupant loads for a multiline, multilevel or multiplatform station, maximum occupant load for each platform shall be considered separately for determining the egress capacity from that platform.

c) At levels where egress routes from separate platforms converge, occupant loads of all platforms shall be considered to calculate egress capacity from that level. Simultaneous loads shall be considered for all egress routes passing through each level of that station.

d) Platform occupant load shall be based on the greater of the AM or PM 'peak hour loads' generated by the system and train loads.

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e) Peak hour load shall be converted to peak minute loads by dividing by 50 and multiplying further by a system surge factor varying from 1.15 to 1.5, as defined by the transit system authority. Surge factor may require to be further enhanced where increased footfalls are anticipated like stations catering to sports complex, etc.

f) Platform occupant load shall be determined by factoring in the peak hour entraining loads at platform edges and train loads, in emergency evacuation scenario, as defined here:

1) *Train on fire* — It is assumed that a train loaded to crush capacity travelling in peak direction at peak hour has caught fire, and as per the operating procedure it is brought to the next station, whereupon it shall require to be evacuated.

2) The train in this case being called the 'incident train' and the platform on which it is arriving being called 'incident platform' of the 'incident station'.

3) Passengers waiting on all the platforms of the 'incident station' shall require to be evacuated as well.

4) Number of passengers shall be determined as defined in (g) below.

5) Only one source of fire, that is, train fire shall be assumed at a time.

6) It is assumed that the train on non-incident platform shall not stop at the incident station and shall stop only at previous/ next station.

g) Platform occupant load, for emergency evacuation scenario, shall be the addition of two headway entraining loads for peak direction platform, one headway entraining load for off-peak direction platforms and one crush train load.

NOTE — *See also* **J-4.1**(b) and **J-4.1**(c).

h) *Occupancy in non-public areas*:

1) Use of designated non-public areas by station staff whose work assignments require their presence in the station structures shall be permitted.

2) Unmanned plant rooms and any other areas where usual occupancy is less than10 persons at any given time shall be treated as unoccupied areas.

j) *Segregation with non-transit occupancy*:

Non-transit occupancies, of area up to 250 m^2, shall be permitted to be accommodated within the station building. Occupant load of areas under non-transit occupancies shall be in accordance with Table 3.

J-5 EGRESS PROVISIONS

J-5.1 Evacuation Time

a) *Means of egress — Public areas* — Egress from metro station shall be designed to facilitate the evacuation of a pre-defined platform occupant load to a designated point of safety in pre-defined emergency scenario(s), as defined by the transit system authority.

b) *Evacuation time from platform* — Enough egress capacity shall be provided to evacuate the platform occupant load within 4 min from enclosed stations and within 5.5 min from open stations.

c) *Evacuation time to point of safety* — Further, station design should permit evacuation of the remotest person on platform to a point of safety within 6 min in case of enclosed stations and within 8 min in case of open stations.

NOTE — Evacuation time specified in (b) and (c) may be modified based on actual engineering analysis by evaluating material heat release rates, station geometry and emergency ventilation systems.

d) For open stations where the concourse is below or protected from the platform by distance or materials as determined by an appropriate engineering analysis, that concourse shall be permitted to be defined as a point of safety.

e) For enclosed stations equipped with an emergency ventilation system and where the emergency ventilation system provides protection for the concourse from exposure to the effects of a train fire at the platform as confirmed by engineering analysis, that concourse is permitted to be defined as a point of safety.

J-5.2 General Arrangement

a) Means of egress from each station platform shall be provided so that they are equally distributed as far as possible, in capacity and placement, throughout the length of platform.

b) There shall be at least two means of egress remote from each other.

c) Means of egress may however be allowed to converge at concourse or subsequent levels with sufficient capacity to achieve the required evacuation time.

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d) As far as possible, all the egress capacity required for emergency evacuation shall be provided with the unenclosed stairs and escalators which are used for normal circulation.

J-5.3 Travel Distance

The maximum travel distance on the platform to a point at which a means of egress route leaves the platform shall not be more than 100 m. This shall however be subject to fulfilling the egress requirements specified in **J-5.2**.

J-5.4 Means of Egress

J-5.4.1 *Non-public Areas*

Means of egress from unoccupied non-public areas shall be permitted to be merged into public means of egress.

J-5.4.2 *Non-transit Occupancies*

Separate means of egress shall be provided for such non-transit occupancies which are segregated from the station public area to ensure independent evacuation from either occupancy. Such means of egress may be allowed to converge beyond station concourse area with the approval of the competent authority.

J-5.4.3 *Platform, Corridors, Ramps*

Platforms, corridors and ramps serving as means of egress shall be designed as per following criteria:

a) A minimum clear width of 1 200 mm shall be provided along all platforms, corridors, and ramps serving as means of egress.

b) In computing the means of egress capacity available on platforms, corridors, and ramps, 300 mm shall be deducted at each sidewall, and 450 mm shall be deducted at platform edges that are open to the trainway.

c) The maximum means of egress capacity of platforms, corridors, and ramps shall be computed at 0.082 0 people/mm-min.

d) The maximum means of egress travel speed along platforms, corridors, and ramps shall be computed at 38.0 m/min.

e) The means of egress travel speed for concourses and other areas where a lesser pedestrian density is anticipated shall be computed at 60.0 m/min.

J-5.4.4 *Stairways*

a) Unenclosed stairs and escalators shall be permitted to be counted as contributing to the means of egress capacity in stations.

b) Minimum widths of such unenclosed staircases shall be 1 800 mm for unidirectional stairs, and 2 400 mm for bi-directional stairs.

c) Wall or floor mounted railings on both sides shall be permitted on stairs without affecting the widths stated in (b) above by more than 300 mm.

d) Enclosed stairs in the means of egress shall be minimum 1 200 mm wide.

e) Capacity and travel speed for stairs shall be computed at 0.055 5 people/mm-min and 14.6 m/min, respectively.

J-5.4.5 *Escalators*

a) Escalators shall not account for more than one-half of the means of egress capacity at any one level.

b) In calculating the egress capacity of escalators,
   1) one escalator at each level shall be considered as being out of service, and
   2) the escalator chosen shall be the one having the most adverse effect upon egress capacity.

c) Where escalators are permitted as a means of egress in stations, the following criteria shall be complied with:
   1) The escalators shall be constructed of non-combustible materials (exceptions like rollers and handrails shall be permitted with the approval of the Competent Authority).
   2) Escalators running in the direction of egress shall be permitted to remain operating.
   3) Escalators running reverse to the direction of egress shall be capable of being stopped either locally by a manual stopping device at the escalator or remotely by a manual stopping device at a remote location or remotely as part of a pre-planned evacuation response. A stopped escalator shall be counted as equivalent to 1 m wide staircase.

d) Where provision is made for remote stopping of escalators counted as means of egress, one of the following shall apply:

   The stop shall be delayed until it is preceded by a minimum 15 s audible signal or warning message sounded at the escalator; wherein (1) the signal or message shall have a sound intensity that is at least 15 dBA above the average ambient sound level for the entire length of the escalator, (2) the signal shall be

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distinct from the fire alarm signal, and (3) the warning message shall meet audibility and intelligibility requirements.

OR

Where escalators are equipped with the necessary controls to decelerate in a controlled manner under the full rated load, the stop shall be delayed for at least 5 s before beginning deceleration, and the deceleration rate shall be no greater than 0.052 m/s^2.

e) Escalators with or without intermediate landings shall be acceptable as a means of egress, regardless of vertical rise.

f) Escalators exposed to the outdoor environment shall be provided with slip-resistant landing and floor plates.

g) Stopped escalators shall be permitted to be started in the direction of egress in accordance with the requirements for stopping of escalators described in **J-5.4.5**(c)(3) and **J-5.4.5**(d).

h) Capacity and travel speed for escalators shall be computed at 120 people/min and 18.5 m/min (vertical component of travel speed), respectively.

J-5.4.6 *Lifts*

Lifts meeting the following requirements shall be counted as one of the means of egress in stations.

J-5.4.6.1 *Capacity of lifts*

Where lifts are counted as contributing to the means of egress capacity,

a) lifts shall have minimum 60 min fire resistance rating;

b) they shall account for no more than 50 percent of the required egress capacity;

c) at least one lift shall be considered out of service, and one lift shall be reserved for fire service; and

d) the capacity of each lift shall be the carrying capacity of the lifts within 30 min.

J-5.4.6.2 *Holding area for lifts*

Lifts counted as one of the means of egress from any level of a station shall be accessed through holding areas or lobbies at that level, which shall be designed as follows:

a) The holding areas or lobbies shall be separated from the platform by a smoke tight fire separation having a fire resistance rating of at least 60 min but not less than the time required to evacuate the holding area occupant load.

b) At least one stair shall be accessible from the holding area.

c) The holding area shall be sized to accommodate one person per 0.2 m^2.

d) If the holding area includes portions of the platform, the area within 600 mm of the trainway shall not be considered in the calculation.

e) Upon activation of smoke control in the platform or adjacent trainway areas, the holding area shall be pressurized to a minimum of 25 Pa.

f) The holding area shall be provided with emergency voice alarm devices with two-way communication to the system operations control centre.

J-5.4.6.3 *Design features of lifts*

Lifts counted as one of the means of egress shall be designed as follows:

a) Shaft enclosures shall be constructed as fire separations having a 120 min fire resistance rating.

b) The design shall limit water flow into the shaft.

c) No more than two lifts used for means of egress or fire department access shall share the same machine room or lifts pit.

d) Machine rooms shall be separated from each other by fire separation having a minimum fire resistance rating of 120 min.

e) The lifts shall be connected to back-up power supply.

f) During emergency evacuation, the lifts shall travel only between the incident level and a point of safety.

J-5.4.7 *Doors and Gates*

The egress capacity for doors and gates in a means of egress serving public areas shall be computed as,

a) 60 people per minute (p/min) for single leaf doors and gates,

b) 0.082 people/mm-min for bi-parting multi-leaf doors and gates measured for the clear width dimension, and

c) gates in a means of egress shall be designed in accordance with the requirements for doors serving as a means of egress.

J-5.4.8 *Fare Barriers*

a) Fare barriers complying with following provisions shall be permitted in the means of egress serving the stations. Such barriers shall be designed to release, permitting unimpeded

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travel in the direction of egress under all the following conditions:

1) Power failure or ground fault condition,
2) Activation of the station fire alarm signal, and
3) Manual activation from a switch in a constantly attended location in the station or operations control centre.

b) Fare barriers that do not comply with the requirements of **J-5.4.8**(a) shall be permitted in the means of egress where barriers in the equipment are designed to provide egress when a horizontal force not exceeding 66 N is applied in the egress direction.

c) Gate-type fare barriers in the means of egress shall meet the following criteria:
   1) Each unit shall provide a minimum of 450 mm clear width at and below a height of 1 000 mm and 530 mm clear width above that height.
   2) Each unit shall be credited with a capacity of 50 p/min for egress calculations.
   3) Fare barriers shall be designed so that their failure to operate properly will not prohibit movement of passengers in the direction of emergency egress.

J-5.4.9 *Horizontal Exits*

Horizontal exits shall be permitted for up to 100 percent of the number of horizontal exits and required egress capacity provided that not more than 50 percent of the number and required capacity is into a single building and provided they comply with the following provisions:

a) Width of the horizontal exit shall at least be same as that of the exit doorways;
b) A horizontal exit shall be equipped with at least one fire/smoke door of minimum 60 min fire resistance, of self-closing type. Further, it should have direct connectivity to the egress staircase for evacuation.
c) Where there is a difference in level between connected areas for horizontal exits, ramps, slope not more than 1 in 12 shall be provided.
d) Doors in horizontal exits shall be able to open at all times from both sides.

J-5.4.10 *Platform Screen and Edge Door*

Horizontal sliding platform screen or platform edge doors shall be permitted to separate the platform from the trainway in stations provided that the doors permit emergency egress from the train to the platform regardless of the stopping position of the train; and the doors provide egress when a force not exceeding 220 N is applied from the train side of the doors. The doors shall be designed to withstand positive and negative pressures caused by passing trains.

J-5.4.11 *Access for Fire Brigade Personnel*

A dedicated access staircase for firemen shall be provided in each underground station. This access shall be arranged so as to provide uninterrupted access from ground level to station concourse and platform levels. If continuous access is not feasible, smoke sealed lobbies shall be provided at concourse or other intermediate levels and such lobbies shall be protected with fire doors of adequate rating. Firemen staircases shall be maintained under positive pressure at all times.

J-5.4.12 Emergency and escape lighting and illumination of means of all exits shall comply with the various provisions under **3.4.7** in all respects.

J-6 FIRE SEPARATION AND COMPARTMENTATION

J-6.1 Fire compartments shall be provided in transit stations in accordance with the provisions of this Section. Fire ratings of various occupancies within open stations and enclosed stations shall be as indicated in Table 27.

J-6.2 Further transit station shall be divided into fire compartments by means of compartment walls and compartment floors by a fire separation of at least 120 min between following occupancies:

a) Public areas and non-public areas,
b) Transit and non-transit areas, and
c) Ancillary areas located beneath and within 3 m of the trainway in open stations

J-6.3 No fire separation shall be required for occupancies like ticketing offices, toilets, other offices and the like.

J-6.4 Incidental kiosks inside stations for other purposes like commercial use, etc shall be fire separated (120 min rating) from the station building, if areas occupied by such occupancies exceed 6 m^2.

J-6.5 Fire Doors

Fire doors shall comply with the following requirements:

a) Fire doors shall be constructed of non-combustible material having appropriate fire resistance, and two fire doors may be fitted in an opening if each door by itself is capable of closing the opening and the two doors together achieve the required level of fire resistance.
b) All fire doors shall be fitted with an automatic self-closing device, of same fire rating as of the door, which is capable of closing the door

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Table 27 Fire Ratings for Mass Rapid Transit Station Occupancies
(*Clause* J-6.1)

Sl No.	Occupancies	Fire Rating of Enclosures h		Fire Rating of Doors h	
		Open Station	Enclosed Station	Open Station	Enclosed Station
(1)	(2)	(3)	(4)	(5)	(6)
i)	Auxiliary substation, electrical UPS/battery room	2	3	1.5	3
ii)	Signalling equipment room, telecom equipment room, S&T (signalling and train control) UPS/battery room, electrical cable shafts, S&T cable shafts	2	2	1.5	1.5
iii)	Environmental control system (ECS) plant room, tunnel ventilation room, firemen's staircase, emergency equipment store, CDMA room, GSM room, sewage ejector room, sump pump room, chiller plant room, pump room, DG panel room	2	2	1.5	1.5
iv)	Station manager room, cash and ticket supervisor room, security room, stores, cleaners room, refuse storage, toilets, plumbing shafts, staff mess rooms, distribution board room and the like.	1	2	0.5	1.5

from any angle and against any latch fitted to the door.

c) Any fire door fitted within an opening which is provided as a means of escape shall be capable of being opened manually, not be held open by any means other than by an electromagnetic or electro-mechanical device which can be activated by the presence of smoke and/or the fire alarm system, provided that this shall not apply in the case of fire doors opening into pressurised exit staircases.

J-6.6 Smoke Compartmentation

a) Smoke compartments shall be created to ensure that in case of a fire scenario, the escape routes are not full of smoke and a safe passage is provided to fire fighters to reach fire location.

b) Smoke barriers shall be provided within the ceiling at platform and concourse levels at locations and spacing as determined by the engineering analysis and shall be designed to withstand temperatures up to 250°C for 60 min.

c) Smoke barriers shall also be provided around all openings containing staircases, escalators and lifts in public areas connecting platform to levels above or below them.

d) All smoke compartments created within the station areas shall be designed with segregated smoke extraction systems.

J-7 OTHER SPECIFICS REGARDING SAFETY REQUIREMENTS

a) Materials used as interior wall and ceiling and other decorative features in enclosed stations shall be non-combustible.

b) For protection against intrusion of flammable and combustible liquids and flooding of underground transit systems, any structure including emergency egress or access stairs or vent or fan shaft structure utilized for ventilation of underground system shall be permitted to be terminated at grade, provided that the level at which it is terminated is at least 450 mm above the surrounding ground level/footpath level.

c) Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow shall be designed to operate in an ambient atmosphere of 250°C for a minimum of 60 min.

d) Operation of the emergency ventilation system components shall be initiated from the central supervising station.

e) All types of kiosks like ticketing booth, information counter, commercial, if any, etc, shall be constructed with non-combustible materials.

f) Enclosed stations shall be provided with back-up power connected to lighting, protective signalling systems, emergency communication system, and fire command centre.

g) Emergency lighting shall be provided throughout the station as per **3.4.7.1**.

h) Voice evacuation/public address system shall be provided throughout the station, and ancillary buildings as per requirements.

j) Equipment rooms shall be protected by fire suppression systems as per relevant standards.

k) Emergency command centres and emergency response procedures shall be in place.

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m) Evacuation shall take place under the guidance and control of authorized, trained system employees or other authorized personnel as warranted under an emergency situation.

n) Adequate warning signs, directional signs, exit signs shall be provided throughout the facility.

J-8 BACK-UP OR EMERGENCY POWER SUPPLY

The back-up/emergency power supply shall have a capacity to cater all critical loads such as emergency lighting, protective signalling system, communication system, fire station and control room, lifts providing required egress capacity, etc.

J-9 FIRE PROTECTION FACILITIES

The following requirements shall apply to all open and enclosed metro stations above grade. Provisions for underground stations are not covered hereunder.

J-9.1 Details of Protection and Facilities Required

J-9.1.1 *Pumping Arrangements*

Each station shall be provided with two pumps having a minimum discharge of 1 620 litre/min with different prime movers. It is possible to provide two electrically driven pumps, if assured back-up power is available for driving the pumps. Jockey pump having a capacity of 180 litre/min shall also be provided to take care of minor system leakages. Electrical wiring for the pumps shall be routed from outside the station buildings in any case (*see also* **J-9.1.9**).

J-9.1.2 *Extinguishers*

a) Water CO_2 type, CO_2/ABC types, shall be provided in each platform and distributed in such a way that extinguisher is available within a travel distance of 30 m from any point.

b) Water CO_2 type, CO_2/ABC types, shall be provided in each concourse for every 300 m^2 floor area and distributed in such a way that extinguisher is available within a travel distance of 30 m from any point.

c) At least one extinguisher shall be provided for each equipment room and other enclosures for every 300 m^2 floor area.

J-9.1.3 *Small Bore Hose Reels*

a) One hose reel shall be provided for every 1 000 m^2 floor area of station platform or part thereof subject to a travel distance of 45 m to the nearest hose reel.

b) One hose reel shall be provided for every 1 000 m^2 floor area concourse or part thereof subject to a travel distance of 45 m to the nearest hose reel.

c) If equipment rooms are covered with hose reels for concourse and platform, it is acceptable.

J-9.1.4 *Fire Alarm System*

a) Provisions of detection system shall be purely based on judgement in metro stations. Detectors are required to be provided only in areas where there are false ceiling(s), false floor(s) and areas for equipment rooms. Wherever there are false ceilings, the detectors shall be provided both above and below false ceiling giving due consideration to depth of false ceiling/flooring. However, in concourse, the detectors below false ceiling may not be effective due to heights/cross ventilation and therefore may not be provided. In other areas, because of high heights and cross-ventilations, detectors will not be effective and hence they can be dispensed. A conventional detection system shall suffice at a normal station.

b) Manual call station(s) shall be provided at central location(s) on each platform (near emergency plunger) and at least two on the concourse, on each sidewall. When the concourse is in two halves, at least one manual call station shall be provided on each side.

J-9.1.5 *Clean Agent Suppression System*

Main panels like HT, LT and main power distribution, DG change over and main supply panels for the station shall be protected with the above system. Suitable detection mechanism shall be provided for triggering the system automatically.

J-9.1.6 *Provision of Hydrants and Wet Risers*

a) Minimum two hydrants shall be provided at each platform with hose box containing two lengths of hose pipes 15 m each with a nozzle (coverage about 45 m). Location of hydrants shall be staggered for better coverage. The hydrants shall cover the entire length of the platform when two hose pipes are coupled to the landing valves and used. If not fully covered, additional hydrant(s) shall be provided.

b) Minimum two hydrants shall be provided for each concourse with hose box containing two lengths of hose pipes 15 m each with a nozzle subject to travel distance of 30 m to reach the nearest hydrant. Commercial areas, if any, shall also be covered with the provision of hydrants as stated above. If equipment rooms

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and other areas are covered within 30 m of the hydrants, the same are acceptable.

c) Hydrants shall be provided at each entry to the station at ground and upper levels near staircase. At least one hydrant for parking area shall be provided subject to a travel distance of 30 m to the nearest hydrant.

J-9.1.7 *Automatic Sprinkler System*

Sprinklers are required to be provided only in the commercial areas and any combustible storage area within the station (*see also* **J-9.1.9**).

J-9.1.8 *Water Requirement*

a) For stand-alone metro stations, exclusive water requirement for the fire protection system for the installed pumping capacity as stated in **J-9.1.1** shall be at least 50 000 litre.

b) However, when commercial areas are present within metro stations, firefighting facilities shall need augmentation as in **J-9.1.9**.

J-9.1.9 In case of other type of occupancy like commercial areas inside metro stations and combustible storage area, if any within the station, the pumping/ water requirements shall be provided as per the Table 28.

Water capacity stated in the Table 28 shall be stored in two equal and interconnected compartments. Size of the main header shall not be less than 150 mm in all cases.

Entire fire protection system shall be designed and installed as per the relevant Indian Standards.

Table 28 Water Capacity
(*Clause* J-9.1.9)

Sl No.	Area Occupied by Commercial Occupancies	Hydrant Pump Capacity	Sprinkler Pump Capacity	Jockey Pumps	Common Standby Pump	Water Capacity
	m^2	litre/min	litre/min	litre/min	litre/min	litre
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Up to and including 300	← 2 280 (Common pump) →		180	2 280	75 000
ii)	More than 300 and up to 1 000	← 2 850 (Common pump) →		180	2 850	100 000
iii)	More than 1 000	2 850	2 850	180 each	2 850	200 000

ANNEX K

(*Clause* 6.4.4)

FIRE AND LIFE SAFETY REQUIREMENTS FOR METRO TRAINWAYS

K-1 APPLICATION

Provisions of this annex shall apply to all portions of underground, elevated and at-grade metro trainway including tail buffer tracks and sidings not intended to be occupied by the passengers. These provisions may be amended, if required, as per the approval of the Competent Authority.

K-2 USE AND OCCUPANCY

K-2.1 Passengers shall be allowed to enter the trainway only in the case it becomes necessary to evacuate a train.

K-2.2 Passenger evacuation from train onto the trainway shall take place only under the guidance and control of authorized, trained system employee or other authorized personnel as warranted under an emergency situation.

K-2.3 Warning signs in accordance with **K-4.4.1** shall be posted at locations where unauthorized personnel might trespass.

K-3 CONSTRUCTION

K-3.1 Construction Type

K-3.1.1 *Cut and Cover*

Where trainways are to be constructed by cut and cover method, perimeter walls, base and roof slabs and other

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related constructions shall be of not less than Type 1 or Type 2 or combination of Types 1 and 2 non-combustible constructions as defined in this Part. The type of construction shall be further determined by an engineering analysis of potential fire exposure hazards to the structure.

K-3.1.2 *Bored Tunnels*

Where trainway sections are to be constructed by a tunnelling method through earth, unprotected steel liners, reinforced concrete, shotcrete, or equivalent shall be permitted to be used.

K-3.1.3 *Rock Tunnels*

Where trainway sections are to be constructed by a tunnelling method through rock, steel bents with concrete liner, if lining is required, shall be permitted to be used.

K-3.1.4 *Underwater Tunnels*

Underwater tunnels shall be not less than Type 2 constructions.

K-3.1.5 *Mid Tunnel Ventilation Shaft and Trainway Exit structures*

Mid tunnel ventilation shafts and trainway emergency egress or access stairs shall not be less than Type 1 construction.

K-3.1.6 *At-Grade Construction*

Materials used for at-grade construction shall not be less than Type 2 materials. The type of construction shall be further determined by an engineering analysis of potential fire exposure hazards to the structure.

K-3.1.7 *Elevated Viaduct or Portals*

All elevated structures necessary for trainway support and all structures and enclosures on or under the trainway shall be of not less than Type 1 or Type 2 or combination of Type 1 and Type 2 construction. The type of construction shall be further determined by an engineering analysis of potential fire exposure hazards to the structure.

K-3.2 Protection against Intrusion of Flammable and Combustible Liquids and Flooding of Enclosed Trainway

Any structure including emergency egress or access stairs or vent or fan shaft structure utilized for ventilation of underground system shall be permitted to be terminated at grade, provided that the level at which it is terminated is at least 450 mm above the surrounding ground level/footpath level.

K-3.3 Compartmentation

K-3.3.1 Ancillary areas shall be separated from trainway areas within underwater trainway sections by construction having a minimum 180 min fire resistance rating.

K-3.3.2 Ancillary areas shall be separated from trainway areas within enclosed trainway sections by construction having a minimum 120 min fire resistance rating.

K-3.4 Combustible Components

Where combustible components not specifically mentioned here are installed in a trainway, a fire hazard analysis shall be conducted to determine that the level of occupant fire safety is not adversely affected by the contents.

K-3.5 Walking Surfaces

Walking surfaces designated for evacuation of passengers shall be constructed of non-combustible materials.

K-4 EMERGENCY EGRESS

K-4.1 Location of Egress Routes

K-4.1.1 The system shall incorporate a walking surface or other approved means for passengers to evacuate a train at any point along the trainway so that they can proceed to the nearest station or other point of safety.

K-4.1.2 Walkway continuity shall be maintained at special track sections like cross over or pocket tracks. Walkway continuity shall be provided by cross walks at track level.

K-4.1.3 Within enclosed trainways, the maximum distance between emergency exits/exit stairways shall not exceed 750 m.

K-4.1.4 For trainways in twin bore tunnels or trainways in a tunnel divided by a minimum 120 min fire rated wall separation, cross-passageways shall be permitted to be used *in-lieu* of emergency exit stairways.

K-4.1.5 Where cross passageways are utilized *in-lieu* of emergency exit stairways, the following requirements shall apply:

a) First cross-passageway shall be provided not farther than 500 m from the end of platform of an enclosed station or from the tunnel portal or from a mid-tunnel exit way.

b) Distance between any two cross-passageways shall not be more than 250 m.

c) The crossover in an enclosed trainway shall be considered as cross-passageway. The distance between crossover and subsequent cross-passageway shall not be more than 250 m.

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d) Cross-passageways shall be separated from each trainway with separate self-closing fire door assemblies having a fire protection rating of minimum 90 min.

e) A tenable environment shall be maintained in the portion of the trainway that is not involved in an emergency and that is being used for evacuation.

f) A ventilation system for the incident trainway shall be designed to control smoke in the vicinity of the passengers.

g) Provisions shall be made for evacuating passengers *via* the non-incident trainway to a nearby station or other emergency exit.

h) The provisions shall include measures to protect passengers evacuating from non-incident tunnel from oncoming traffic and from other hazards.

j) Where cross-passageways are used *in-lieu* of emergency exit stairways, the interior of the cross-passage shall not be used for any purpose other than as an area of refuge or for access/egress to the opposite tunnel, except for installation of non-combustible equipment inside the cross passageways, provided that such equipment does not infringe the required clear space of the cross-passage.

K-4.1.6 *Level of Cross Passage*

The level of cross-passage inside the tunnel shall be designed in accordance to the following requirements:

a) In trainways where passengers have to walk on the track bed during evacuation, the floor of the cross-passages in such trainways shall be kept close to the level of the track bed. The maximum permitted level difference between the level of track bed and the floor of the cross passage shall be 250 mm. Further, a smooth surface for transition of level difference shall be provided at such cross-passages.

b) In trainways where passengers have to walk on a walkway mounted at the level of the train floor during evacuation, the floor of the cross-passages in such trainways shall be kept in level with the walkway. Further, such walkways shall always be provided on the cross-passageway side of the trainway for unobstructed access to the cross-passageway.

K-4.1.7 For open-cut trainways, an engineering analysis shall be conducted to evaluate the impact of the trainway configuration on safe egress from a train fire to a point of safety.

K-4.1.8 Where the engineering analysis indicates that the configuration will impact tenability beyond the immediate vicinity of the fire, egress routes shall be provided such that the maximum distance from any point within the open-cut section to a point of egress from the trainway shall not be more than 380 m.

K-4.1.9 All the distances mentioned in **K-4.1.3**, **K-4.1.5** and **K-4.1.8** shall be permitted with a maximum variation of $^{+10}_{0}$ percent.

K-4.2 Size of Egress Routes

K-4.2.1 Cross-passageways shall be a minimum of 1 200 mm in clear width and 2 100 mm in height.

K-4.2.2 The width of exit stairs shall not be required to exceed 1 200 mm for enclosed trainways.

K-4.2.3 If double leaf doors wider than 1 200 mm are provided in egress routes serving trainways, then size of active leaf shall not be less than 810 mm.

K-4.3 Egress Components

K-4.3.1 Walking surfaces serving as egress routes within guide ways shall have a uniform, slip-resistant design except as permitted herein.

a) Where the trainway track bed serves as the emergency egress pathway, it shall be nominally level and free of obstructions.

b) Walkways that are more than 750 mm above the floor or grade below shall be provided with a continuous handrail along the side opposite the trainway.

c) Raised walkways that are greater than 1 200 mm wide and located between two trainways shall not be required to have a handrail.

d) Doors in the means of egress, except cross-passageway doors, shall open in the direction of exit travel.

e) Doors in the means of egress shall,

   1) open fully when a force not exceeding 220 N is applied to the latch side of the door, and

   2) be adequate to withstand positive and negative pressures caused by passing trains and the emergency ventilation system.

K-4.3.2 Horizontal sliding doors shall be permitted in cross-passageways.

K-4.4 Signage, Illumination and Emergency Lighting

K-4.4.1 Warning signs posted on entrances to the

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trainway and on fences or barriers adjacent to the trainway shall clearly state the hazard (for example, DANGER: HIGH VOLTAGE — 25 000 V) with letter sizes and colours in conformance with requirements of *Metro Railway Rules*.

K-4.4.2 System egress points shall be illuminated.

K-4.4.3 Points of exit from elevated and enclosed trainways shall be marked with internally or externally illuminated signs.

K-4.4.4 *Identification*

Emergency exit facilities shall be identified and maintained to allow for their intended use.

K-4.4.5 Enclosed trainways greater in length than the minimum length of one train shall be provided with directional signs as appropriate for the emergency procedures developed for the metro system.

K-4.4.6 Directional signs indicating station or portal directions shall be installed at maximum 25 m intervals on either side of the enclosed trainways.

K-4.4.7 Directional signs shall be readily visible by passengers for emergency evacuation.

K-5 FIRE PROTECTION AND LIFE SAFETY SYSTEMS

K-5.1 Emergency Access

K-5.1 Except as described herein, points of egress and exits from the guide way shall serve as emergency access routes.

K-5.2 If security fences are used along the trainway, access gates shall be provided in security fences.

K-5.3 Access gates shall be a minimum 1 200 mm wide and shall be of the hinged or sliding type.

K-5.4 Access gates shall be placed as close as practicable to the portals to permit easy access to tunnels.

K-5.5 Information that clearly identifies the route and location of each gate shall be provided on the gates or adjacent thereto.

K-5.6 Access to the elevated trainway shall be from stations or by mobile ladder equipment from roadways adjacent to the track way.

K-5.7 If no adjacent or crossing roadways exist for the elevated trainway, access roads at a maximum of 750 m intervals shall be required.

K-5.8 Where the configuration of an open-cut trainway prevents or impedes access for firefighting, provisions shall be made to permit fire fighter access to that section of trainway at intervals not exceeding 750 m.

K-5.9 All the distances mentioned in **K-5.7** and **K-5.8** above shall be permitted with a maximum variation of $^{+10}_{0}$ percent.

ANNEX M

(*Clause* 6.7.3)

FIRE PROTECTION CONSIDERATIONS FOR VENTING IN INDUSTRIAL BUILDINGS

M-1 APPLICATION

M-1.1 The provisions given below are applicable only to single storey industrial buildings (factories and storage buildings) covering large floor areas without sub-dividing/separating walls which are usually designed to meet modern production methods.

M-1.2 The requirements of fire and explosion venting of industrial buildings, as dealt with in this section, fall under two categories:

a) Smoke and fire venting, and

b) Explosion relief vents.

M-2 SMOKE AND FIRE VENTING

M-2.1 The basic considerations for formulating the design and other requirements for smoke and fire vents are as given in **M-2.1.1** to **M-2.1.20**.

M-2.1.1 The smoke and hot combustion products from a fire, being lighter than the surrounding air, tend to rise, and on reaching the roof or ceiling spread out (mushroom) on all sides and form a layer which floats on top of the cold air beneath. In the absence of vents, this layer becomes progressively deeper until the whole building is filled with hot smoky gases. The time consumed for this to happen may be only a few minutes, depending on variables like, type of materials on fire, process/storage conditions involved, etc.

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M-2.1.2 The hot gases at the roof level moved by convection currents contribute to rapid lateral spread of fire.

M-2.1.3 The provision of properly designed and suitably located vents in adequate number helps the speedy removal of smoke and hot gases, thereby preventing spread of fire, besides reducing risks of explosion of unburnt gases and reducing damage to the contents and structure of the building by heat and smoke. In addition, they facilitate firefighting operations, and minimise personal hazards to the firemen.

M-2.1.4 The time taken for accumulation of smoke and hot gases within a building on fire being very short, the venting devices installed shall be designed to operate in the early stage of the fire and must be automatic so as to ensure speed and efficiency in their operation.

M-2.1.5 The smoke and fire venting system shall be designed in such a manner as to keep the temperature of the combustion products from the fire as low as possible, preferably below approximately 150°C.

M-2.1.6 Automatic venting systems are complementary to the fire extinguishing systems, and automatic sprinklers, where provided, should operate before the operation of the vents; otherwise, venting may delay sprinkler operation.

M-2.1.7 It is easier to vent a building of smoke than clear it of smoke once it has been filled.

M-2.1.8 Venting is particularly desirable in large area industrial buildings or warehouses, windowless buildings, underground structures or in areas housing hazardous operations. Automatic fire vents shall be provided for all industrial occupancies (including storage buildings) classified as medium hazard or above having floor areas exceeding 750 m^2, irrespective of whether they are compartmentalized or not.

M-2.1.9 These provisions do not cover other aspects, of ventilation (or lighting) designed for regulation of temperature within a building for personal comfort or meeting process needs.

M-2.1.10 Similarly, fire and smoke venting requirements as given here under are also not applicable to multi-storeyed buildings, as their requirements are different and more complex.

M-2.1.11 It is difficult to determine precise venting requirements on account of the many variables involved. For instance, the rate of combustion varies appreciably according to the nature, shape, size and packaging of the combustible materials as well as the size, height and disposition of the stacks of materials.

M-2.1.12 In industrial buildings of floor area less than 750 m^2 and used as low fire hazard occupancies, conventional ventilators fitted high up near the eaves of the external walls may serve as vents for smoke and hot gases, provided care is taken to ensure that they are kept open at all times or are designed to open automatically in case of fire.

M-2.1.13 Extinction of fires by closing the doors and windows is not likely in the case of industrial buildings because of their large size, where sufficient air to sustain the fire at least in the initial stages can be expected to be present.

M-2.1.14 Of the two types of building ventilation, namely, vertical and horizontal, vertical ventilation is the one commonly adopted in the case of single storey industrial buildings.

M-2.1.15 Since 70 to 80 percent of heat produced in a fire is convective heat, the ventilation system has to be suitably designed to ensure early outflow of the heat and thereby minimise fire spread.

M-2.1.16 Combustible roof linings shall be avoided, as they themselves will contribute to the spread of fire, thereby multiplying the venting problems.

M-2.1.17 A wind blowing across a flat roof or a roof with a pitch under 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out on the leeward side, but oppose outward flow on the windward side of the roof.

M-2.1.18 For vents to work at full efficiency, the area of the inlets for cold air entering the compartment must equal at least the total area of the vents. Ideally, the inlets shall be as close to the ground as possible.

M-2.1.19 Where roof vents are installed in a single-storey building any neighbouring buildings, particularly those of more than one storey, will be subject to some degree of exposure hazard either from flying birds or radiation, or both, as a result.

M-2.1.20 If vents are to be installed, the size, design, number and disposition of the vents and the associated roof screens/curtain boards have to be assessed after careful analysis of the various factors stated under **M-2.1.11**, as well as other related factors like type of building construction, nature and height of roof, process hazards, exposure hazard, etc.

M-2.2 Venting Area

M-2.2.1 The estimated requirements for ventilation are largely based on the assumed build-up of the fire from the time of initial outbreak to the time of effective fire fighting action by fire brigade.

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M-2.2.2 The vent area required to be provided shall be approximately proportional to the perimeter of the fire area, because the entrained air forms the bulk of the vented gases.

M-2.2.3 The effective area shall be the minimum cross-sectional area through which the hot gases must flow out to the atmosphere.

M-2.2.4 No consideration shall be given to the increased air movement obtained by power operated fans, since it must be assumed that in the event of fire, power will be interrupted, or fans damaged by heat.

M-2.2.5 The total vent areas to be provided shall be as per the following ratios of effective area of vent openings to floor area for various occupancy classifications indicated:

a) Low heat release content (Sub-division G-1) — 1 : 150

b) Moderate heat release content (Sub-division G-2) — 1 : 100

c) High heat release content (Sub-division G-3) — 1 : 30 to 1 : 50

M-2.3 Types of Vents

M-2.3.1 Venting shall be accomplished by any of the types such as monitors continuous gravity vents, until type vents or sawtooth roof skylights.

M-2.3.2 Where monitor type vents are installed, wire glass or metal panels shall be used only if the sash is arranged to open automatically.

M-2.3.3 The use of plain thin glass for venting shall be avoided on account of its unpredictable behaviour during fire. However, if glass or other suitable plastic sheet materials with early disintegration characteristics are used, they should be designed for automatic operation.

M-2.3.4 Where monitors or unit type vents are used, the panels shall be hinged at the bottom and designed to open automatically. Both sides of the vents shall be designed to vent simultaneously to ensure that their effectiveness at the time of fire is not in any way impeded by wind direction.

M-2.3.5 Where movable shutters are provided for continuous gravity vents, these shall open automatically in the event of fire.

M-2.3.6 Unit type vents shall be of relatively small area, ranging between 1 m^2 and 9 m^2, having light weight metal frames and housing with hinged dampers which shall be designed for both manual and automatic operation.

M-2.3.7 Sawtooth roof skylight shall be considered as satisfactory for venting purposes only when designed for automatic operation.

M-2.3.8 Likewise, exterior wall windows shall not be reckoned as satisfactory means for venting of fire gases and smoke in industrial buildings. However, they may be reckoned as additional means of venting when, they are located close to the caves and are provided with ordinary glass or movable sash arranged for both manual and automatic operation.

M-2.3.9 Baffles shall not be installed inside vents, as they greatly reduce the effective area for venting.

M-2.4 Vent Operation

M-2.4.1 The vents shall be automatic in operation, unless where specified in these provisions that they shall be designed for both manual and automatic operation.

M-2.4.2 The release mechanism shall be simple for operation and independent of electrical power, since electrical services may be interrupted by fire.

M-2.4.3 The automatic operation of vents shall be achieved by actuation of fusible links or other types of heat and smoke detectors, or by interlocking with operation of sprinkler system or any other automatic fire extinguishing system covering the area. Following their release, the vents shall be designed to open by a system of counterweights and associated equipment utilizing the force of gravity or spring loaded levers.

M-2.4.4 Automatic fire alarm system, where installed, shall be coupled to the automatic vents to ensure simultaneous operation.

M-2.4.5 Automatic sprinklers, where installed, shall operate before the vents open order to avoid any likely delay in sprinkler operation. However, heat actuated devices used for vent release shall be suitably shielded from sprinkler discharge so that water does not delay their action. Further, provision of operating the vents manually may also be provided.

M-2.4.6 Premises where height of roof apex is 10 m or more or where the materials handled or stored have high smoke producing characteristics, in addition to fusible links, the vent release mechanism shall be interlinked to smoke actuated automatic fire detectors to ensure early operation of vents.

M-2.4.7 Non-corrosive materials shall be used for hinges, hatches and other related parts to ensure long fail-safe operation of the vents.

M-2.4.8 In case of any doubts regarding the types of vents required to be installed for any particular occupancy, authorities having jurisdiction shall be consulted.

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M-2.5 Size, Spacing and Disposition of Vents

M-2.5.1 Vents shall be correctly sited to ensure their functional efficiency. Ideally, they shall be sited at the highest point in each area to be covered.

M-2.5.2 They shall, as far as possible, be located immediately above the risk to be protected so as to allow free and speedy removal of smoke and other combustion products in the event of fire.

M-2.5.3 The minimum dimension for an effective vent opening shall be not less than 1.25 m in any direction.

M-2.5.4 The spacing of the individual vent shall be based on the principle that more number of well distributed smaller vents are more effective than fewer number of badly located larger vents.

M-2.5.5 The maximum spacing between vents for the three occupancy classifications shall be as follows:

a) Low heat release content : 45 m between centres

b) Moderate heat release content : 36 to 37 m between centres

c) High heat release content : 22.5 to 30 m between centres, depending on the severity of fire potential.

M-2.5.6 Vents shall be placed in a sheltered situation where advantage can be taken of the prevailing wind. The design of the vent shall be such as to produce a suction effect. A wind blowing across a flat roof or one with a pitch of 40° produces a negative pressure, that is, it tends to draw gases out of the building and so aids venting of hot gases. Wind blowing across a roof of pitch greater than 40° will draw gases out of the leeward side, but oppose outward flow on the windward side of the roof.

M-2.5.7 Low level inlets, with total area not less than the total area of vents, shall be provided to permit outside air to be drawn in to aid automatic venting. These inlets, which may be in the form of doors, windows or such other openings, shall be designed for manual operation when desired.

M-2.6 Roof Screens or Curtain Boards

M-2.6.1 Industrial buildings with large areas and having no subdivision/separating walls limiting the area of individual compartments to 750 m^2 or less, shall be provided with roof screens or curtain boards.

These screens which extend from the roof downwards at specific intervals not only prevent lateral spread of heat and smoke in the event of fire below, but substantially assist in early operation of automatic sprinklers and vents.

M-2.6.2 They shall be of sheet metal or any other substantially non-combustible material strong enough to withstand damage by heat or impact.

M-2.6.3 They shall be reasonably gas-tight, although small openings for passage of pipes, conduits, etc, shall be permitted.

M-2.6.4 They shall extend down from the roof/ceiling for a minimum depth of 2.2 m. Around specific hazards, the depth shall be 4 m. Where roof/ceiling height exceeds 15 m they shall extend down to within 3 m of the floor. For pitched sawtoothed roofs, they shall extend down to truss level dividing the roof into compartments.

M-2.6.5 In moderate hazard occupancies, the distance between the screens/curtain boards shall not exceed 75 m and the curtained areas shall be limited to a maximum of 4 500 m^2.

M-2.6.6 In high hazard occupancies, the distance between screens shall not exceed 30 m and the curtained area shall be limited to 750 m^2.

M-2.6.7 The curtained roof area shall be so arranged that they effectively aid in the venting of smoke and hot gases through the automatic vents provided in each area.

M-2.6.8 In sprinklered buildings, the screens shall preferably be so located as to coincide with the individual sprinkler system areas.

M-3 EXPLOSION RELIEF VENTS

M-3.1 Industrial premises where combustible dusts can accumulate or where flammable gases, vapours or mists in explosive concentrations may be present are constantly exposed to explosion hazards. Pressures developed by such explosions may be of the order of 7×10^5 Pa and ordinary buildings will not be able to withstand the shock of such pressures. Hence, such buildings require explosion relief vents for preventing structural damage.

M-3.2 Basic Principle/Considerations

M-3.2.1 Most ordinary building walls will not withstand a sustained internal pressure as great as 6.9×10^3 Pa. Hence, explosion relief vents for buildings must be designed to operate at pressures well below those at which the building walls will fail.

M-3.2.2 There is a rise in pressure during an explosion within an enclosure even with open, unobstructed vents, and any delay in opening the venting devices increases that pressure.

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M-3.2.3 Structural damage can be minimised by locating hazardous operations or equipment outside buildings and cut-off from other operations by a pressure resisting wall. Such isolated processes or equipment shall be housed in single-storey buildings properly vented and a device provided at the inlet of the collector which will prevent an explosion from blowing back through the duct work and into the building.

M-3.2.4 Where highly hazardous operations cannot be located outside of main buildings they shall be segregated by pressure resisting walls and each such unit shall be ventilated outdoors. External walls may be of heavy construction, if equipped with suitable vents or high weight panels which blow out easily.

M-3.2.5 Operations or equipment involving explosion hazards shall not be permitted in basements or areas partially below grade.

M-3.2.6 Fire can be expected to follow an explosion in most occupancies, so that any fixed fire extinguishing equipment, like sprinklers, if installed, shall be such that only the minimum damage is caused to it.

M-3.2.7 For a given material, the finer the particle size of the dust, the more violent is the explosion. Some materials, such as aluminium powder, hydrogen, and acetylene, are difficult to vent effectively due to the rapid rate of pressure rise. Some slow burning materials, such as coal dust in a confined space, may do much damage because of the longer duration of their presence. Some dusts, such as magnesium, titanium and zirconium and several metal hydrides may react with and ignite in some common inert gases, such as nitrogen and carbon dioxide.

M-3.2.8 The maximum explosion pressure in a vented structure decreases as the size of the vent increases, but is independent of the rupturing pressure of a diaphragm.

M-3.2.9 The most effective vent for the release of explosion pressures is an unobstructed vent opening.

M-3.2.10 Pressure required to rupture diaphragms of the same area and material directly varies with the thickness of the material.

M-3.2.11 The slower the rate of pressure rise, the more easily can the explosion be vented.

M-3.2.12 The degree of venting required is directly proportional to the degree of explosion hazard.

M-3.2.13 Experience has shown that most explosions of dusts, vapours and gases do not involve a large part of the total volume of the enclosure, and frequently occur near the upper or lower limits of the explosive range. Consequently, such explosions are relatively weak compared with the optimum.

M-3.2.14 Rectangular unrestricted vents are as effective as square vents of equal area.

M-3.3 Types of Explosion Relief Vents

M-3.3.1 The explosion relief vents shall be any one or more of the following types, depending on individual requirements as assessed by the Authority. Open or unobstructed vents, louvres, open roof vents, hanger type doors, building doors, windows, roof or wall panels or movable fixed sash.

M-3.3.2 The effect or external wind pressure or suction on these devices shall be taken into consideration while designing and selecting the type of vents, since wind pressures may reach over 2×10^5 Pa in severe wind storms.

M-3.3.3 The type of vent for explosion relief for any occupancy shall be selected with life safety as the primary aim followed by minimum damage to property.

M-3.3.4 Where large hanger type doors of metal curtain doors in side walls are used as vents, care shall be taken to ensure that they are kept wide open during operations.

M-3.3.5 Where weather hoods are used to cover roof vents, they shall be as light as possible and lightly attached so as to enable them to be blown off quickly when an explosion occurs.

M-3.3.6 Doors and windows when used as explosion vents shall be installed to swing outwards. Doors shall have friction, spring or magnetic latches that will function automatically to permit the door to open under slight internal pressure.

M-3.3.7 Movable sash shall be of the top or bottom hinged or protected type. These shall be equipped with a latch or friction device to prevent accidental opening due to wind action or intrusion. Such latches or locks shall be well maintained.

M-3.3.8 Fixed sash shall be set in place with very light wall anchorages, or, if tight, shall be securely fitted and glazed with plastic panes in plastic putty.

M-3.3.9 Where the process is such that the whole of a building or a room may be desirable to arrange for a lightly constructed wall or roof to collapse and thus avert the worst effects of an explosion.

M-3.4 Design, Size and Disposition of Vents

M-3.4.1 The required area of explosion vents shall ordinarily depend on the expected maximum intensity of an explosion in the occupancy, the strength of the structure, the type of vent closure and other factors.

M-3.4.2 Venting shall be planned in such a manner as to prevent injury to personnel and damage to exposure.

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In congested locations, substantial ducts or diverters shall be provided to direct the blast.

M-3.4.3 When ductwork is used, the ducts shall be of sufficient strength to withstand the maximum expected explosion pressure.

M-3.4.4 Where explosions are likely within duct and piping systems, they shall be vented by the use of suitable diaphragms designed to blow out at a predetermined pressure. There shall be no physical connection between ductwork system for more than one collector.

M-3.4.5 In large structures, the position of vents shall be relative to the point of origin of explosion, when it can be determined.

M-3.4.6 Where relatively slow explosions involving coal dust, chlorinated solvents, etc, are involved, light, hinged swinging panels may be preferred to diaphragm type of vents.

M-3.4.7 Obstructions of any kind blocking the vents from the risk covered shall be avoided, particularly where risks of rapid violent explosions are present.

M-3.4.8 Counter weights add to the inertia of the vents and so shall be avoided.

M-3.4.9 Various relieving devices, including devices actuated by detonators, shall start to open at as low a pressure as possible. They shall be of light construction, so that full opening can be quickly attained.

M-3.4.10 Vents shall be of such size and design as to prevent rupture of the protected device or apparatus.

M-3.4.11 Skylights or monitors with movable sash that will open outwards, or fixed sash containing panes of glass or plastic that will blow out readily under pressure from within, can be used to supplement wall vents or windows, provided resistance to their displacement or opening is kept as low as consistent with the requirements for structural strength.

M-3.4.12 Flexible plastic sheets when used for vent closures shall be installed in slotted frames in such a way that pressure from within bulges the sheets and releases them from the holding frame.

M-3.4.13 Fragile sheets made of plastic, when used for vent closures, shall be thin sheets that will crack or rupture under less pressure than single strength glass. For this reason use of transparent or translucent plastic sheets is more advantageous than use of glass in window sash.

M-3.4.14 If closed vents are used they shall be larger in area than unenclosed vents to provide equivalent explosion pressure relief.

M-3.4.15 Small enclosures, such as machines, shall be vented more generously than buildings, because if an explosion occurs in a machine, its entire volume may be involved.

M-3.4.16 Vents for the protection of buildings and equipment shall be installed on the following basis:

a) Small enclosures of less than 30 m^3, machines and ovens of light construction: 1 000 cm^2 for each 0.3 m^3 to 0.9 m^3.

b) For small enclosures of more substantial construction having reasonably high bursting strength: 1 000 cm^2 for each 0.9 m^3.

c) Fairly large enclosures of 30 to 700 m^3, such as bins, silos, rooms, storage tanks, etc: 1 000 cm^2 for each 0.9 m^3 to 1.5 m^3. In these cases, attempt shall be made to the extent possible to predict the likely point of origin of the explosion in relation to the vent.

d) Large rooms and buildings over 700 m^3 containing hazardous equipment comprising a small fraction of the entire volume:

   1) For heavy reinforced concrete, walls: 100 cm^2 for each 2.25 m^3.
   2) For light reinforced concrete, brick or wood construction: 1 000 cm^2 for each 1.65 m^3 to 2.25 m^3.
   3) For lightweight construction such as prefabricated panels: 1 000 cm^2 for each 1.5 m^3 to 1.65 m^3.

e) Large rooms or building over 700 m^3 containing hazardous equipment comprising a large part of the entire volume of a room or building shall be vented as generously as possible: 1 000 cm^2 for each 0.3 m^3 to 1.05 m^3.

f) In order to obtain these ratios, the size of the building or room must be limited. For some hazardous materials, such as hydrogen, acetylene, carbon disulphide, etc, these limits are extremely low.

g) Emphasis shall always be placed on segregating hazardous areas by means of firewalls or separating walls to prevent spread of fire.

h) Interior walls of light construction, such as tile, shall be avoided in hazardous locations, since they can cause injuries to personnel in the event of an explosion.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part.

	IS No.	*Title*
(1)	3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(2)	IS/ISO 834-1 : 1999	Fire resistance tests — Elements of building construction Part 1 General requirements
	IS/ISO 834-4 : 2000	Fire resistance tests — Elements of building construction: Part 4 Specific requirements for load bearing vertical separating elements
	IS/ISO 834-5 : 2000	Fire resistance tests — Elements of building construction: Part 5 Specific requirements for load bearing horizontal separating elements
	IS/ISO 834-6 : 2000	Fire resistance tets — Elements of building constructions: Part 6 Specific requirements for beams
	IS/ISO 834-7 : 2000	Fire resistance tests — Elements of building construction: Part 7 Specific requirements for columns
	IS/ISO 834-8 : 2003	Fire resistance tests — Elements of building construction: Part 8 Specific requirements for non-load bearing vertical separating elements
	IS/ISO 834-9 : 2003	Fire resistance tests — Elements of building construction: Part 9 Specific requirements for non-load bearing ceiling elements
(3)	8757 : 1999	Glossary of terms associated with fire safety (*first revision*)
	7673 : 2004	Glossary of terms for fire fighting equipment (*first revision*)
(4)	8758 : 2013	Code of practice for fire precautionary measures in construction of temporary structures and pandals (*second revision*)
(5)	9668 : 1990	Code of practice for provision and maintenance of water supplies and fire fighting
	3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
(6)	1646 : 2015	Code of practice for fire safety of buildings (general) : Electrical installations (*third revision*)
(7)	9457 : 2005	Code of practice for safety colours and safety signs (*first revision*)
	12349 : 1988	Fire protection — Safety sign
	12407 : 1988	Graphic symbols for fire protection plans
(8)	11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm system
(9)	655 : 2006	Specification for air ducts
(10)	1649 : 1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances (*first revision*)
	1642 : 2013	Code of practice for safety of buildings (general): Details of construction (*second revision*)
(11)	12777 : 1989	Method for classification of flame spread of products
(12)	1642 : 2013	Code of practice for safety of buildings (general): Details of construction (*second revision*)
(13)	16246 : 2015	Elastomer insulated cables with limited circuit Integrity when affected by fire — Specification
(14)	6044 (Part 1) : 2013	Liquefied petroleum gas storage installations — Code of Practice : Part 1 Residential commercial and industrial cylinder installations
	6044 (Part 2) : 2001	Code of Practice for liquefied petroleum gas storage Installations: Part 2 Commercial, industrial and domestic bulk storage installations
(15)	2175 : 1988	Specification for heat sensitive fire detectors for use in automatic fire alarm system (*second revision*)
	IS/ISO 7240-5 : 2003	Fire detection and alarm systems: Part 5 Point-type heat detectors
	IS/ISO 7240-7 : 2011	Fire detection and alarm systems: Part 7 Point-type smoke detectors using scattered light, transmitted light or ionization

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IS No.	*Title*
IS/ISO 7240-11 : 2011	Fire detection and alarm systems: Part 11 Manual call points
IS/ISO 7240-15 : 2004	Fire detection and alarm systems: Part 15 Point-type fire detectors using scattered light, transmitted light or ionization sensor in combination with a heat sensor
11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm system
(16) 2189 : 2008	Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (*second revision*)
(17) 636 : 1988	Specification for non-percolating flexible fire fighting delivery hose (*third revision*)
884 : 1985	Specification for first-aid hose reel for fire fighting(*first revision*)
901 : 1988	Specification for couplings, double male and double female instantaneous pattern for fire fighting (*third revision*)
902 : 1992	Specification for suction hose couplings for fire fighting purposes (*third revision*)
903 : 1993	Specification for fire hose delivery couplings, branch pipe, nozzles and nozzle spanner (*fourth revision*)
904 : 1983	Specification for two-way and three-way suction collecting heads for fire fighting purposes (*second revision*)
905 : 1980	Specification for delivery breechings, dividing and collecting, instantaneous pattern for fire fighting purposes (*second revision*)
906 : 1988	Specification for revolving branch pipe for fire fighting (*third revision*)
907 : 1984	Specification for suction strainers, cylindrical type for fire fighting purpose (*second revision*)
908 : 1975	Specification for fire hydrant, stand post type (*second revision*)
909 : 1992	Specification for underground fire hydrant : Sluice valve type (*third revision*)
910 : 1980	Specification for combined key for hydrant, hydrant cover and lower valve (*second revision*)

IS No.	*Title*
926 : 1985	Specification for fireman's axe (*second revision*)
927 : 1981	Specification for fire hooks (*second revision*)
928 : 1984	Specification for fire bells (*second revision*)
937 : 1981	Specification for washers for water fittings for fire fighting purposes (*second revision*)
939 : 1977	Specification for snatch block for use with fibre rope for fire brigade use (*first revision*)
941 : 1985	Specification for blowers and exhauster for fire fighting (*second revision*)
942 : 1982	Functional requirements for 275 l/min portable pump set for fire fighting (*second revision*)
943 : 1979	Functional requirement for 680 l/min trailer pump for fire brigade use (*second revision*)
944 : 1979	Functional requirement for 1800 l/min trailer pump for fire brigade use (*second revision*)
947 : 1985	Functional requirement for towing tender for trailer fire pump for fire brigade use (*first revision*)
948 : 1983	Functional requirement for water tender, Type A, for fire brigade use (*second revision*)
949 : 2012	Functional requirement for emergency (rescue) tender (*third revision*)
950 : 2012	Functional requirements for water tender, Type B for fire brigade use (*third revision*)
952 : 1986	Specification for fog nozzle for fire brigade use (*second revision*)
955 : 1980	Functional requirements for dry power tender for fire-brigade use (150 kg capacity) (*first revision*)
957 : 1967	Specification for control van for fire brigade
1941 (Part 1) : 1976	Functional requirements for electric motor sirens : Part 1 AC, 3-Phase, 50 Hz, 415 volts type (*second revision*)
2097 : 2012	Specification for foam making branch pipe and foam inductor (*second revision*)
2175 : 1988	Specification for heat sensitive fire detectors for use in automatic detectors for use in automatic fire alarm system (*second revision*)
2546 : 1974	Specification for galvanized mild steel fire bucket (*first revision*)

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IS No.	*Title*
2696 : 1974	Functional requirements for 1125 l/min light fire engine (*first revision*)
2745 : 1983	Specification for non-metal helmet for firemen and civil defence personnel (*second revision*)
2871 : 2012	Specification for branch pipe, universal for fire fighting purposes (*second revision*)
2878 : 2004	Specification for fire extinguisher, carbon-dioxide type (portable and trolley mounted) (*third revision*)
2930 : 1980	Functional requirements for hose laying tender for fire brigade use (*first revision*)
3582 : 1984	Specification for basket strainers for fire fighting purposes (cylindrical type) (*first revision*)
4308 : 2003	Specification for dry chemical powder for fire fighting B and C class fires (*second revision*)
4571 : 1977	Specification for aluminium extension ladders for fire brigade use (*first revision*)
4643 : 1984	Specification for suction wrenches for fire brigade use (*first revision*)
4861 : 1984	Specification for dry powder for fighting fires in burning metals (*first revision*)
4927 : 1992	Specification for unlined flax canvas hose for fire fighting (*first revision*)
4928 : 1986	Specification for delivery valve for centrifugal pump outlets (*first revision*)
4947 : 2006	Specification for gas cartridges for use in fire extinguishers (*third revision*)
4989 : 2006	Foam concentrate for producing mechanical foam for fire fighting — Specification (*third revision*)
4989 (Part 4) : 2003	Specification for multipurpose aqueous film forming foam liquid concentrate for extinguishing hydrocarbon and polar solvent fires
5131 : 2002	Specification for dividing breeching with control, for fire brigade use (*second revision*)
5290 : 1993	Specification for landing valve (*third revision*)
5486 : 1985	Specification for quick release knife (*first revision*)
5505 : 1985	Specification for multi-edged rescue axe (non-wedging) (*first revision*)
5612	Specification for hose-clamps and hose-bandages for fire brigade use
(Part 1) : 1977	Hose clamps (*first revision*)
(Part 2) : 1977	Hose bandages (*first revision*)
5714 : 1981	Specification for hydrant, stand-pipe for fire fighting (*first revision*)
6026 : 1985	Specification for hand operated sirens (*first revision*)
6067 : 1983	Functional requirements for water tender, Type 'X' for fire brigade use (*first revision*)
IS/ISO 7240-5 : 2003	Fire detection and alarm systems — Part 5: Point-type heat detectors
IS/ISO 7240-7 : 2011	Fire detection and alarm systems — Part 7: Point-type smoke detectors using scattered light, transmitted light or ionization
IS/ISO 7240-11 : 2011	Fire detection and alarm systems — Part 11 Manual call points
8090 : 1992	Specification for couplings, branch pipe, nozzle, used in hose reel tubing for fire fighting (*first revision*)
8096 : 1992	Specification for fire beaters (*first revision*)
8149 : 1994	Functional requirements for twin CO_2 fire extinguishers (trolley mounted) (*first revision*)
8423 : 1994	Specification for controlled percolating hose for fire fighting (*first revision*)
8442 : 2008	Specification for stand post type water and foam monitor for fire fighting (*first revision*)
9972 : 2002	Specification for automatic sprinkler heads (*first revision*)
10460 : 1983	Functional requirements for small foam tender for fire brigade use
10658 : 1999	Specification for higher capacity dry powder fire extinguisher (trolley mounted) (*first revision*)
10993 : 1984	Functional requirements for 2 000 kg dry powder tender for fire brigade use
11101 : 1984	Specification for extended branch pipe for fire brigade use

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IS No.	*Title*
11108 : 1984	Specification for portable fire extinguisher halon-1211 type
11833 : 1986	Specification for dry powder fire extinguisher for metal fires
12717 : 1989	Functional requirements of fire fighting equipment — High capacity portable pumpset (1 100-1 600 l/min)
12796 : 1989	Specification for fire rake
13039 : 1991	Code of practice for provision and maintenance of external hydrant system
13385 : 1992	Specification for fire extinguisher 50 capacity wheel mounted water type (Gas cartridge)
13386 : 1992	Specification for 50 litre capacity fire extinguisher, mechanical foam type
14609 : 1999	Specification for ABC dry powder for fire fighting
14933 : 2001	Specification for high pressure fire fighting hose
14951 : 2001	Specification for fire extinguisher, 135 litre capacity mechanical foam type
15051 : 2002	Specification for high pressure fire hose delivery couplings
IS 15105 : 2002/ ISO 6182-1	Design and installation of fixed automatic sprinkler fire extinguishing system
IS 15220 : 2002/ ISO 7201-1	Specification for halon 1211 and halon 1301 — fire extinguishing media for fire protection
IS 15683 : 2006/ ISO 7165 : 2009	Portable fire extinguishers — Performance and construction — Specification
11360 : 1985	Specification for smoke detectors for use in automatic electrical fire alarm system
IS 15493 : 2004/ ISO 14520-1	Gaseous fire extinguishing systems : General requirements
IS 15505 : 2004/ ISO 14520-6	Gaseous fire extinguishing systems: HCFC Blend A extinguishing systems
IS 15506 : 2004/ ISO 14520-14	Gaseous fire extinguishing systems — IG 55 extinguishing systems
IS 15525 : 2004/ ISO 14520-13	Gaseous fire extinguishing systems — IG 100 extinguishing systems
IS 15501 : 2004/ ISO 14520-15	Gaseous fire extinguishing systems — IG 541 extinguishing systems
IS 15497 : 2004/ ISO 14520-12	Gaseous fire extinguishing systems — IG 01 extinguishing systems
15519 : 2004	Code of practice for water mist fire protection systems — System design, installation and commissioning
IS 15517 : 2004/ ISO 14520-9	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and local application including in cabinet subfloors systems
IS 15517 : 2004/ ISO 14520-9	Gaseous fire extinguishing systems — HFC 227ea (Hepta Fluoro Propane) extinguishing system
(18) 2190 : 2010	Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (*fourth revision*)
(19) 884 : 1985	Specification for first aid hose reel for fire fighting (*first revision*)
(20) 15105 : 2002	Design and installation of fixed automatic sprinkler fire extinguishing system
(21) 15325 : 2003	Design and installation of fixed automatic high and medium velocity water spray system — Code of practice
(22) 12835 (Part 1) : 1989	Design and installation of fixed foam fire extinguishing system — Code of practice: Part 1 Low expansion foam
(23) 15528 : 2004	Gaseous fire extinguishing systems — Carbon dioxide, total flooding and local application (sub-floor and in-cabinet), high and low floor pressure (refrigerated) systems
(24) 15519 : 2004	Water mist fire protection systems — System design, installation and commission ing — Code of Practice
(25) 15493 : 2004	Gaseous fire extinguishing Systems — General requirements
15497 : 2004	Gaseous fire extinguishing systems — IG 01 extinguishing systems
15501 : 2004	Gaseous fire extinguishing systems — IG 541 extinguishing systems
15505 : 2004	Gaseous fire extinguishing systems — HCFC Blend A

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IS No.	*Title*
15506 : 2004	Gaseous fire extinguishing systems — IG 55 extinguishing systems
15517 : 2004	Gaseous fire extinguishing systems — HFC 227 ea (Hepta fluoro propane) extinguishing systems
15525 : 2004	Gaseous fire extinguishing systems — IG 100 extinguishing systems
(26) 2189 : 2008	Code of practice for selection, installation and maintenance of automatic fire detection and alarm system (*fourth revision*)
2190 : 2010	Code of practice for selection, installation and maintenance of portable first-aid fire extinguishers (*fourth revision*)
3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
9668 : 1990	Code of practice for provision and maintenance of water supplies for fire fighting
13039 : 1991	Code of practice for provision and maintenance of external hydrant system
13039 : 2014	External hydrant systems — Provision and maintenance — Code of practice
(27) 4878 : 1986	Byelaws for construction of cinema buildings (*first revision*)
(28) 2726 : 1988	Code of practice for fire safety of industrial buildings : Cotton ginning and pressing (including cotton seed delintering) factories (*first revision*)
3034 : 1993	Code of practice for fire safety of industrial buildings : Electrical generating and distributing stations (*second revision*)
3058 : 1990	Code of practice for fire safety of industrial buildings : Viscose rayon yarn and/or staple fibre plants (*first revision*)
3079 : 1990	Code of practice for fire safety of industrial buildings : Cotton textile mills (*first revision*)
3594 : 1991	Code of practice for fire safety of industrial buildings : General storage and warehousing including cold storage (*first revision*)
3595 : 1984	Code of practice for fire safety of industrial buildings : Coal pulverizers and associated equipment (*first revision*)
3836 : 2000	Code of practice for fire safety of industrial buildings : Jute mills (*second revision*)
4209 : 2013	Code of safety for chemical laboratories (*second revision*)
4226 : 1988	Code of practice for fire safety of industrial buildings : Aluminium/ Magnesium powder factories (*first revision*)
4886 : 1991	Code of practice for fire safety of industrial buildings : Tea factories (*first revision*)
6329 : 2000	Code of practice for fire safety of industrial buildings : Saw mills and wood works (*first revision*)
9109 : 2000	Code of practice for fire safety of industrial buildings : Paint and Varnish factories
11457 (Part 1) : 1985	Code of practice for fire safety of chemical industries: Part 1 Rubber and plastic
(29) 13039 : 2014	External hydrant systems — Provision and maintenance — Code of practice

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NATIONAL BUILDING CODE OF INDIA

PART 5 BUILDING MATERIALS

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 5) lists Indian Standard specifications for materials used in building construction. The Indian Standards for methods of tests, to ensure the requirements demanded of the materials in the various situations, are also included. This is with a view to ensuring the quality and effectiveness of building materials used in the construction and of their storage, which are as important as other aspects of building activity like planning, designing and constructing the building itself.

Historically, choice of building materials was determined by what was locally available, appropriateness to geo-climatic conditions and affordability of users. In the recent past, different initiatives have been taken in the areas of research and development, standardization, and development and promotion of innovative materials. A review of the recent trends indicates that the growth in the area of building materials covers emerging trends and latest developments in the use of wastes, mineral admixtures in cement and concrete, substitutes to conventional timber, composite materials and recycling of wastes, at the same time ensuring desired response of materials in relation to fire safety, long term performance and durability. In addition to these, nowadays, development of specific materials is being researched which may be structured and designed to meet needs to specially developed construction technologies in time to come, such as, for disaster prone areas or aggressive climatic and industrial situations.

To encourage use of appropriate materials, it may be desirable to have to the largest extent possible, performance oriented approach for specifications rather than prescriptive approach. The approach has been already adopted in some cases in development of standards, wherever found possible.

Indian Standards cover the requirements for most of the materials in use. However, there may be a gap between development of new materials and techniques of application and formulation of standards. It, therefore, becomes necessary for a Building Code to be flexible to recognize building materials other than those for which Indian Standards are available. This Part of the Code, therefore, since its first version, duly takes care of this aspect and explicitly provides for use of new or alternate building materials, provided it is proved by authentic tests that the new or alternative material is effective and suitable for the purpose intended. However, it is worthwhile that more and more emphasis is given to the satisfaction of performance requirements expected of a building material, so that a wide range of such new or alternate materials can be evaluated and used, if found appropriate.

As already emphasized, quality of material is quite important for their appropriate usage, whether it is a material for which an Indian Standard is available or a new or alternative material as defined in **4** of this Part of the Code. While continuing to emphasize on conformity of building materials to available Indian Standards, this Part recommends that the building regulating authority may also recognize the use of building materials conforming to other specifications and test methods (*see* **4.2**), in case Indian Standards are not available for particular materials. Third party certification schemes available in the country for quality assurance of above materials can be used with advantage to ensure the appropriateness of these materials.

It is well recognized that buildings during their construction and subsequently in their operation consume lot of resources. The holistic approach for ensuring proper and sustainable developments is to take care of the concerned aspects affecting sustainability during the conceptualization, planning, design, construction, and operation and maintenance stages. The building material production, transportation and utilization assume a substantial component of the embodied energy that goes into a building. It is therefore important that sustainability of building materials is well understood and ensured in a building project. This Part of the Code recognizes this aspect and covers appropriate provision therefore.

This Part of the Code was first published in 1970 and subsequently revised in 1983 and 2005 as Part 5 of NBC 2005. The first and second revision of this Part incorporated an updated version of the list of Indian Standards given at the end of this Part of the Code. Also the list of building materials was completely revised to make it more user-friendly. This second revision of this Part, while basically retaining the structure of 2005 version of the Code, incorporates the following modifications:

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a) The clause on new/alternative materials has been extended to give examples of some potential new/ alternative materials;
b) Recognizing the importance of sustainability in building construction and built environment, a new clause giving broad aspects relating to sustainable materials, has been added;
c) The list at the end of this Part has been updated to reflect the latest available Indian Standard specifications and methods of test.
d) In the above list, existing categories have been re-organized and some new categories have been added either under the existing principal categories or as separate principal categories. In the process, the categories such as, bricks, blocks and other masonry units; mortar (including sand for mortar); supplementary cementitious materials; mesh/net for mosquito/vector prevention; concrete door and window frame; other composite material doors and windows; fire check doors; stone flooring, etc, have been added.
e) The headings of some of the categories have been rechristened to more appropriately reflect the materials/ products actually covered thereunder.

A reference to SP 21 : 2005 'Summaries of Indian Standards for Building Materials' may be useful. This publication gives the summaries of Indian Standards covering various building materials, fittings and components except standards relating to paints.

All standards cross-referred in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Part is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part.

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NATIONAL BUILDING CODE OF INDIA

PART 5 BUILDING MATERIALS

1 SCOPE

This Code (Part 5) covers the requirements of building materials and components, and criteria for accepting new or alternative building materials and components.

2 MATERIALS

Every material used in fulfillment of the requirements of this Part, unless otherwise specified in the Code or approved, shall conform to the relevant Indian Standards. A list of Indian Standard specifications as the 'accepted standards' is given at the end of this Part of the Code. At the time of publication of the Code, the editions indicated were valid. All standards are subject to amendments and revisions. The Authority shall take cognizance of such amendments and revisions. The latest version of the specification shall, as far as possible, be adopted at the time of enforcement of this Part of the Code.

3 SUSTAINABLE MATERIALS

Choice of building materials is important in sustainable design because of the extensive network of activities such as extraction, processing and transportation steps required for making a material, and activities involved thereafter till building construction and even thereafter. These activities may pollute the air, soil and water, as well as destroy natural habitats and deplete natural resources. One of the most effective strategies for minimizing the environmental impacts of material usage is to reuse existing buildings. Rehabilitation of existing building, and their shell and non-shell components, not only reduces the volume of solid waste generated and its subsequent diversion to landfills but also the environmental impacts associated with the production, delivery and use or installation of new building materials. However, the use of sustainable building materials is one of the best strategies in the pursuit of sustainable buildings.

An ideal sustainable building material is not only environment friendly but also causes no adverse impact on health of occupants, is readily available, can be reclaimed and recycled, and is not only made from renewable raw material, but also uses predominantly renewable energy in its extraction, production, transportation, fixing and ultimate disposal. Practically, this kind of ideal material may not be available and hence, when selecting sustainable materials, it may be best to choose materials which fulfill most of these criteria. Sustainable building materials also offer specific benefits to the building owner and building occupants, such as, reduced maintenance/replacement costs over the life of the building; energy conservation; improved occupant health and productivity; lower costs associated with changing space configurations; and greater design flexibility.

The selection of sustainable building materials shall be made in accordance with Part 11 'Approach to Sustainability' of the Code.

4 NEW OR ALTERNATIVE MATERIALS

4.1 The provisions of this Part are not intended to prevent the use of any material not specifically prescribed under **2**. Any such material may be approved by the Authority or an agency appointed by them for the purpose, provided it is established that the material is satisfactory for the purpose intended and the equivalent of that required in this Part or any other specification issued or approved by the Authority. The Authority or an agency appointed by them shall take into account the following parameters, as applicable to the concerned new or alternative building material:

a) Requirements of the material specified/ expected in terms of the provisions given in the standards on its usage, including its applicability in geo-climatic condition;
b) General appearance;
c) Dimension and dimensional stability;
d) Structural stability including strength properties;
e) Fire safety;
f) Durability;
g) Thermal properties;
h) Mechanical properties;
j) Acoustical properties;
k) Optical properties;
m) Biological effect;
n) Environmental aspects;
p) Working characteristics;
q) Ease of handling;
r) Consistency and workability;
s) UV resistance; and
t) Toxicity.

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Some of such new/alternative materials may be ferrocement, decorative concrete, polymer concrete, micro-concrete repair materials, dry-mix mortar, non-shrink grout, optical fibres, special materials for bunkers/blast resistant structures, artificial stones used in restoration of heritage structures, nanotechnology based advanced materials, aluminium composite panels, vermiculite based boards, exfoliated perlite, geopolymeric cement, pervious concrete, UPVC doors and windows, stainless steel insulated water tanks, etc.

For establishing the performance of the material/ component, laboratory/field tests, and field trials, as required, and study of historical data are recommended. For sampling and frequency of tests for new or alternate materials, similar product standards shall be referred to.

The above materials would no longer be treated as new/ alternative materials as soon as Indian Standards for the same are established.

4.2 Approval in writing of the Authority or an agent appointed by them for the purpose of approval of material, shall be obtained by the owner or his agent before any new, alternative or equivalent material is used. The Authority or their agent shall base such approval on the principle set forth in **4.1** and shall require that tests be made (*see* **8.1**) or sufficient evidence or proof be submitted, at the expense of the owner or his agent, to substantiate any claim for the proposed material.

NOTE — For interpretation of the term 'Authority' (*see also* **8.1**), the definition of 'Authority having jurisdiction' given in Part 2 'Administration' of the Code shall apply.

5 THIRD PARTY CERTIFICATION

For ensuring the conformity of materials for which Indian Standards exist and for new or alternative building materials, to requisite quality parameters the services under the third party certification schemes of the Government, may be utilized with advantage.

6 USED MATERIALS

Utilization of used materials may not be precluded provided these meet the requirements of this Part for new materials (*see* Part 2 'Administration' of the Code).

7 STORAGE OF MATERIALS

All building materials shall be stored on the building site in such a way as to prevent deterioration or the loss or impairment of their structural and other essential properties (*see* Part 7 'Construction Management, Practices and Safety' of the Code).

8 METHODS OF TEST

8.1 Every test of material as required in this Part or by the Authority shall be carried out in accordance with the methods of test prescribed in relevant Indian Standards. In cases of methods of tests for which Indian Standards are not available, the same shall conform to the methods of tests issued by the Authority or their agent. A list of Indian Standard methods of test is given at the end of this Part of the Code as the 'accepted standards'. Laboratory tests shall be conducted by recognized laboratories acceptable to the Authority.

8.1.1 The manufacturer/supplier shall satisfy himself that materials conform to the requirements of the specifications and if requested shall supply a certificate to this effect to the purchaser or his representative. When such test certificates are not available, the specimen of the material shall be tested.

LIST OF STANDARDS

Following are the Indian Standards for various building materials and components, to be complied with in fulfillment of the requirements of the Code.

In the following list, while enlisting the Indian Standards, the materials have been categorized in such a way as to make the list user friendly. In the process, if so required, some of the standards have been included even in more than one category of products, such as in the category based on composition as well as on end application of the materials. The list has been arranged in alphabetical order of their principal category as given below:

1) Aluminium and other light metals and their alloys
2) Bitumen and tar products
3) Bricks, blocks and other masonry building units
4) Builder's hardware
5) Building chemicals
6) Building lime and products
7) Clay and stabilized soil products
8) Cement and concrete (including steel reinforcement for concrete)
9) Composite matrix products (including cement and resin matrix products)
10) Conductors and cables
11) Doors, windows and ventilators
12) Electrical wiring, fittings and accessories
13) Fillers, stoppers and putties
14) Floor covering, roofing and other finishes
15) Glass
16) Gypsum based materials

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17) Mortar (including sand for mortar)
18) Paints and allied products
19) Polymers, plastics and geosynthetics/ geotextiles
20) Sanitary appliances and water fittings
21) Steel and its alloys
22) Stones
23) Structural sections
24) Thermal insulation materials
25) Threaded fasteners, rivets and nails
26) Timber, bamboo and other lignocellulosic building materials
27) Unit weights of building materials
28) Waterproofing and damp-proofing materials
29) Welding electrodes and wires
30) Wire ropes and wire products (including wire for fencing)

1. ALUMINIUM AND OTHER LIGHT METALS AND THEIR ALLOYS

IS No.	*Title*
733 : 1983	Specification for wrought aluminium and aluminium alloys bars, rods and sections for general engineering purposes (*third revision*)
734 : 1975	Wrought aluminium and aluminium alloys forging stock and forgings (for general engineering purposes) (*second revision*)
736 : 1986	Specification for wrought aluminium and aluminium alloys plate for general engineering purposes (*third revision*)
737 : 2008	Specification for wrought aluminium and aluminium alloys sheet and strip for general engineering purposes (*fourth revision*)
738 : 1994	Specification for wrought aluminium and aluminium alloys drawn tube for general engineering purposes (*third revision*)
739 : 1992	Specification for wrought aluminium and aluminium alloys — Wire for general engineering purposes (*third revision*)
740 : 1977	Specification for wrought aluminium and aluminium alloys rivet stock for general engineering purposes (*second revision*)
1254 : 2007	Corrugated aluminium sheet (*fourth revision*)
1284 : 1975	Wrought aluminium alloys bolt and screw stock for general engineering purposes (*second revision*)
1285 : 2002	Specification for wrought aluminium and aluminium alloys — Extruded round tube and hollow sections for general engineering purposes (*third revision*)
2479 : 1981	Colour code for the identification of aluminium and aluminium alloys for general engineering purposes (*second revision*)
2676 : 1981	Dimensions for wrought aluminium and aluminium alloy sheet and strip
2677 : 1979	Dimensions for wrought aluminium and aluminium alloys, plates and hot rolled sheets
3577 : 1992	Wrought aluminium and its alloys — Rivet, bolt and screw stock — Dimensions and tolerances (*first revision*)
3965 : 1981	Dimensions for wrought aluminium and aluminium alloys bar, rod and section (*first revision*)
6477 : 1983	Dimensions for wrought aluminium and aluminium alloys extruded hollow sections
14712 : 1999	Specification for wrought aluminium and its alloys — Chequered/tread sheets for general engineering purposes
15965 : 2012	Pre-painted aluminium zinc alloy metallic coated steel strip and sheet (Plain)

2. BITUMEN AND TAR PRODUCTS

IS No.	*Title*
73 : 2013	Specification for paving bitumen (*fourth revision*)
212 : 1983	Specification for crude coal tar for general use (*second revision*)
215 : 1995	Specification for road tar (*third revision*)
216 : 2006	Specification for coal tar pitch (*second revision*)
217 : 1988	Specification for cutback bitumen (*second revision*)
218 : 1983	Specification for creosote oil for use as wood preservatives (*second revision*)
454 : 1994	Specification for cutback bitumen from waxy crude (*second revision*)

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IS No.	*Title*
702 : 1988	Specification for industrial bitumen (*second revision*)
1201 to 1220	Methods for testing tar and bituminous materials (*first revision*)
1201 : 1978	Sampling (*first revision*)
1202 : 1978	Determination of specific gravity (*first revision*)
1203 : 1978	Determination of penetration (*first revision*)
1204 : 1978	Determination of residue of specified penetration (*first revision*)
1205 : 1978	Determination of softening point (*first revision*)
1206	Determination of viscosity
(Part 1) : 1978	Industrial viscosity (*first revision*)
(Part 2) : 1978	Absolute viscosity (*first revision*)
(Part 3) : 1978	Kinematic viscosity (*first revision*)
1207 : 1978	Determination of equiviscous temperature (EVT) (*first revision*)
1208 : 1978	Determination of ductility (*first revision*)
1209 : 1978	Determination of flash point and fire point (*first revision*)
1210 : 1978	Float test (*first revision*)
1211 : 1978	Determination of water content (Dean and Stark method) (*first revision*)
1212 : 1978	Determination of loss on heating (*first revision*)
1213 : 1978	Distillation test (*first revision*)
1215 : 1978	Determination of matter insoluble in toluene (*first revision*)
1216 : 1978	Determination of solubility in carbon disulphide or trichloroethylene (*first revision*)
1217 : 1978	Determination of mineral matter (ASH) (*first revision*)
1218 : 1978	Determination of phenols (*first revision*)
1219 : 1978	Determination of naphthalene (*first revision*)
1220 : 1978	Determination of volatile matter content (*first revision*)
3117 : 2004	Specification for bitumen emulsion for roads and allied applications (anionic type) (*first revision*)
8887 : 2004	Specification for bitumen emulsion for roads (cationic type) (*second revision*)
9381 : 1979	Methods for testing tar and bituminous materials: Determination of FRAASS breaking point of bitumen
9382 : 1979	Methods for testing tar and bituminous materials: Determination of effect of heat and air by thin film oven test
10511 : 1983	Method for determination of asphaltenes in bitumen by precipitation with normal haptane
10512 : 2003	Method for determination of wax content in bitumen (*first revision*)
13758	Coal tar pitch — Methods of test
(Part 1) : 1993	Determination of matter insoluble in quinoline
(Part 2) : 1993	Determination of coking value
15172 : 2002	Methods for testing tar and bituminous materials — Determination of curing index for cutback bitumens
15173 : 2002	Methods for testing tar and bituminous materials — Determination of breaking point for cationic bitumen emulsion
15174 : 2002	Methods for testing tar and bituminous material — Determination of breaking point for anionic bitumen emulsion
15462 : 2004	Specification for polymer and rubber modified
15799 : 2008	Methods for testing tar and bituminous materials — Determination of durability of bitumen
15808 : 2008	Specification for multigrade bitumen for use in pavement construction

3. BRICKS, BLOCKS AND OTHER MASONRY BUILDING UNITS

IS No.	*Title*
1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
1725 : 2013	Specification for stabilized soil blocks used in general building construction (*second revision*)
2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
2185	Specification for concrete masonry units

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IS No.	*Title*
(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
(Part 4) : 2008	Cellular concrete blocks using preformed foam
2222 : 1991	Specification for burnt clay perforated building bricks (*third revision*)
2691 : 1988	Specification for burnt clay facing bricks (*second revision*)
2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types)
3115 : 1992	Specification for lime based blocks (*second revision*)
3316 : 1974	Specification for structural granite (*first revision*)
3495 (Parts 1 to to 4) : 1992	Methods of test of burnt clay building bricks (*third revision*) Determination of compressive strength Determination of water absorption Determination of efflorescence Determination of warpage
3583 : 1988	Specification for burnt clay paving bricks (*second revision*)
3620 : 1979	Specification for laterite stone block for masonry (*first revision*)
3952 : 2013	Specification for burnt clay hollow bricks and blocks for walls and partitions (*third revision*)
4139 : 1989	Specification for calcium silicate bricks (*second revision*)
4860 : 1968	Specification for acid resistant bricks
4885 : 1988	Specification for sewer bricks (*first revision*)
5454 : 1978	Methods for sampling of clay building bricks (*first revision*)
5751 : 1984	Specification for precast concrete coping blocks (*first revision*)
5779 : 1986	Specification for burnt clay soling bricks (*first revision*)
6165 : 1992	Dimensions for special shapes of clay bricks (*first revision*)
9893 : 1981	Specification for precast concrete blocks for lintels and sills
10360 : 1982	Specification for lime pozzolana concrete blocks for paving
12440 : 1988	Specification for precast concrete stone masonry blocks
12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)
13757 : 1993	Specification for burnt clay fly ash building bricks
15658 : 2006	Specification for precast concrete blocks for paving

4. BUILDER'S HARDWARE

IS No.	*Title*
204	Specification for tower bolts
(Part 1) : 1991	Ferrous metals (*fifth revision*)
(Part 2) : 1992	Non-ferrous metals (*fifth revision*)
205 : 1992	Specification for non-ferrous metal butt hinges (*fourth revision*)
206 : 2010	Specification for tee and strap hinges (*fifth revision*)
208 : 1996	Specification for door handles (*fifth revision*)
281 : 2009	Specification for mild steel sliding door bolts for use with padlocks (*fourth revision*)
362 : 1991	Specification for parliament hinges (*fifth revision*)
363 : 1993	Specification for hasps and staples (*fourth revision*)
364 : 1993	Specification for fanlight catch (*third revision*)
452 : 1973	Specification for door springs, rat-tail type (*second revision*)
453 : 1993	Specification for double-acting spring hinges (*third revision*)
729 : 1979	Specification for drawer locks, cupboard locks and box locks (*third revision*)
1019 : 1974	Specification for rim latches (*second revision*)
1341 : 1992	Specification for steel butt hinges (*sixth revision*)
1823 : 1980	Specification for floor door stoppers (*third revision*)
1837 : 1966	Specification for fanlight pivots (*first revision*)
2209 : 1976	Specification for mortice locks (vertical type) (*third revision*)
2681 : 1993	Specification for nonferrous metal

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IS No.	*Title*
	sliding door bolts for use with padlocks (*third revision*)
3564 : 1995	Specification for door closers (hydraulically regulated) (*second revision*)
3818 : 1992	Specification for continuous (piano) hinges (*third revision*)
3828 : 1966	Specification for ventilator chains
3843 : 1995	Specification for steel backflap hinges (*first revision*)
3847 : 1992	Specification for mortice night latches (*second revision*)
4621 : 1975	Specification for indicating bolts for use in public baths and lavatories (*first revision*)
4948 : 2002	Specification for welded steel wire fabric for general use (*second revision*)
4992 : 1975	Specification for door handles for mortice locks (vertical type) (*first revision*)
5187 : 1972	Specification for flush bolts (*first revision*)
5899 : 1970	Specification for bathroom latches
5930 : 1970	Specification for mortice latch (vertical type)
6315 : 1992	Specification for floor springs (hydraulically regulated) for heavy doors (*second revision*)
6318 : 1971	Specification for plastic window stays and fasteners
6343 : 1982	Specification for door closers (pneumatically regulated) for light door weighing up to 40 kg (*first revision*)
6607 : 1972	Specification for rebated mortice locks (vertical type)
7196 : 1974	Specification for hold fast
7197 : 1974	Specification for double action floor springs (without oil check) for heavy doors
7534 : 1985	Specification for sliding locking bolts for use with padlocks (*first revision*)
8756 : 1978	Specification for ball catches for use in wooden almirah
9106 : 1979	Specification for rising butt hinges
9131 : 1979	Specification for rim locks
9460 : 1980	Specification for flush drop handle for drawer
9899 : 1981	Specification for hat coat and wardrobe hooks
10019 : 1981	Specification for mild steel stays and fasteners
10090 : 1982	Specification for numericals
10342 : 1982	Specification for curtain rail system
12817 : 2013	Specification for stainless steel butt hinges (*second revision*)
12867 : 1989	Specification for PVC hand rails covers
14912 : 2001	Specification for door closers concealed type (hydraulically regulated)
15833 : 2009	Specification for stainless steel tower bolts
15834 : 2008	Specification for stainless steel sliding door bolts for use with padlocks
16015 : 2013	Specification for mortice locks with lever mechanism (vertical type, sliding door locks and dead locks)
16016 : 2013	Specification for cylindrical locks with pin tumbler mechanism

5. BUILDING CHEMICALS

a) Anti-termite Chemicals

IS No.	*Title*
8944 : 2005	Specification for chlorpyrifos emulsifiable concentrates (*first revision*)
16131 : 2015	Specification for imidacloprid suspension concentrate (sc)

b) Chemical Admixture/Water Proofing Compounds

IS No.	*Title*
2645 : 2003	Specification for integral water-proofing compounds for cement mortar and concrete (*second revision*)
6925 : 1973	Methods of test for determination of water soluble chlorides in concrete admixtures
9103 : 1999	Specification for concrete admixtures (*first revision*)

c) Sealants/Fillers

IS No.	*Title*
1834 : 1984	Specification for hot applied sealing compound for joint in concrete (*first revision*)

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IS No.	*Title*
1838	Specification for preformed fillers for expansion joint in concrete pavements and structures (non-extruding and resilient type)
(Part 1) : 1983	Bitumen impregnated fibre (*first revision*)
(Part 2) : 1984	CNSL aldehyde resin and coconut pith
(Part 3) : 2011	Polymer based
10566 : 1983	Methods of tests for preformed fillers for expansion joint in concrete paving and structural construction
11433	Specification for one grade polysulphide based joint sealant
(Part 1) : 1985	General requirements
(Part 2) : 1986	Methods of test
12118	Specification for two parts polysulphide based sealants
(Part 1) : 1987	General requirements
(Part 2) : 1987	Methods of test

d) Adhesives

IS No.	*Title*
848 : 2006	Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) (*second revision*)
849 : 1994	Specification for cold setting case in glue for wood (*first revision*)
851 : 1978	Specification for synthetic resin adhesives for construction work (non-structural) in wood (*first revision*)
852 : 1994	Specification for animal glue for general wood-working purposes (*second revision*)
1508 : 1972	Specification for extenders for use in synthetic resin adhesives (urea-formaldehyde) for plywood (*first revision*)
4835 : 1979	Specification for polyvinyl acetate dispersion-based adhesives for wood (*first revision*)
9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition
12830 : 1989	Rubber based adhesives for fixing PVC tiles to cement
12994 : 1990	Epoxy adhesives, room temperature curing general purpose
15477 : 2004	Specification for adhesives for use with ceramic tiles and mosaics

6. BUILDING LIME AND PRODUCTS

IS No.	*Title*
712 : 1984	Specification for building limes (*third revision*)
1624 : 1986	Method of field testing of building lime (*second revision*)
2686 : 1977	Specification for cinder as fine aggregates for use in lime concrete (*first revision*)
3068 : 1986	Specification for broken brick (burnt-clay) coarse aggregates for use in lime concrete (*second revision*)
3115 : 1992	Specification for lime based blocks (*second revision*)
3182 : 1986	Specification for broken bricks (burnt clay) fine aggregates for use in lime mortar (*second revision*)
4098 : 1983	Specification for lime-pozzolana mixture (*first revision*)
4139 : 1989	Specification for calcium silicate bricks (*second revision*)
6932	Method of tests for building limes
(Part 1) : 1973	Determination of insoluble residue, loss on ignition, insoluble matter, silicon dioxide, ferric and aluminium oxide, calcium oxide and magnesium oxide
(Part 2) : 1973	Determination of carbon dioxide content
(Part 3) : 1973	Determination of residue on slaking of quicklime
(Part 4) : 1973	Determination of fineness of hydrated lime
(Part 5) : 1973	Determination of unhydrated oxide
(Part 6) : 1973	Determination of volume yield of quicklime
(Part 7) : 1973	Determination of compressive and transverse strength
(Part 8) : 1973	Determination of workability
(Part 9) : 1973	Determination of soundness
(Part 10) : 1973	Determination of popping and pitting of hydrated lime
(Part 11) : 1984	Determination of setting time of hydrated lime
10360 : 1982	Specification for lime pozzolana concrete blocks for paving

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IS No.	*Title*
10772 : 1983	Specification for quick setting lime pozzolana mixture
12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)
15648 : 2006	Specification for pulverized fuel ash for lime-pozzolana mixture applications

7. CLAY AND STABILIZED SOIL PRODUCTS

a) Blocks

IS No.	*Title*
3952 : 2013	Specification for burnt clay hollow bricks and blocks for walls and partitions (*third revision*)

b) Stabilized Soil Products

IS No.	*Title*
1725 : 2013	Specification for stabilized soil blocks used in general building construction (*second revision*)

c) Bricks

IS No.	*Title*
1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
2222 : 1991	Specification for burnt clay perforated building bricks (*third revision*)
2691 : 1988	Specification for burnt clay facing bricks (*second revision*)
3495 (Parts 1 to 4) : 1992	Methods of test of burnt clay building bricks (*third revision*)
	Determination of compressive strength
	Determination of water absorption
	Determination of efflorescence
	Determination of warpage
3583 : 1988	Specification for burnt clay paving bricks (*second revision*)
3952 : 2013	Specification for burnt clay hollow bricks and blocks for walls and partitions (*third revision*)
4885 : 1988	Specification for sewer bricks (*first revision*)
5454 : 1978	Methods for sampling of clay building bricks (*first revision*)
5779 : 1986	Specification for burnt clay soling bricks (*first revision*)
6165 : 1992	Dimensions for special shapes of clay bricks (*first revision*)
13757 : 1993	Specification for burnt clay fly ash building bricks

d) Jallies

IS No.	*Title*
7556 : 1988	Specification for burnt clay jallies (*first revision*)

e) Tiles

IS No.	*Title*
654 : 1992	Specification for clay roofing tiles, Mangalore pattern (*third revision*)
1464 : 1992	Specification for clay ridge and ceiling tiles (*second revision*)
1478 : 1992	Specification for clay flooring tiles (*second revision*)
2690	Specification for burnt clay flat terracing tiles
(Part 1) : 1993	Machine made (*second revision*)
(Part 2) : 1992	Hand made (*second revision*)
3367 : 1993	Specification for burnt clay tiles for use in lining irrigation and drainage works (*second revision*)
3951	Specification for hollow clay tiles for floor and roofs
(Part 1) : 2009	Filler type (*second revision*)
(Part 2) : 2009	Structural type (*second revision*)
8920 : 1978	Methods for sampling of burnt clay tiles
13317 : 1992	Specification for clay roofing county tiles, half round and flat tiles

8. CEMENT AND CONCRETE (INCLUDING STEEL REINFORCEMENT FOR CONCRETE)

a) Aggregates

IS No.	*Title*
383 : 2016	Specification for coarse and fine aggregates for concrete (*third revision*)
650 : 1991	Specification for standard sand for testing of cement (*second revision*)
1542 : 1992	Specification for sand for plaster (*second revision*)
2116 : 1980	Specification for sand for masonry mortars (*first revision*)

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IS No.	*Title*
2386	Methods of test for aggregates for concrete
(Part 1) : 1963	Particle size and shape
(Part 2) : 1963	Estimation of deleterious materials and organic impurities
(Part 3) : 1963	Specific gravity, density, voids, absorption and bulking
(Part 4) : 1963	Mechanical properties
(Part 5) : 1963	Soundness
(Part 6) : 1963	Measuring mortar making properties of fine aggregates
(Part 7) : 1963	Alkali aggregate reactivity
(Part 8) : 1963	Petrographic examination
2430 : 1986	Methods of sampling of aggregates of concrete (*first revision*)
6579 : 1981	Specification for coarse aggregate for water bound macadam (*first revision*)
9142 : 1979	Specification for artificial light-weight aggregates for concrete masonry units

b) Cement

IS No.	*Title*
269 : 2015	Specification for ordinary Portland cement (*sixth revision*)
455 : 2015	Specification for Portland slag cement (*fifth revision*)
1489	Specification for Portland pozzolana cement
(Part 1) : 2015	Flyash based (*fourth revision*)
(Part 2) : 2015	Calcined clay based (*fourth revision*)
3466 : 1988	Specification for masonry cement (*second revision*)
6452 : 1989	Specification for high alumina cement for structural use (*first revision*)
6909 : 1990	Specification for supersulphated cement (*first revision*)
8041 : 1990	Specification for rapid hardening Portland cement (*second revision*)
8042 : 2015	Specification for white Portland cement (*third revision*)
8043 : 1991	Specification for hydrophobic Portland cement (*second revision*)
12330 : 1988	Specification for sulphate resisting Portland cement
12600 : 1989	Specification for low heat Portland cement
16415 : 2015	Specification for composite cement

c) Supplementary Cementitious Materials (Mineral Admixtures including Pozzolanas)

IS No.	*Title*
1344 : 1981	Specification for calcined clay pozzolana (*second revision*)
1727 : 1967	Methods of test for pozzolanic materials (*first revision*)
3812	Specification for pulverized fuel ash
(Part 1) : 2013	For use as pozzolana in cement, cement mortar and concrete (*third revision*)
(Part 2) : 2013	For use as admixture in cement mortar and concrete (*third revision*)
6491 : 1972	Method of sampling of flyash
12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
12870 : 1989	Methods of sampling calcined clay pozzolana
15388 : 2003	Specification for silica fume
16354 : 2015	Specification for metakaolin for use in cement, cement mortar and concrete

d) Chemical Admixtures

IS No.	*Title*
6925 : 1973	Methods of test for determination of water soluble chlorides in concrete admixtures
9103 : 1999	Specification for admixtures for concrete (*first revision*)

e) Concrete

IS No.	*Title*
456 : 2000	Code of Practice for plain and reinforced concrete (*fourth revision*)
1343 : 2012	Code of Practice for prestressed concrete (*second revision*)
4926 : 2003	Code of Practice for ready-mixed concrete (*second revision*)

f) Cement and Concrete Sampling and Methods of Test

IS No.	*Title*
516 : 1959	Methods of test for strength of concrete
1199 : 1959	Methods of sampling and analysis of concrete
2770 (Part 1) : 1967	Methods of testing bond in reinforced concrete: Pullout test

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IS No.	*Title*
3085 : 1965	Methods of test for permeability of cement mortar and concrete
3535 : 1986	Methods of sampling hydraulic cement (*first revision*)
4031	Methods of physical tests for hydraulic cement
(Part 1) : 1996	Determination of fineness by dry sieving (*second revision*)
(Part 2) : 1999	Determination of fineness by specific surface by Blaine air permeability method (*second revision*)
(Part 3) : 1988	Determination of soundness (*first revision*)
(Part 4) : 1988	Determination of consistency of standard cement paste (*first revision*)
(Part 5) : 1988	Determination of initial and final setting times (*first revision*)
(Part 6) : 1988	Determination of compressive strength of hydraulic cement (other than masonry cement)(*first revision*)
(Part 7) : 1988	Determination of compressive strength of masonry cement (*first revision*)
(Part 8) : 1988	Determination of transverse and compressive strength of plastic mortar using prism (*first revision*)
(Part 9) : 1988	Determination of heat of hydration (*first revision*)
(Part 10) : 1988	Determination of drying shrinkage (*first revision*)
(Part 11) : 1988	Determination of density (*first revision*)
(Part 12) : 1988	Determination of air content of hydraulic cement mortar (*first revision*)
(Part 13) : 1988	Measurement of water retentivity of masonry cement (*first revision*)
(Part 14) : 1989	Determination of false set
(Part 15) : 1991	Determination of fineness by wet sieving
4032 : 1985	Methods of chemical analysis for hydraulic cement (*first revision*)
5816 : 1999	Method of test for splitting tensile strength of concrete (*first revision*)
8142 : 1976	Methods of test for determining setting time of concrete by penetration resistance
9013 : 1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
9284 : 1979	Method of test for abrasion resistance of concrete
12423 : 1988	Methods for colorimetric analysis of hydraulic cement
12803 : 1989	Methods of analysis of hydraulic cement by X-ray fluorescence spectrometer
12813 : 1989	Method of analysis of hydraulic cement by atomic absorption spectrophotometer
13311	Methods of non-destructive testing of concrete
(Part 1) : 1992	Ultrasonic pulse velocity
(Part 2) : 1992	Rebound hammer
14959	Method of test for determination of water soluble and acid soluble chlorides in mortar and concrete
(Part 1) : 2001	Fresh mortar
(Part 2) : 2001	Hardened mortar and concrete

g) Treatment of Concrete Joints

IS No.	*Title*
1834 : 1984	Specification for hot applied sealing compound for joint in concrete (*first revision*)
1838	Specification for preformed fillers for expansion joint in concrete pavements and structures (non extruding and resilient type)
(Part 1) : 1983	Bitumen impregnated fibre (*first revision*)
(Part 2) : 1984	CNSL aldehyde resin and coconut pith
(Part 3) : 2011	Polymer based
10566 : 1983	Methods of test for preformed fillers for expansion joints in concrete paving and structural construction
11433	Specification for one grade polysulphide based joint sealant
(Part 1) : 1985	General requirements
(Part 2) : 1986	Methods of test
12118	Specification for two parts polysulphide based sealants
(Part 1) : 1987	General requirements
(Part 2) : 1987	Methods of test

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h) Steel Reinforcement and Prestressing Steel for Concrete

IS No.	*Title*
432	Specification for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement
(Part 1) : 1982	Mild steel and medium tensile steel bars (*third revision*)
(Part 2) : 1982	Hard drawn steel wire (*third revision*)
1566 : 1982	Specification for hard drawn steel wire fabric for concrete reinforcement (*second revision*)
1608 : 2005	Metallic materials — Tensile testing at ambient temperature (*third revision*)
1785	Specification for plain hard drawn steel wire for pre-stressed concrete
(Part 1) : 1983	Cold drawn stress-relieved wire (*second revision*)
(Part 2) : 1983	As drawn wire (*first revision*)
1786 : 2008	Specification for high strength deformed steel bars and wires for concrete reinforcement (*fourth revision*)
2090 : 1983	Specification for high tensile steel bars used in prestressed concrete (*first revision*)
6003 : 2010	Specification for indented wire for prestressed concrete (*second revision*)
6006 : 2014	Specification for uncoated stress-relieved strand for prestressed concrete (*second revision*)
10790	Methods of sampling of steel for prestressed and reinforced concrete
(Part 1) : 1984	Prestressing steel
(Part 2) : 1984	Reinforcing steel
13620 : 1993	Specification for fusion bonded epoxy coated reinforcing bars
14268 : 1995	Specification for uncoated stress relieved low relaxation seven ply strand for prestressed concrete
16172 : 2014	Specification for reinforcement couplers for mechanical splices of bars in concrete

9. COMPOSITE MATRIX PRODUCTS

a) Cement Matrix Products

i) *Precast Concrete Products*

IS No.	*Title*
2174 : 1962	Specification for reinforced concrete dust bins
2185	Specification for concrete masonry units
(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
(Part 4) : 2008	Cellular concrete blocks using preformed foam
4996 : 1984	Specification for reinforced concrete fence posts (*first revision*)
5751 : 1984	Specification for precast concrete coping blocks (*first revision*)
5758 : 1984	Specification for precast concrete kerbs (*first revision*)
5820 : 1970	Specification for precast concrete cable covers
6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
6073 : 2006	Specification for autoclaved reinforced cellular concrete floor and roof slabs (*first revision*)
6441	Methods of test for autoclaved cellular concrete products
(Part 1) : 1972	Determination of unit weight or bulk density and moisture content
(Part 2) : 1972	Determination of drying shrinkage
(Part 4) : 1972	Corrosion protection of steel reinforcement in autoclaved cellular concrete
(Part 5) : 1972	Determination of compressive strength
(Part 6) : 1973	Strength, deformation and cracking of flexural members subject to bending — Short duration loading test
(Part 7) : 1973	Strength, deformation and cracking of flexural members subject to bending — Sustained loading test
(Part 8) : 1973	Loading tests for flexural members in diagonal tension
(Part 9) : 1973	Jointing of autoclaved cellular concrete elements
6523 : 1983	Specification for precast reinforced concrete door and window frames (*first revision*)

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IS No.	*Title*
9375 : 1979	Specification for precast reinforced concrete plant guards
9872 : 1981	Specification for precast concrete septic tanks
9893 : 1981	Specification for precast concrete blocks for lintels and sills
12440 : 1988	Specification for precast concrete stone masonry blocks
12592 : 2002	Specification for precast concrete manhole covers and frames (*first revision*)
13356 : 1992	Specification for precast ferrocement water tanks (250 to 10 000 litres capacity)
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel unit for construction of floors and roofs
14241 : 1995	Specification for precast L-Panel units for roofing

ii) *Asbestos Fibre Cement Products*

IS No.	*Title*
459 : 1992	Specification for corrugated and semi-corrugated asbestos cement sheets (*third revision*)
1592 : 2003	Specification for asbestos cement pressure pipes and joints (*fourth revision*)
1626	Specification for asbestos cement building pipes and pipe fittings, gutters and gutter fittings and roofing fittings
(Part 1) : 1994	Pipes and pipe fittings (*second revision*)
(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
(Part 3) : 1994	Roofing fittings (*second revision*)
2096 : 1992	Specification for asbestos cement flat sheets (*first revision*)
2098 : 1997	Specification for asbestos cement building boards (*first revision*)
5913 : 2003	Methods of test for asbestos cement products (*second revision*)
6908 : 1991	Specification for asbestos cement pipes and fittings for sewerage and drainage (*first revision*)
7639 : 1975	Method of sampling asbestos cement products
9627 : 1980	Specification for asbestos cement pressure pipes (light duty)
13000 : 1990	Specification for silica-asbestos-cement flat sheets
13008 : 1990	Specification for shallow corrugated asbestos cement sheets

iii) *Other Fibre Cement Products*

IS No.	*Title*
14862 : 2000	Specification for fibre cement flat sheets
14871 : 2000	Specification for products in fibre reinforced cement long corrugated or asymmetrical section sheets and fittings for roofing and cladding

iv) *Concrete Pipes and Pipes Lined/Coated with Concrete or Mortar*

IS No.	*Title*
458 : 2003	Specification for precast concrete pipes (with and without reinforcement) (*fourth revision*)
784 : 2001	Specification for prestressed concrete pipes (including specials) (*second revision*)
1916 : 1989	Specification for steel cylinder pipe with concrete lining and coating (*first revision*)
3597 : 1998	Methods of test for concrete pipes (*second revision*)
4350 : 1967	Specification for concrete porous pipes for under drainage
7319 : 1974	Specification for perforated concrete pipes
7322 : 1985	Specification for specials for steel cylinder reinforced concrete pipes (*first revision*)
15155 : 2002	Specification for bar/wire wrapped steel cylinder pipe with mortar lining and coating

b) Resin Matrix Products

IS No.	*Title*
1998 : 1962	Methods of test for thermosetting synthetic resin bonded laminated sheets
2036 : 1995	Specification for phenolic laminated sheets (*second revision*)

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IS No.	*Title*
2046 : 1995	Specification for decorative thermosetting synthetic resin bonded laminated sheets (*second revision*)

10. CONDUCTORS AND CABLES

IS No.	*Title*
694 : 2010	Polyvinyl chloride insulated unsheathed and sheathed cables/ cords with rigid and flexible conductor for rated voltages up to and including 450/750 V (*fourth revision*)
1554	Specification for PVC insulated (heavy duty) electric cables
(Part 1) : 1988	For working voltages up to and including 1 100 volts (*third revision*)
(Part 2) : 1988	For working voltages from 3.3 kV up to and including 11 kV (*second revision*)
3961	Recommended current rating for cables
(Part 1) : 1967	Paper-insulated lead-sheathed cables
(Part 2) : 1967	PVC-insulated and PVC-sheathed heavy duty cables
(Part 3) : 1968	Rubber insulated cables
(Part 5) : 1968	PVC insulated light duty cables
4289	Specification for flexible cables for lifts and other flexible connections
(Part 1) : 1984	Elastomer insulated cables (*first revision*)
(Part 2) : 2000	PVC insulated circular cables
7098	Specification for cross-linked polyethylene insulated sheathed cables
(Part 1) : 1988	For working voltage up to and including 1 100 V (*first revision*)
(Part 2) : 2011	For working voltages form 3.3 kV up to and including 33 kV (*second revision*)
(Part 3) : 1993	For working voltages from 66 kV upto and including 220 kV
8130 : 2013	Specification for conductors for insulated electric cables and flexible cords (*second revision*)
9968	Specification for elastomer-insulated cables
(Part 1) : 1988	For working voltages up to and including 1 100 V (*first revision*)
(Part 2) : 2002	For working voltages from 3.3 kV up to and including 33 kV (*first revision*)
10810	Methods of test for cables
(Part 0) : 1984	General
(Part 1) : 1984	Annealing test for wires used in conductors
(Part 2) : 1984	Tensile test for aluminium wires
(Part 3) : 1984	Wrapping test for aluminium wires
(Part 4) : 1984	Persulphate test of conductor
(Part 5) : 1984	Conductor resistance test
(Part 6) : 1984	Thickness of thermoplastic and elastomeric insulation and sheath
(Part 7) : 1984	Tensile strength and elongation at break of thermoplastic and elastomeric insulation and sheath
(Part 8) : 1984	Breaking strength and elongation at break for impregnated paper insulation
(Part 9) : 1984	Tear resistance for paper insulation
(Part 10) : 1984	Loss of mass test
(Part 11) : 1984	Thermal ageing in air
(Part 12) : 1984	Shrinkage test
(Part 13) : 1984	Ozone resistance test
(Part 14) : 1984	Heat shock test
(Part 15) : 1984	Hot deformation test
(Part 16) : 1986	Accelerated ageing test by oxygen pressure method
(Part 17) : 1986	Tear resistance test for heavy duty sheath
(Part 19) : 1984	Bleeding and blooming test
(Part 20) : 1984	Cold bend test
(Part 21) : 1984	Cold impact test
(Part 22) : 1984	Vicat softening point
(Part 23) : 1984	Melt-flow index
(Part 24) : 1984	Water soluble impurities test of insulating paper
(Part 25) : 1984	Conductivity of water extract test of insulating paper
(Part 26) : 1984	*p*H value of water extract test of insulating paper
(Part 27) : 1984	Ash content test of insulating paper
(Part 28) : 1984	Water absorption test (Electrical)
(Part 29) : 1984	Environmental stress cracking test
(Part 30) : 1984	Hot set test

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IS No.	*Title*
(Part 31) : 1984	Oil resistance test
(Part 32) : 1984	Carbon content test for polyethylene
(Part 33) : 1984	Water absorption test (Gravimetric)
(Part 34) : 1984	Measurement of thickness of metallic sheath
(Part 35) : 1984	Determination of tin in lead alloy for sheathing
(Part 36) : 1984	Dimensions of armouring material
(Part 37) : 1984	Tensile strength and elongation at break of armouring materials
(Part 38) : 1984	Torsion test on galvanized steel wires for armouring
(Part 39) : 1984	Winding test on galvanized steel strips for armouring
(Part 40) : 1984	Uniformity of zinc coating on steel armour
(Part 41) : 1984	Mass of zinc coating on steel armour
(Part 42) : 1984	Resistivity test of armour wires and strips and conductance test of armour (wires/strips)
(Part 43) : 1984	Insulation resistance
(Part 44) : 1984	Spark test
(Part 45) : 1984	High voltage test
(Part 46) : 1984	Partial discharge test
(Part 47) : 1984	Impulse test
(Part 48) : 1984	Dielectric power factor test
(Part 49) : 1984	Heating cycle test
(Part 50) : 1984	Bending test
(Part 51) : 1984	Dripping test
(Part 52) : 1984	Drainage test
(Part 53) : 1984	Flammability test
(Part 54) : 1984	Static flexibility test
(Part 55) : 1986	Abrasion test
(Part 56) : 1987	Accelerated ageing by the air-pressure method
(Part 57) : 1987	Flexing test
(Part 58) : 1998	Oxygen index test
(Part 59) : 1988	Determination of the amount of halogen acid gas evolved during combustion of polymeric materials taken from cables
(Part 60) : 1988	Thermal stability of PVC insulation and sheath
(Part 61) : 1988	Flame retardant test
(Part 62) : 1993	Fire resistance test for bunched cables
(Part 63) : 1993	Smoke density of electric cables under fire conditions
(Part 64) : 2003	Measurement of temperature index
12943 : 1990	Brass glands for PVC cables

11. DOORS, WINDOWS AND VENTILATORS

a) Wooden Doors, Windows and Ventilators

IS No.	*Title*
1003	Specification for timber panelled and glazed shutters
(Part 1) : 2003	Door shutters (*fourth revision*)
(Part 2) : 1994	Window and ventilator shutters (*third revision*)
2191	Specification for wooden flush door shutters (cellular and hollow core type)
(Part 1) : 1983	Plywood face panels (*fourth revision*)
(Part 2) : 1983	Particle board face panels and hardboard face panels (*third revision*)
2202	Specification for wooden flush door shutters (solid core type)
(Part 1) : 1999	Plywood face panels (*sixth revision*)
(Part 2) : 1983	Particle board face panels and hardboard face panels (*third revision*)
4020	Method of tests for door shutters
(Part 1) : 1998	General (*third revision*)
(Part 2) : 1998	Measurement of dimensions and squareness (*third revision*)
(Part 3) : 1998	Measurement of general flatness (*third revision*)
(Part 4) : 1998	Local planeness test (*third revision*)
(Part 5) : 1998	Impact indentation test (*third revision*)
(Part 6) : 1998	Flexure test (*third revision*)
(Part 7) : 1998	Edge loading test (*third revision*)
(Part 8) : 1998	Shock resistance test (*third revision*)
(Part 9) : 1998	Buckling resistance test (*third revision*)
(Part 10) : 1998	Slamming test (*third revision*)
(Part 11) : 1998	Misuse test (*third revision*)
(Part 12) : 1998	Varying humidity test (*third revision*)
(Part 13) : 1998	End immersion test (*third revision*)
(Part 14) : 1998	Knife test (*third revision*)
(Part 15) : 1998	Glue adhesion test (*third revision*)
(Part 16) : 1998	Screw withdrawal resistance test (*third revision*)
4021 : 1995	Specification for timber door, window and ventilator frames

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IS No.	*Title*
6198 : 1992	Specification for ledged, braced and battened timber shutters (*second revision*)

b) Metal Doors, Windows and Ventilators

IS No.	*Title*
1038 : 1983	Specification for steel doors, windows and ventilators (*third revision*)
1361 : 1978	Specification for steel windows for industrial buildings (*first revision*)
1948 : 1961	Specification for aluminium doors, windows and ventilators
1949 : 1961	Specification for aluminium windows for industrial buildings
4351 : 2003	Specification for steel door frames (*second revision*)
6248 : 1979	Specification for metal rolling shutters and rolling grills (*first revision*)
7452 : 1990	Specification for hot rolled steel sections for doors, windows and ventilators (*second revision*)
10451 : 1983	Specification for steel sliding shutters (top hung type)
10521 : 1983	Specification for collapsible gates

c) Plastic Doors and Windows

IS No.	*Title*
14856 : 2000	Specification for glass fibre reinforced (GRP) panel type door shutters for internal use
15380 : 2003	Specification for moulded raised high density fibre (HDF) panel doors
15931 : 2012	Specification for solid panel foam UPVC door shutters

d) Concrete Door and Window Frames

IS No.	*Title*
6523 : 1983	Specification for precast reinforced concrete door and window frames (*first revision*)

e) Other Composite Material Doors and Windows

IS No.	*Title*
16073 : 2013	Specification for bamboo-jute composite panel door shutter
16074 : 2014	Specification for steel flush door shutters
16096 : 2013	Specification for phenol bonded bamboo-jute composite hollow door shutter

f) Fire Check Doors

IS No.	*Title*
3614	Specification for fire-check doors
(Part 1) : 1966	Plate, metal covered and rolling type
(Part 2) : 1992	Metallic and non-metallic fire check doors — Resistance test and performance criteria

g) Mesh/Net for Mosquito/Vector Prevention

IS No.	*Title*
1568 : 1970	Specification for wire cloth for general purposes (*first revision*)
3150 : 1982	Specification for hexagonal wire netting for general purposes (*second revision*)
11199 : 1985	Specification for HDPE mono-filament twine door nets

12. ELECTRICAL WIRING, FITTINGS AND ACCESSORIES

IS No.	*Title*
371 : 1999	Specification for ceiling roses (*third revision*)
374 : 1979	Specification for electric ceiling type fans and regulators (*third revision*)
418 : 2004	Specification for tungsten filament lamp for domestic and similar general lighting purposes (*fourth revision*)
1258 : 2005	Specification for bayonet lamp holders (*fourth revision*)
1293 : 2005	Specification for plugs and socket-outlets of rated voltage up to and including 250 volts and rated current up to and including 16 amperes (*third revision*)
1554	PVC insulated (heavy duty) electric cables
(Part 1) : 1988	For working voltages upto and including 1 100 V (*third revision*)
(Part 2) : 1988	For working voltages from 3.3 kV upto and including 11 kV (*second revision*)
2086 : 1993	Specification for carriers and bases used in re-wirable type electric fuses up to 650 volts (*third revision*)
2206 (Part 1) : 1984	Specification for flameproof electric lighting fittings: Well glass and bulkhead types (*first revision*)

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IS No.	*Title*
2215 : 2006	Specification for starters for fluorescent lamps (*third revision*)
2412 : 1975	Specification for link clips for electrical wiring (*first revision*)
2418	Specification for tubular fluorescent lamps for general lighting services
(Part 1) : 1977	Requirements and tests (*first revision*)
(Part 2) : 1977	Standard lamp data sheets (*first revision*)
(Part 3) : 1977	Dimensions of G-5 and G-13 bi-pin caps (*first revision*)
(Part 4) : 1977	Go and no-go gauges for G-5 and G-13 bi-pin caps (*first revision*)
2675 : 1983	Specification for enclosed distribution fuseboards and cutouts for voltages not exceeding 1 000 V (*second revision*)
3323 : 1980	Specification for bi-pin lamp holders for tubular fluorescent lamps (*first revision*)
3324 : 1982	Specification for holders for starters for tubular fluorescent lamps (*first revision*)
3419 : 1988	Specification for fittings for rigid non-metallic conduits (*second revision*)
3480 : 1966	Specification for flexible steel conduits for electrical wiring
3528 : 1966	Specification for waterproof electric lighting fittings
3553 : 1966	Specification for watertight electric lighting fittings
3837 : 1976	Specification for accessories for rigid steel conduits for electrical wiring (*first revision*)
3854 : 1997	Specification for switches for domestic and similar purposes (*second revision*)
4160 : 2005	Specification for interlocking switch socket outlets (*first revision*)
4649 : 1968	Specification for adaptors for flexible steel conduits
5077 : 1969	Specification for decorative lighting outfits
8030 : 1976	Specification for luminaires for hospitals
9537	Specification for conduits for electrical installations
(Part 1) : 1980	General requirements
(Part 2) : 1981	Rigid steel conduits
(Part 3) : 1983	Rigid plain conduits for insulating materials
(Part 4) : 1983	Pliable self-recovering conduits for insulating materials
(Part 5) : 2000	Pliable conduits of insulating materials
(Part 6) : 2000	Pliable conduits of metal or composite materials
(Part 8) : 2003	Rigid non threadable conduits of aluminium alloy
9926 : 1981	Specification for fuse wires used in rewirable type electric fuses up to 650 volts
10322	Specification for luminaires
(Part 1) : 2014	General requirements and tests (*first revision*)
(Part 2) : 1982	Constructional requirements
(Part 3) : 1984	Screw and screwless terminations
(Part 4) : 1984	Methods of tests
(Part 5/Sec 1) : 2012	Particular requirements, Section 1 General purpose luminaires (*first revision*)
(Part 5/Sec 2) : 2012	Particular requirements, Section 2 Recessed luminaires (*first revision*)
(Part 5/Sec 3) : 2012	Particular requirements, Section 3 Luminaires for road and street lighting (*first revision*)
(Part 5/Sec 4) : 1987	Particular requirements, Section 4 Portable general purpose luminaires
(Part 5/Sec 5) : 2013	Particular requirements, Section 5 Flood light (*first revision*)
(Part 5/Sec 6) : 2013	Particular requirements, Section 6 Hand lamps
(Part 5/Sec 7) : 2013	Particular requirements, Section 7 Lighting chains
(Part 5/Sec 8) : 2013	Particular requirements, Section 8 Emergency lighting
11037 : 1984	Electronic type fan regulators
12449	Starting devices (other than glow starters)
(Part 1) : 1988	General and safety requirements
(Part 2) : 1988	Performance requirements
12776 : 2002	Specification for galvanized strand for earthing (*first revision*)

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IS No.	*Title*
13010 : 2002	AC watt-hour meters, Class 0.5, 1 and 2 (*first revision*)
13779 : 1999	AC static watthour meters (Class 1 and 2) (*first revision*)
13947 (Part 5/ Sec 2) : 2004	Specification for low-voltage switchgear and controlgear: Part 5 Control circuit devices and switching elements, Section 2 Proximity switches
14763 : 2000	Conduit for electrical purposes, outside diameters of conduits for electrical installations and threads for conduits and fittings
14768	Conduit fittings for electrical installations
(Part 1) : 2000	General requirements
(Part 2) : 2003	Metal conduit fittings
14772 : 2000	Enclosures for accessories for household and similar fixed electrical installations
14927	Cable trunking and ducting systems for electrical installations
(Part 1) : 2001	General requirements
(Part 2) : 2001	Cable trunking and ducting systems intended for mounting on walls or ceilings
14930	Conduit systems for electrical installations
(Part 1) : 2001	General requirements
(Part 2) : 2001	Particular requirements for conduit system buried underground
15111	Self ballasted lamps for general lighting services:
(Part 1) : 2002	Safety requirements
(Part 2) : 2002	Performance requirements
15368 : 2003	Cable reels for household and similar purposes
15518 (Part 1) : 2004	Safety requirements for incandescent lamps: Part 1 Tungsten filament lamps for domestic and similar general lighting purposes
15787 : 2008	Switch-socket-outlets (non-interlock type)
15968 : 2013	Ballasts for tubular fluorescent lamps — Performance requirements
15974 : 2013	Auxiliaries for lamps — Starting devices (other than glow starters) — Performance requirements
16102	Self ballasted LED-lamps for general lighting services
(Part 1) : 2012	Safety requirements
(Part 2) : 2012	Performance requirements
16103	LED modules for general lighting
(Part 1) : 2012	Safety specification
(Part 2) : 2012	Performance requirements
16148 : 2014	Performance specification for metal halide lamps
16246: 2015	Specification for elastomer insulated cables with limited circuit integrity when affected by fire
IS/IEC 60079-1: 2007	Explosive atmospheres — Part 1 : Equipment protection by flameproof enclosures "d"
IS/IEC 60898-1: 2002	Electrical accessories — Circuit breakers for overcurrent protection for household and similar installations — Part 1: Circuit-breakers for ac operation
IS/IEC 60947-1 : 2007	Low voltage switchgear and controlgear — Part 1: General rules (*first revision*)
IS/IEC 60947-2 : 2003	Low voltage switchgear and controlgear — Part 2: Circuit breakers
IS/IEC 60947-3 : 1999	Low voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units
IS/IEC 60794-1-1: 2001	Optical fibre cables — Part 1: Generic specification, Section 1 General
IS/IEC 60794-1-2 : 2003	Optical fibre cables — Part 1: Generic specification, Section 2 Basic optical cable test procedures
IS/IEC 60794-2: 2002	Optical fibre cables — Part 2 Sectional specification for indoor cables

13. FILLERS, STOPPERS AND PUTTIES

IS No.	*Title*
110 : 1983	Specification for ready mixed paint, brushing, grey filler, for enamels, for use over primers (*second revision*)
419 : 1967	Specification for putty for use on window frames (*first revision*)
423 : 1961	Specification for plastic wood, for joiner's filler (*revised*)
3709 : 1966	Specification for mastic cement for bedding of metal windows

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IS No.	*Title*
7164 : 1973	Specification for stopper
13184 : 1991	Specification for mastic filler, epoxy based (two pack)

14. FLOOR COVERING, ROOFING AND OTHER FINISHES

a) Concrete Flooring

IS No.	*Title*
1237 : 2012	Specification for cement concrete flooring tiles (*second revision*)
6073 : 2006	Specification for autoclaved reinforced cellular concrete floor and roof slabs (*first revision*)
13801 : 2013	Specification for chequered cement concrete tiles (*first revision*)
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel units for construction of floors and roofs
15658 : 2006	Specification for precast concrete blocks for paving

b) Flooring Compositions

IS No.	*Title*
657 : 1982	Specification for materials for use in the manufacture of magnesium oxychloride flooring compositions (*second revision*)
9162 : 1979	Methods of tests for epoxy resin, hardeners and epoxy resin composition for floor topping
9197 : 1979	Specification for epoxy resin, hardness and epoxy resin compositions for floor topping
10132 : 1982	Method of test for materials for use in the preparation of magnesium oxychloride flooring composition

c) Linoleum Flooring

IS No.	*Title*
653 : 1992	Specification for linoleum sheets and tiles (*third revision*)
9704 : 1980	Methods of tests for linoleum sheets and tiles

d) Rubber Flooring

IS No.	*Title*
809 : 1992	Specification for rubber flooring materials for general purposes (*first revision*)

e) Stone Flooring

IS No.	*Title*
1128 : 1974	Specification for limestone (slab and tiles) (*first revision*)
1130 : 1969	Specification for marble (blocks, slabs and tiles)
3316 : 1974	Specification for structural granite (*first revision*)
3622 : 1977	Specification for sand stone (slabs and tiles) (*first revision*)
14223 (Part 1) : 1994	Specification for polished building stones: Part 1 Granite

f) Bituminous Flooring

IS No.	*Title*
1195 : 2002	Specification for bitumen mastic for flooring (*third revision*)
5317 : 2002	Specification for pitch-mastic for bridge decking and roads (*second revision*)
8374 : 1977	Specification for bitumen mastic, anti-static and electrically conducting grade
9510 : 1980	Specification for bitumen mastic acid resisting grade
13026 : 1991	Specification for bitumen mastic for flooring for industries handling LPG and other light hydrocarbon products
15194 : 2002	Specification for pitch-mastic flooring for industries handling heavy hydrocarbon products like kerosene, diesel and furnace oil

g) Plastic Flooring

IS No.	*Title*
3461 : 1980	Specification for PVC asbestos floor tiles (*first revision*)
3462 : 1986	Specification for unbacked flexible PVC flooring (*second revision*)
3464 : 1986	Methods of test for plastic flooring and wall tiles (*second revision*)

h) Ceramic/Vitreous Flooring and Wall Finishing

IS No.	*Title*
2333 : 1992	Specification for plaster of Paris for ceramic industry (*second revision*)
4457 : 2007	Specification for ceramic unglazed vitreous acid resisting tile (*second revision*)
13630 (Part 1) : 2006	Ceramic tiles — Methods of test, sampling and basis for acceptance Determination of dimensions and surface quality (*first revision*)

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IS No.	*Title*
(Part 2) : 2006	Determination of water absorption and bulk density (*first revision*)
(Part 3) : 2006	Determination of moisture expansion using boiling water — Unglazed tiles (*first revision*)
(Part 4) : 2006	Determination of linear thermal expansion (*first revision*)
(Part 5) : 2006	Determination of resistance to thermal shock (*first revision*)
(Part 6) : 2006	Determination of modulus of rupture and breaking strength (*first revision*)
(Part 7) : 2006	Determination of chemical resistance — Unglazed tiles (*first revision*)
(Part 8) : 2006	Determination of chemical resistance — Glazed tiles (*first revision*)
(Part 9) : 2006	Determination of crazing resistance — Glazed tiles (*first revision*)
(Part 10) : 2006	Determination of frost resistance (*first revision*)
(Part 11) : 2006	Determination of resistance to surface abrasion — Glazed tiles (*first revision*)
(Part 12) : 2006	Determination of resistance to deep abrasion — Unglazed tiles (*first revision*)
(Part 13) : 2006	Determination of scratch hardness of surface according to Mohs'(*first revision*)
(Part 14) : 2006	Determination of impact resistance by measurement of coefficient of restitution
(Part 15) : 2006	Ceramic tiles — Sampling and basis for acceptance
13712 : 2006	Ceramic tiles — Definitions, classifications, characteristics and marking (*first revision*)
15622 : 2006	Specification for pressed ceramic tiles

j) Clay Flooring

IS No.	*Title*
1478 : 1992	Specification for clay flooring tiles (*second revision*)
3951	Specification for hollow clay tiles for floor and roofs
(Part 1) : 2009	Filler type (*second revision*)
(Part 2) : 2009	Structural type (*second revision*)

k) Roofing

IS No.	*Title*
277 : 2003	Galvanized steel sheets (plain and corrugated) —Specification (*sixth revision*)
459 : 1992	Specification for corrugated and semi-corrugated asbestos cement sheets (*third revision*)
654 : 1992	Specification for clay roofing tiles, Mangalore pattern (*third revision*)
1464 : 1992	Specification for clay ridge and ceiling tiles (*second revision*)
2690	Specification for burnt clay flat terracing tiles
(Part 1) : 1993	Machine made (*second revision*)
(Part 2) : 1992	Handmade (*second revision*)
3951	Specification for hollow clay tiles for floor and roofs
(Part 1) : 2009	Filler type (*second revision*)
(Part 2) : 2009	Structural type (*second revision*)
6073 : 2006	Specification for autoclaved reinforced cellular concrete floor and roof slabs (*first revision*)
6250 : 1981	Specification for roofing slate tiles (*first revision*)
10388 : 1982	Specification for corrugated coir wood wool cement roofing sheets
12583 : 1988	Specification for corrugated bitumen roofing sheets
12866 : 1989	Specification for plastic translucent sheets made from thermosetting polyester resin (glass fibre reinforced)
13317 : 1992	Specification for clay roofing country tiles, half round and flat tiles
13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
14201 : 1994	Specification for precast reinforced concrete channel units for construction of floors and roofs
14241 : 1995	Specification for precast L-Panel units for roofing

m) Other Floorings and Roofings

IS No.	*Title*
4456	Methods of test for chemical resistant mortars
(Part 1) : 1967	Silicate type and resin type
(Part 2) : 1967	Sulphur type

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IS No.	*Title*
4457 : 2007	Specification for ceramic unglazed vitreous acid resisting tile (*second revision*)
4832	Specification for chemical resistant mortars
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1968	Sulphur type
4860 : 1968	Specification for acid resistant bricks
14862 : 2000	Specification for fibre cement flat sheets
14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
14871 : 2000	Specification for products in fibre reinforced cement — Long corrugated or asymmetrical section sheets and fittings for roofing and cladding

n) Wall Coverings/Finishing

IS No.	*Title*
1542 : 1992	Specification for sand for plaster (*second revision*)
3952 : 2013	Specification for burnt clay hollow bricks and blocks for walls and partitions (*third revision*)
4456	Methods of test for chemical resistant mortars
(Part 1) : 1967	Silicate type and resin type
(Part 2) : 1967	Sulphur type
4832	Specification for chemical resistant mortars
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1968	Sulphur type
15418 : 2003	Specification for finished wall papers, wall vinyls and plastic wall coverings in roll form

15. GLASS

IS No.	*Title*
2553 (Part 1) : 1990	Specification for safety glass: Part 1 General purpose (*third revision*)
2835 : 1987	Specification for flat transparent sheet glass (*third revision*)
3438 : 1994	Specification for silvered glass mirrors for general purposes (*second revision*)
5437 : 1994	Specification for figured rolled and wired glass (*first revision*)
14900 : 2000	Specification for transparent float glass

16. GYPSUM BASED MATERIALS

IS No.	*Title*
2095	Specification for gypsum plaster boards
(Part 1) : 2011	Plain gypsum plaster boards (*third revision*)
(Part 2) : 2001	Coated/laminated gypsum plaster boards (*second revision*)
(Part 3) : 1996	Reinforced gypsum plaster boards (*second revision*)
2542	Methods of test for gypsum plaster, concrete and products
(Part 1/Sec 1) : 1978	Plaster and concrete, Section 1 Normal consistency of gypsum plaster (*first revision*)
(Part 1/Sec 2) : 1978	Plaster and concrete, Section 2 Normal consistency of gypsum concrete (*first revision*)
(Part 1/Sec 3) : 1978	Plaster and concrete, Section 3 Setting time of plaster and concrete (*first revision*)
(Part 1/Sec 4) : 1978	Plaster and concrete, Section 4 Transverse strength of gypsum plaster (*first revision*)
(Part 1/Sec 5) : 1978	Plaster and concrete, Section 5 Compressive strength and dry set density of gypsum plaster (*first revision*)
(Part 1/Sec 6) : 1978	Plaster and concrete, Section 6 Soundness of gypsum plaster (*first revision*)
(Part 1/Sec 7) : 1978	Plaster and concrete, Section 7 Mechanical resistance of gypsum plaster by dropping ball test (*first revision*)
(Part 1/Sec 8) : 1978	Plaster and concrete, Section 8 Freedom from coarse particles (*first revision*)
(Part 1/Sec 9) : 1978	Plaster and concrete, Section 9 Expansion of plaster (*first revision*)
(Part 1/Sec 10) : 1978	Plaster and concrete, Section 10 Sand in set plaster (*first revision*)
(Part 1/Sec 11) : 1978	Plaster and concrete, Section 11 Wood fibre content in gypsum plaster (*first revision*)

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IS No.	*Title*
(Part 1/Sec 12) : 1978	Plaster and concrete, Section 12 Dry bulk density (*first revision*)
(Part 2/Sec 1) : 1981	Gypsum products, Section 1 Measurement of dimensions (*first revision*)
(Part 2/Sec 2) : 1981	Gypsum products, Section 2 Determination of mass (*first revision*)
(Part 2/Sec 3) : 1981	Gypsum products, Section 3 Determination of mass and thickness of paper surfacing (*first revision*)
(Part 2/Sec 4) : 1981	Gypsum products, Section 4 Transverse strength (*first revision*)
(Part 2/Sec 5) : 1981	Gypsum products, Section 5 Compressive strength (*first revision*)
(Part 2/Sec 6) : 1981	Gypsum products, Section 6 Water absorption (*first revision*)
(Part 2/Sec 7) : 1981	Gypsum products, Section 7 Moisture content (*first revision*)
(Part 2/Sec 8) : 1981	Gypsum products, Section 8 Nail retention of precast reinforced gypsum slabs (*first revision*)
2547	Specification for gypsum building plaster
(Part 1) : 1976	Excluding premixed lightweight plaster (*first revision*)
(Part 2) : 1976	Premixed lightweight plaster (*first revision*)
2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types) (*first revision*)
8272 : 1984	Specification for gypsum plaster for use in the manufacture of fibrous plasterboards (*first revision*)
9498 : 1980	Specification for inorganic aggregates for use in gypsum plaster
12679 : 1989	Specification for by-product gypsum for use in plaster, blocks and boards

17. MORTAR (INCLUDING SAND FOR MORTAR)

IS No.	*Title*
2116 : 1980	Specification for sand for masonry mortars (*first revision*)
2250 : 1981	Code of Practice for preparation and use of masonry mortars (*first revision*)
3085 : 1965	Method of test for permeability of cement mortar and concrete
4098 : 1983	Specification for lime-pozzolana mixture (*first revision*)
4456	Methods of test for chemical resistant mortars
(Part 1) : 1967	Silicate type and resin type
(Part 2) : 1967	Sulphur type
4832	Chemical resistant mortars
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1968	Sulphur type
13077 : 1991	Guide for preparation and use of mud mortar in masonry
14959	Method of test determination of water soluble and acid soluble chlorides in mortar and concrete
(Part 1) : 2001	Fresh mortar and concrete
(Part 2) : 2001	Hardened mortar and concrete

18. PAINTS AND ALLIED PRODUCTS

a) Water Based Paints and Pigments

IS No.	*Title*
427 : 2013	Specification for distemper, dry, colour as required (*third revision*)
428 : 2013	Specification for washable distemper (*third revision*)
5410 : 2013	Specification for cement paint (*second revision*)
15489 : 2013	Specification for paint, plastic emulsion (*first revision*)

b) Ready Mixed Paints, Enamels and Powder Coatings

IS No.	*Title*
101	Methods of sampling and test for paints, varnishes and related products
(Part 1/Sec 1) : 1986	Test on liquid paints (general and (general and physical), Section 1 Sampling (*third revision*)
(Part 1/Sec 2) : 1987	Test on liquid paints (general and physical), Section 2 Preliminary examination and preparation of samples for testing (*third revision*)
(Part 1/Sec 3) : 1986	Test on liquid paints (general and physical), Section 3 Preparation of panels (*third revision*)
(Part 1/Sec 4) : 1987	Test on liquid paints (general and physical), Section 4 Brushing test (*third revision*)

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IS No.	*Title*
(Part 1/Sec 5) : 1989	Test on liquid paints (general and physical), Section 5 Consistency (*third revision*)
(Part 1/Sec 6) : 1987	Test on liquid paints (general and physical), Section 6 Flash point (*third revision*)
(Part 1/Sec 7) : 1987	Test on liquid paints (general and physical), Section 7 Mass per 10 litres (*third revision*)
(Part 2/Sec 1) : 1988	Test on liquid paints (Chemical examination), Section 1 Water content (*third revision*)
(Part 2/Sec 2) : 1986	Test on liquid paints (Chemical examination), Section 2 Volatile matter (*third revision*)
(Part 3/Sec 1) : 1986	Tests on paint film formation, Section 1 Drying time (*third revision*)
(Part 3/Sec 2) : 1989	Tests on paint film formation, Section 2 Film thickness (*third revision*)
(Part 3/Sec 4) : 1987	Tests on paint film formation, Section 4 Finish (*third revision*)
(Part 3/Sec 5) : 1987	Tests on paint film formation, Section 5 Fineness of grind (*third revision*)
(Part 4/Sec 1) : 1988	Optical test, Section 1 Opacity (*third revision*)
(Part 4/Sec 2) : 1989	Optical test, Section 2 Colour (*third revision*)
(Part 4/Sec 3) : 1988	Optical test, Section 3 Light fastness test (*third revision*)
(Part 4/Sec 4) : 1988	Optical test, Section 4 Gloss (*third revision*)
(Part 5/Sec 1) : 1988	Mechanical test on paint films, Section 1 Hardness tests (*third revision*)
(Part 5/Sec 2) : 1988	Mechanical test on paint films, Section 2 Flexibility and adhesion (*third revision*)
(Part 5/Sec 3) : 1999	Mechanical test on paint films, Section 3 Impact resistance (*fourth revision*)
(Part 5/Sec 4) : 1988	Mechanical test on paint films, Section 4 Print free test (*third revision*)
(Part 6/Sec 1) : 1988	Durability tests, Section 1 Resistance to humidity under conditions of condensation (*third revision*)
(Part 6/Sec 2) : 1989	Durability tests, Section 2 Keeping properties (*third revision*)
(Part 6/Sec 3) : 1990	Durability tests, Section 3 Moisture vapour permeability (*third revision*)
(Part 6/Sec 4) : 1991	Durability tests, Section 4 Degradation of coatings (pictorial aids for evaluation) (*third revision*)
(Part 6/Sec 5) : 1997	Durability tests, Section 5 Accelerated weathering test
(Part 7/Sec 1) : 1989	Environmental tests on paint films, Section 1 Resistance to water (*third revision*)
(Part 7/Sec 2) : 1989	Environmental tests on paint films, Section 2 Resistance to liquids (*third revision*)
(Part 7/Sec 3) : 1990	Environmental tests on paint films, Section 3 Resistance to heat (*third revision*)
(Part 7/Sec 4) : 1990	Environmental tests on paint films, Section 4 Resistance to bleeding of pigments (*third revision*)
(Part 8/Sec 1) : 1989	Tests for pigments and other solids, Section 1 Residue on sieve (*third revision*)
(Part 8/Sec 2) : 1990	Tests for pigments and other solids, Section 2 Pigments and non –volatile matter (*third revision*)
(Part 8/Sec 3) : 1993	Tests for pigments and other solids, Section 3 Ash content (*third revision*)
(Part 8/Sec 4) : 2015	Tests for pigments and other solids, Section 4 Phthalic anhydride (*fourth revision*)
(Part 8/Sec 5) : 1993	Tests for pigments and other solids, Section 5 Lead restriction test (*third revision*)
(Part 8/Sec 6) : 1993	Tests for pigments and other solids, Section 6 Volume solids
(Part 9/Sec 1) : 1993	Tests for lacquers and varnish, Section 1 Acid value (*third revision*)
(Part 9/Sec 2) : 1993	Tests for lacquers and varnish, Section 2 Rosin test (*third revision*)
104 : 1979	Specification for ready mixed paint, brushing, zinc chrome, priming (*second revision*)

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IS No.	*Title*
109 : 1968	Specification for ready mixed paint, brushing, priming, plaster to Indian Standard colours No. 361 and 631 (*first revision*)
133 : 2004	Specification for enamel, interior (a) undercoating, (b) finishing (*fourth revision*)
133 (Part 1) : 2013	Specification for enamel, interior (a) undercoating, (b) finishing : Part 1 For household and decorative purposes (*fifth revision*)
137 : 1965	Specification for ready mixed paint, brushing, matt or egg-shell flat, finishing, interior, to Indian Standard colour, as required (*revised*)
158 : 2015	Specification for ready mixed paint, brushing, bituminous, black, lead-free, acid, alkali, and heat resisting (*fourth revision*)
164 : 1981	Specification for ready mixed paint for road marking (*second revision*)
168 : 1993	Specification for ready mixed paint, air-drying semi-glossy/matt, for general purposes (*third revision*)
341 : 1973	Specification for black Japan, Types A, B and C (*first revision*)
2074 : 1992	Specification for ready mixed paint, air drying red oxide-zinc chrome, priming (*second revision*)
2075 : 2000	Specification for ready mixed paint, stoving, red oxide-zinc chrome, priming (*second revision*)
2339 : 2013	Specification for aluminium paint for general purposes (*first revision*)
2932 (Part 1) : 2013	Specification for enamel, synthetic, exterior (a) undercoating, (b) finishing: Part 1 For household and decorative applications (*fourth revision*)
2933 (Part 1) : 2013	Specification for enamel, exterior: (a) undercoating (b) finishing: Part 1 for domesic and decorative applications
3536 : 1999	Specification for ready mixed paint, brushing, wood primer (*first revision*)
3537 : 1966	Specification for ready mixed paint, finishing, interior for general purposes, to Indian Standard colours No. 101, 216, 217, 219, 275, 281, 352, 353, 358 to 361, 363, 364, 388, 410, 442, 444, 628, 631, 632, 634, 693, 697, white and black
3539 : 1966	Specification for ready mixed paint, undercoating, for use under oil finishes, to Indian Standard colours, as required
3585 : 1966	Specification for ready mixed paint, aluminium, brushing, priming, water resistant, for wood work
3678 : 1966	Specification for ready mixed paint, thick white, for lettering
9862 : 1981	Specification for ready mixed paint, brushing, bituminous black lead free, acid, alkali, water and chlorine resisting
11883 : 1986	Specification for ready mixed paint, brushing, red oxide, priming for metals
12744 (Part 1) : 2013	Specification for ready mixed paint, air drying, red oxide, zinc phosphate, priming: Part 1 for domestic and decorative applications (*fourth revision*)
13183 : 1991	Specification for aluminium paints, heat resistant
13213 : 1991	Specification for polyurethane full gloss enamel (two pack)
13607 : 1992	Specification for ready mixed paint, finishing, general purposes, synthetic
13871 : 1993	Specification for powder coatings
14506 : 1998	Specification for epoxy redoxide zinc phosphate weldable primer, two component
14589 : 1999	Specification for zinc priming paint, epoxy based, two pack

c) Thinners and Solvents

IS No.	*Title*
82 : 1973	Methods of sampling and test for thinners and solvents for paints (*first revision*)
430 : 1972	Paint remover, solvent type, non-flammable (*second revision*)
431 : 1972	Paint remover, solvent type, flammable (second revision)
533 : 2007	Specification for gum spirit of turpentine (oil of turpentine) (*third revision*)

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IS No.	*Title*
5667 : 1970	Specification for thinner for cellulose nitrate based paints and lacquers
14314 : 1995	Specification for thinner general purposes for synthetic paints and varnishes

d) Varnishes and Lacquers

IS No.	*Title*
337 : 1975	Specification for varnish, finishing, interior (*first revision*)
344 : 1976	Specification for varnish, stoving (*first revision*)
347 : 1975	Specification for varnish, shellac, for general purposes (*first revision*)
348 : 1968	Specification for French polish (*first revision*)
524 : 1983	Specification for varnish, finishing, exterior, synthetic (*second revision*)
525 : 1968	Specification for varnish, finishing, exterior and general purposes (*first revision*)
642 : 1963	Specification for varnish medium for aluminium paint (*revised*)
10018 : 1981	Specification for lacquer, cellulose, nitrate clear, finishing, glossy for wood

19. POLYMERS, PLASTICS AND GEOSYNTHETICS/GEOTEXTILES

IS No.	*Title*
1998 : 1962	Methods of test for thermosetting synthetic resin bonded laminated sheets
2036 : 1995	Specification for phenolic laminated sheets (*second revision*)
2046 : 1995	Specification for decorative thermosetting synthetics resin bonded laminated sheets (*second revision*)
2076 : 1981	Specification for unsupported polyvinyl chloride sheeting (*first revision*)
2508 : 1984	Specification for low density polyethylene films (*second revision*)
6307 : 1985	Specification for rigid PVC sheets (*first revision*)
10889 : 2004	Specification for high density polyethylene films (*first revision*)
12830 : 1989	Specification for rubber based adhesives for fixing PVC tiles to cement
13162	Methods of test for geotextiles
(Part 2) : 1991	Determination of resistance to exposure of ultra-violet light and water (Xenon arc type apparatus)
(Part 3) : 1992	Determination of thickness at specified pressure
(Part 4) : 1992	Determination of puncture resistance by falling cone method
(Part 5) : 1992	Determination of tensile properties using a wide width strip
13262 : 1992	Specification for pressure sensitive adhesive tapes with plastic base
13325 : 1992	Method of test for the determination to tensile properties of extruded polymer geogrids using the wide strip
13326 (Part 1) : 1992	Method of test for the evaluation of interface friction between geosynthetics and soil: Part 1 Modified direct shear technique
14182 : 1994	Specification for solvent cement for use with unplasticized polyvinyl-chloride plastic pipe and fittings
14293 : 1995	Method of test for trapezoid tearing – Geotextiles
14294 : 1995	Method of determination of apparent opening size by dry sieving technique – Geotextiles
14324 : 1995	Method of test for determination of water permeability-permittivity — Geotextiles
14443 : 1997	Specification for polycarbonate sheets
14500 : 1998	Specification for linear low-density polyethylene (LLDPE) films
14643 : 1999	Specification for unsintered polytetrafluoroethylene (PTFE) tape for thread sealing applications
14706 : 1999	Sampling and preparation of test specimen of geotextiles
14714 : 1999	Determination of abrasion resistance of geotextiles
14715 : 2000	Specification for woven jute geotextiles
14716 : 1999	Determination of mass per unit area of geotextiles
14739 : 1999	Methods for determination of creep of geotextiles
14753 : 1999	Specification for poly(methyl) methacrylate (PMMA) (Acrylic) sheets

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IS No.	*Title*
14986 : 2001	Jute geo-grid for rain water erosion control in road and railway embankments and hill slopes
15060 : 2001	Tensile test for joints/seams by wide width method of geotextiles
15351 : 2015	Specification for textiles — Laminated high density polyethylene (HDPE) woven fabric (geo-membrane) for waterproof lining (*second revision*)

20. SANITARY APPLIANCES AND WATER FITTINGS

a) General

IS No.	*Title*
782 : 1978	Specification for caulking lead (*third revision*)
804 : 1967	Specification for rectangular pressed steel tanks (*first revision*)
1726 : 1991	Specification for cast iron manhole covers and frames (*third revision*)
2963 : 2013	Specification for copper alloy waste fittings and waste plug for wash-basins and sinks (*second revision*)
5219 : 2013	Specification for cast copper alloy traps (*first revision*)
5455 : 1969	Specification for cast-iron steps for manholes
5961 : 1970	Specification for cast iron gratings for drainage purposes
9140 : 1996	Method of sampling of vitreous and fire clay sanitary appliances (*second revision*)
9872 : 1981	Specification for precast concrete septic tanks
12592 : 2002	Specification for precast concrete manhole covers and frames (*first revision*)
12701 : 1996	Specification for rotational moulded polyethylene water storage tanks (*first revision*)
13356 : 1992	Specification for precast ferrocement water tanks (250 to 10 000 litres capacity)
14399	Hot press moulded thermosetting glass fibre reinforced (GRP) sectional water storage tanks
(Part 1) : 1996	Specification for panels
(Part 2) : 1996	Guidelines for assembly, installation and testing

b) Pipes and Fittings excluding valves

i) Brass and Copper Pipes and Fittings

IS No.	*Title*
407 : 1981	Specification for brass tubes for general purposes (*third revision*)
2501 : 1995	Specification for solid drawn copper tubes for general engineering purposes (*third revision*)

ii) *Cast Iron Pipes and Fittings*

IS No.	*Title*
1536 : 2001	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*fourth revision*)
1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
1538 : 1993	Specification for cast iron fittings for pressure pipes for water, gas and sewage (*third revision*)
1729 : 2002	Cast iron/ductile iron drainage pipes and pipe fittings for over ground non-pressure pipeline socket and spigot series (*second revision*)
1879 : 2010	Specification for malleable cast iron pipe fittings (*third revision*)
3989: 2009	Specification for centrifugally cast (spun) iron spigot and socket soil, waste and ventilating pipes, fittings and accessories (*third revision*)
5531: 2014	Specification for cast iron specials for asbestos-cement pressure pipes for water, gas and sewage (*third revision*)
6418 : 1971	Specification for cast iron and malleable cast iron flanges for general engineering purposes
7181 : 1986	Specification for horizontally cast iron double flanged pipes for water, gas and sewage (*first revision*)
8329 : 2000	Specification for centrifugally cast (spun) ductile iron pressure pipes for water, gas and sewage (*third revision*)
8794 : 1988	Specification for cast iron detachable joints for use with asbestos cement pressure pipes (*first revision*)
9523 : 2000	Specification for ductile iron fittings for pressure pipes for water, gas and sewage (*first revision*)

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IS No.	*Title*
10292 : 1988	Dimensional requirements for rubber sealing rings for C.I.D. Joints in asbestos cement piping (*first revision*)
10299 : 1982	Cast iron saddle pieces for service connection from asbestos cement pressure pipes
11606 : 1986	Methods of sampling cast iron pipes and fittings
12820 : 2004	Dimensional requirements of rubber gaskets for mechanical joints and push-on joints for use with cast iron pipes and fittings for carrying water, gas and sewage (*first revision*)
12987 : 1991	Cast iron detachable joints for use with asbestos cement pressure pipes (light duty)
12988 : 1991	Rubber sealing rings for CID joints for light duty AC pipes — Dimensional requirements
13382 : 2004	Specification for cast iron specials for mechanical and push-on flexible joints for pressure pipelines for water, gas and sewage (*first revision*)
15905 : 2011	Specification for hubless centrifugally cast (spun) iron pipes, fittings and accessories — Spigot series

iii) *Lead Pipes and Fittings*

IS No.	*Title*
404 (Part 1) : 1993	Specification for lead pipes: Part 1 For other than chemical purpose (*third revision*)

iv) *Fibre Pipes and Fittings*

IS No.	*Title*
11925 : 1986	Specification for pitch-impregnated fibre pipes and fittings for drainage purposes

v) *Plastic Pipes and Fittings*

IS No.	*Title*
4984 : 1995	Specification for high density polyethylene pipes for water supply (*fourth revision*)
4985 : 2000	Specification for unplasticized PVC pipes for potable water supplies (*third revision*)
7834	Specification for injection moulded PVC socket fittings with solvent cement joints for water supplies
(Part 1) : 1987	General requirements (*first revision*)
(Part 2) : 1987	Specific requirements for 45° elbows (*first revision*)
(Part 3) : 1987	Specific requirements for 90° elbows (*first revision*)
(Part 4) : 1987	Specific requirements for 90° tees (*first revision*)
(Part 5) : 1987	Specific requirements for 45° tees (*first revision*)
(Part 6) : 1987	Specific requirements for sockets (*first revision*)
(Part 7) : 1987	Specific requirements for unions (*first revision*)
(Part 8) : 1987	Specific requirements for caps (*first revision*)
8008	Specification for injection moulded high density polyethylene (HDPE) fittings for potable water supplies
(Part 1) : 2003	General requirements
(Part 2) : 2003	Specific requirements for 90° bends (*first revision*)
(Part 3) : 2003	Specific requirements for 90° tees
(Part 4) : 2003	Specific requirements for reducers
(Part 5) : 2003	Specific requirements for ferrule reducers (*first revision*)
(Part 6) : 2003	Specific requirements for pipe ends
(Part 7) : 2003	Specific requirements for sandwich flanges
(Part 8) : 2003	Specific requirements for reducing tests
(Part 9) : 2003	Specific requirements for end caps (*first revision*)
8360	Specification for fabricated high density polyethelene (HDPE) fittings for potable water supplies
(Part 1) : 1977	General requirements
(Part 2) : 1977	Specific requirements for 90° tees
(Part 3) : 1977	Specific requirements for 90° bends
10124	Specification for fabricated PVC-U fittings for potable water supplies
(Part 1) : 2009	General requirements (*second revision*)
(Part 2) : 2009	Specific requirements for sockets (*second revision*)
(Part 3) : 2009	Specific requirements of straight reducers (*second revision*)
(Part 4) : 2009	Specific requirements for caps (*second revision*)
(Part 5) : 2009	Specific requirements for equal tees (*second revision*)

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IS No.	*Title*
(Part 6) : 2009	Specific requirements for flanged tail piece with metallic flanges (*second revision*)
(Part 7) : 2009	Specific requirements for threaded adaptors (*second revision*)
(Part 8) : 2009	Specific requirements for 90° bends (*second revision*)
(Part 9) : 2009	Specific requirements for 60° bends (*second revision*)
(Part 10) : 2009	Specific requirements for 45° bends (*second revision*)
(Part 11) : 2009	Specific requirements for 30° bends (*second revision*)
(Part 12) : 2009	Specific requirements for 22½° bends (*second revision*)
(Part 13) : 2009	Specific requirements for 11¼° bends (*second revision*)
12235	Methods of test for unplasticised PVC pipes for potable water supplies
(Part 1) : 2004	Measurement of dimensions (*first revision*)
(Part 2) : 2004	Determination of Vicat softening temperature (*first revision*)
(Part 3) : 2004	Test for opacity (*first revision*)
(Part 4) : 2004	Determining the detrimental effect on the composition of water (*first revision*)
(Part 5/Sec 1) : 2004	Longitudinal reversion, Section 1 Determination methods (*first revision*)
(Part 5/Sec 2) : 2004	Reversion test, Section 2 Determination parameters (*first revision*)
(Part 6) : 2004	Stress relief test (*first revision*)
(Part 7) : 2004	Resistance to sulphuric acid (*first revision*)
(Part 8/Sec 1) : 2004	Resistance to internal hydrostatic pressure, Section 1 Resistance to internal hydrostatic pressure at constant internal water pressure (*first revision*)
(Part 8/Sec 2) : 2004	Resistance to internal hydrostatic pressure, Section 2 Leak-tightness of elastomeric sealing ring type socket joints under positive internal pressure and with angular deflection (*first revision*)
(Part 8/Sec 3) : 2004	Resistance to internal hydrostatic pressure, Section 3 Leak-tightness of elastomeric sealing ring type socket joints under negative internal pressure and with angular deflection (*first revision*)
(Part 8/Sec 4) : 2004	Resistance to internal hydrostatic pressure, Section 4 Leak-tightness of elastomeric sealing ring type socket joints under positive internal pressure without angular deflection (*first revision*)
(Part 9) : 2004	Resistance to external blows (impact resistance) at 0°C (Round-the-clock method)
(Part 10) : 2004	Determination of organotin as tin aqueous solution (*first revision*)
(Part 11) : 2004	Resistance to dichloromethane at specified temperature (*first revision*)
(Part 12) : 2004	Determination of titanium dioxide content
(Part 13) : 2004	Determination of tensile strength and elongation
(Part 14) : 2004	Determination of density/relative density (specific gravity)
(Part 15) : 2004	Determination of vinyl chloride monomer content
(Part 16) : 2004	High temperature test
(Part 17) : 2004	Determination of ash content and sulphated ash content
(Part 18) : 2004	Determination of ring stiffness
(Part 19) : 2004	Flattening test
12709 : 1994	Specification for glass-fibre reinforced plastic (GRP) pipes joints and fittings for use for potable water supply (*first revision*)
12818 : 2010	Specification for unplasticized polyvinyl chloride(PVC-U) screen and casing pipes for bore/tubewells (*second revision*)
13592 : 2013	Specification for unplasticized polyvinyl chloride (PVC-U) pipes for soil and waste discharge system for inside and outside buildings including ventilation and rainwater system (*first revision*)
14333 : 1996	Specification for high density polyethylene pipes for sewerage
14402 : 1996	Specification for GRP pipes, joints and fittings for use for sewerage, industrial waste and water (other than potable)

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IS No.	*Title*
14735 : 1999	Specification for unplasticized polyvinyl chloride (UPVC) injection moulded fittings for soil and waste discharge system for inside and outside buildings including ventilation and rain water system
14885 : 2001	Specification for polyethylene pipe for supply of gaseous fuel
15328 : 2003	Specification for unplasticized non-pressure polyvinyl chloride (PVC-U) pipes for use in underground drainage and sewerage system
15450 : 2004	Specification for polyethylene/ aluminium/polyethylene composite pressure pipes for hot and cold water supplies
15778 : 2007	Specification for chlorinated polyvinyl chloride (CPVC) pipes for potable hot and cold water distribution supplies
15801 : 2008	Specification for polypropylene-random copolymer pipes for hot and cold water supplies
15927	Specification for polyethylene fittings for use with polyethylene pipes for the supply of gaseous fuels
(Part 1) : 2012	Fittings for sockets using heated tools
(Part 2) : 2012	Spigot fittings for butt fusion jointing or socket fusion using heated tools, spigot fittings for use with electro-fusion fittings
(Part 3) : 2011	Electro-fusion fittings
16098	Specification for structured - wall plastics piping systems for non-pressure drainage and sewerage
(Part 1) : 2013	Pipes and fittings with smooth external surface, Type A
(Part 2) : 2013	Pipes and fittings with non-smooth external surface, Type B

vi) *Steel Tubes, Pipes and Fittings*

IS No.	*Title*
1239	Specification for steel tubes, tubular and other wrought steel fittings
(Part 1) : 2004	Steel tubes (*sixth revision*)
(Part 2) : 2011	Steel pipe fittings (*fifth revision*)
3589 : 2001	Specification for steel pipes for water and sewage (168.3 to 2 540 mm outside diameter) (*third revision*)
4270 : 2001	Specification for steel tubes used for water wells (*third revision*)
5504 : 1997	Specification for spiral welded pipes (*first revision*)
6286 : 1979	Seamless and welded steel pipe for sub-zero temperature service
6392 : 1971	Steel pipe flanges

vii) *Stoneware Pipes and Fittings*

IS No.	*Title*
651 : 2007	Specification for glazed stoneware pipes and fittings (*sixth revision*)
3006 : 1979	Specification for chemically resistant glazed stoneware pipes and fittings (*first revision*)

viii) *Asbestos Cement Pipes*

[See 8 (a) (ii) under the category 'Composite Matrix Products']

ix) *Concrete Pipes and Pipes lined/coated with Concrete or Mortar*

[See 8 (a) (iv) under the category 'Composite Matrix Products']

c) Kitchen and Sanitary Appliances

IS No.	*Title*
771	Specification for glazed fire clay sanitary appliances
(Part 1) : 1979	General requirements (*second revision*)
(Part 2) : 1985	Specific requirements of kitchen and laboratory sinks (*third revision*)
(Part 3/Sec 1) : 1979	Specific requirements of urinals, Section 1 Slab urinals (*second revision*)
(Part 3/Sec 2) : 1985	Specific requirements of urinals, Section 2 Stall urinals (*third revision*)
(Part 4) : 1979	Specific requirements of post mortom slabs (*second revision*)
(Part 5) : 1979	Specific requirements of shower trays (*second revision*)
(Part 6) : 1979	Specific requirements of bed-pan sinks (*second revision*)
(Part 7) : 1981	Specific requirements of slop sinks (*second revision*)
772 : 1973	Specification for general requirements of enamelled cast iron sanitary appliances (*second revision*)
774 : 2004	Specification for flushing cisterns for water-closets and urinals (other than plastic cisterns) (*fifth revision*)
2326 : 1987	Specification for automatic flushing cisterns for urinals (*second revision*)

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IS No.	*Title*
2548	Specification for plastic seats and covers for water-closets
(Part 1) : 1996	Thermoset seats and covers (*fifth revision*)
(Part 2) : 1996	Thermoplastic seats and covers (*fifth revision*)
2556	Specification for vitreous sanitary appliances (vitreous china)
(Part 1) : 1994	General requirements (*third revision*)
(Part 2) : 2004	Specific requirements of wash-down water-closets (*fifth revision*)
(Part 3) : 2004	Specific requirements of squatting pans (*fifth revision*)
(Part 4) : 2004	Specific requirements of wash basins (*fourth revision*)
(Part 5) : 1994	Specific requirements of laboratory sinks (*third revision*)
(Part 6) : 1995	Specific requirements of urinals and partition plates (*fourth revision*)
(Part 7) : 1995	Specific requirements of accessories for sanitary appliances (*third revision*)
(Part 8) : 2004	Specific requirements of pedestal close coupled wash-down and syphonic water closets (*fifth revision*)
(Part 9) : 2004	Specific requirements of pedestal type bidets (*fifth revision*)
(Part 14): 1995	Specific requirements of integrated squatting pans (*first revision*)
(Part 15) : 2004	Specific requirements of universal water closets (*second revision*)
(Part 16) : 2002	Specific requirements for wash down wall mounted water closets
(Part 17) : 2001	Specific requirements for wall mounted bidets
6411 : 1985	Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)
7231 : 1994	Specification for plastic flushing cisterns for water-closets and urinals (*second revision*)
11246 : 1992	Specification for glass fibre reinforced polyester resins (GRP) squatting pans (*first revision*)
13983 : 1994	Specification for stainless steel sinks for domestic purposes

d) Valves and Water Fittings (including Ferrules)

IS No.	*Title*
778 : 1984	Specification for copper alloy gate, globe, and check valves for water works purposes (*fourth revision*)
781 : 1984	Specification for cast copper alloy screw-down bib taps and stop valves for water services (*third revision*)
1701 : 1960	Specification for mixing valves for ablutionary and domestic purposes
1703 : 2000	Specification for water fittings — Copper alloy float valves (horizontal plunger type) (*fourth revision*)
1711 : 1984	Specification for self-closing taps for water supply purposes (*second revision*)
1795 : 1982	Specification for pillar taps for water supply purposes (*second revision*)
2692 : 1989	Specification for ferrules for water services (*second revision*)
3004 : 1979	Specification for plug cocks for water supply purposes (*first revision*)
3042 : 1965	Specification for single faced sluice gates (200 to 1 200 mm size)
3950 : 1979	Specification for surface boxes for sluice valves (*first revision*)
4038 : 1986	Specification for foot valves for water works purposes (*second revision*)
4346 : 1982	Specification for washers for use with fittings for water services (*first revision*)
5312	Specification for swing check type reflux (non-return) valves
(Part 1) :2004	Single door pattern (*second revision*)
(Part 2) :2013	Multi-door pattern (*first revision*)
8931 : 1993	Specification for cast copper alloy fancy single tap combination tap and stop valves for water services (*first revision*)
9338 : 2013	Specification for cast iron/S.G. iron, cast steel screw-down stop valves for water works purposes (*second revision*)
9739 : 1981	Specification for pressure reducing valves for domestic water supply systems
9758 : 1981	Specification for flush valves and fittings for water-closets and urinals
9762 : 1994	Specification for polyethylene floats (spherical) for float valves (*first revision*)

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IS No.	*Title*
9763 : 2000	Specification for plastic bib taps, pillar taps, angle valves, hot and cold water services (*second revision*)
12234 : 1988	Specification for plastic equilibrium float valve for cold water services
13049 : 1991	Specification for diaphragm type (plastic body) float operated valves for cold water services
13114 : 1991	Specification for forged brass gate, globe and check valves for water works purposes
13349 : 1992	Specification for single faced cast iron thimble mounted sluice gates
14845 : 2000	Specification for resilient seated cast iron air relief valves for water works purposes
14846 : 2000	Specification for sluice valves for water works purposes (50-1 200 mm)

e) Water Meters

IS No.	*Title*
779 : 1994	Specification for water meters (domestic type) (*sixth revision*)
2373 : 1981	Specification for water meters (bulk type) (*third revision*)
6784 : 1996	Method for performance testing of water meters (domestic type) (*second revision*)

21. STEEL AND ITS ALLOYS (*See* 23 FOR STRUCTURAL SECTIONS)

a) General

IS No.	*Title*
1030 : 1998	Carbon steel castings for general engineering purposes (*fifth revision*)
1136 : 2008	Preferred sizes for wrought metal products (*third revision*)
1762 (Part 1) : 1974	Code for designation of steels: Part 1 Based on letter symbols (*first revision*)
2049 : 1978	Colour code for the identification of wrought steel for general engineering purposes (*first revision*)
2644 : 1994	High tensile steel castings (*fourth revision*)
2708 : 1993	Specification for 1.5 percent manganese steel castings for general engineering purposes (*third revision*)
7598 : 1990	Classification of steels (*first revision*)
10461	Resistance to inter-granular corrosion of austenitic stainless steels — Method for determination
(Part 1) : 1994	Corrosion test in nitric acid medium by measurement of loss in mass (Huey test) (*first revision*)
(Part 2) : 1994	Corrosion test in a sulphuric acid/ copper sulphate medium in the presence of copper turnings (Monypenny Strauss Test) (*first revision*)

b) Structural Steel

IS No.	*Title*
2062 : 2011	Specification for hot rolled medium and high tensile structural steel (*seventh revision*)
2830 : 2012	Specification for carbon steel cast billet ingots, billets, blooms and slabs for re-rolling into steel for general structural purposes (*third revision*)
2831 : 2012	Specification for carbon steel cast billets ingots, blooms and slabs for re-rolling into structural steel (Ordinary quality) (*fourth revision*)
8052 : 2006	Specification for steel ingots, billets and blooms for the production of springs, rivets and screws for general engineering applications (*second revision*)
8952 : 1995	Steel ingots, blooms and billets for production of mild steel wire rods for general engineering purposes (*first revision*)
11587 : 1986	Specification for structural weather resistant steels
15103 : 2002	Fire resistant steel
15911 : 2010	Structural steel (Ordinary quality)
15962 : 2012	Structural steels for buildings and structures with improved seismic resistance

c) Sheet and Strip

IS No.	*Title*
277 : 2003	Specification for galvanized steel sheets (plain and corrugated) (*sixth revision*)
412 : 1975	Specification for expanded metal steel sheets for general purposes (*second revision*)
513 : 2008	Specification for cold reduced low carbon steel sheets and strips (*fifth revision*)

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IS No.	*Title*
1079 : 2009	Specification for hot rolled carbon steel sheet and strip (*sixth revision*)
6911 : 1992	Stainless steel plate, sheet and strip (*first revision*)
7226 : 1974	Specification for cold rolled medium, high carbon and low alloy steel strip for general engineering purposes
14246 : 2013	Specification for continuously pre-painted galvanized steel sheets and coils (*first revision*)
15961 : 2012	Hot-dip
15965 : 2012	Pre-painted aluminium zinc alloy metallic coated steel strip and sheet (plain)
12313: 1988	Specification for hot-dip terne coated carbon steel sheets

d) Bars, Rods, Wire and Wire Rods

IS No.	*Title*
280 : 2006	Specification for mild steel wire for general engineering purposes (*fourth revision*)
1148 : 2009	Steel rivet bars (medium and high tensile) for structural purposes (*fourth revision*)
1673 : 1984	Specification for mild steel wire cold heading quality (*second revision*)
1812 : 1982	Specification for carbon steel wire for the manufacture of wood screw (*second revision*)
1835 : 1976	Specification for round steel wire for ropes (*third revision*)
1875 : 1992	Carbon steel billets, blooms, slabs and bars for forgings (*fifth revision*)
1921 : 2005	Specification for resin cored solder wire (*second revision*)
2591 : 1982	Dimensions for hot rolled bars for threaded components (*second revision*)
3150 : 1982	Specification for hexagonal wire netting for general purposes
4826 : 1979	Specification for hot-dipped galvanized coatings on round steel wires (*first revision*)
6527 : 1995	Stainless steel wire rod (*first revision*)
6528 : 1995	Specification for stainless steel wire (*first revision*)
6603 : 2001	Specification for stainless steel bars and flats (*first revision*)
7887 : 1992	Specification for mild steel wire rods for general engineering purposes (*first revision*)
7904 : 1995	Specification for high-carbon steel wire rods (*first revision*)
10631 : 1983	Stainless steel for welding electrode core wire
IS/ISO 16124 : 2004	Steel wire rod — Dimensions and tolerances

e) Plates and Studs

IS No.	*Title*
1862 : 1975	Specification for studs (*second revision*)
3502 : 2009	Specification for steel chequered plates (*third revision*)

f) Tubes and Tubulars

IS No.	*Title*
1161 : 2014	Specification for steel tubes for structural purposes (*fifth revision*)
4923 : 1997	Specification for hollow mild steel sections for structural use (*second revision*)

g) Slotted Sections

IS No.	*Title*
8081 : 1976	Specification for slotted sections

22. STONES

IS No.	*Title*
1121	Methods of test for determination of strength properties of natural building stones
(Part 1) : 2013	Compressive strength (*second revision*)
(Part 2) : 2013	Transverse strength (*second revision*)
(Part 3) : 2012	Tensile strength (*second revision*)
(Part 4) : 2013	Shear strength (*second revision*)
1122 : 1974	Method of test for determination of true specific gravity of natural building stones (*first revision*)
1123 : 1975	Method of identification of natural building stones (*first revision*)
1124 : 1974	Method of test for determination of water absorption, apparent specific gravity and porosity of natural building stones (*first revision*)
1125 : 2013	Method of test for determination of weathering of natural building stones (*second revision*)
1126 : 2013	Method of test for determination of durability of natural building stones (*second revision*)

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IS No.	*Title*
1127 : 1970	Recommendations for dimensions and workmanship of natural building stones for masonry work (*first revision*)
1128 : 1974	Specification for limestone (slab and tiles) (*first revision*)
1129 : 1972	Recommendation for dressing of natural building stones (*first revision*)
1130 : 1969	Specification for marble (blocks, slabs and tiles)
1706 : 1972	Method of determination of resistance to wear by abrasion of natural building stones (*first revision*)
3316 : 1974	Specification for structural granite (*first revision*)
3620 : 1979	Specification for laterite stone block for masonry (*first revision*)
3622 : 1977	Specification for sand stone (slabs and tiles) (*first revision*)
4121 : 1967	Method of test for determination of water transmission rate by capillary action through natural building stones
4122 : 1967	Method of test for surface softening of natural building stones by exposure to acidic atmospheres
4348 : 1973	Methods of test for determination of permeability of natural building stones (*first revision*)
5218 : 1969	Method of test for toughness of natural building stones
5640 : 1970	Method of test for determining the aggregate impact value of soft coarse aggregates
6241 : 1971	Method of test for determination of stripping value of road aggregates
6250 : 1981	Specification for roofing slate tiles (*first revision*)
6579 : 1981	Specification for coarse aggregate for water bound macadam (*first revision*)
7779	Schedule for properties and availability of stones for construction purposes
(Part 1/ Sec 1) : 1975	Gujarat state, Section 1 Availability of stones
(Part 1/ Sec 2) : 1975	Gujarat state, Section 2 Engineering properties of building stones
(Part 1/Sec 3) : 1975	Gujarat state, Section 3 Engineering properties of stone aggregates
(Part 2/ Sec 1) : 1979	Maharashtra state, Section 1 Availability of stones
(Part 2/ Sec 2) : 1979	Maharashtra state, Section 2 Engineering properties of building stones
(Part 2/ Sec 3) : 1979	Maharashtra state, Section 3 Engineering properties of stone aggregates
(Part 3/ Sec 2) : 1990	Tamil Nadu state, Section 2 Engineering properties of building stones
(Part 3/ Sec 3) : 1980	Tamil Nadu state, Section 3 Engineering properties of stone aggregates
(Part 4/Sec 1 to 3) : 1996	Karnataka state, Sections (1 to 3)
(Part 5/ Sec 1) : 1997	Andhra Pradesh, Section 1 Availability of stones
(Part 5/ Sec 2) : 1997	Andhra Pradesh, Section 2 Engineering properties of building stones
(Part 5/ Sec 3) : 1997	Andhra Pradesh, Section 3 Engineering properties of stone aggregates
9394 : 1979	Specification for stone lintels
14223 (Part 1) : 1994	Specification for polished building stones: Part 1 Granite

23. STRUCTURAL SECTIONS

a) Structural Shapes

IS No.	*Title*
811 : 1987	Specification for cold formed light gauge structural steel sections (*revised*)
1173 : 1978	Specification for hot rolled and slit steel tee bars (*second revision*)
1863 : 1979	Specification for hot rolled steel bulb flats (*first revision*)
2314 : 1986	Specification for steel sheet piling sections (*first revision*)
3443 : 1980	Specification for crane rail sections (*first revision*)
3908 : 1986	Specification for aluminium equal leg angles (*first revision*)
3909 : 1986	Specification for aluminium unequal leg angles (*first revision*)

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IS No.	*Title*
3921 : 1985	Specification for aluminium channels (*first revision*)
3964 : 1980	Specification for light rails (*first revision*)
5384 : 1985	Specification for aluminium I-beams (*first revision*)
6445 : 1985	Specification for aluminium tee sections (*first revision*)

b) Dimensional Standards

IS No.	*Title*
808 : 1989	Dimensions for hot rolled steel beam, column channel and angle sections (*third revision*)
1730 : 1989	Dimensions for steel plates, sheets strips and flats for general engineering purposes (*second revision*)
1732 : 1989	Dimensions for round and square steel bars for structural and general engineering purposes (*second revision*)
1852 : 1985	Rolling and cutting tolerances for hot rolled steel products (*fourth revision*)
2525 : 1982	Dimensions for wrought aluminium and aluminium alloy wire (*first revision*)
2591 : 1982	Dimensions for hot rolled steel bars for threaded components (*second revision*)
2673 : 2002	Dimensions for wrought aluminium and aluminium alloys, extruded round tube (*second revision*)
2676 : 1981	Dimensions for wrought aluminium and aluminium alloys, sheet and strip (*first revision*)
2677 : 1979	Dimensions for wrought aluminium and aluminium alloys, plates and hot rolled sheets (*first revision*)
2678 : 1987	Dimensions and tolerances for wrought aluminium and aluminium alloy, drawn round tubes (*second revision*)
3577 : 1992	Dimensions and tolerances for wrought aluminium and aluminium alloys rivet, bolt and screw stock (*first revision*)
3954 : 1991	Hot rolled steel channel sections for general engineering purposes— Dimensions (*first revision*)
3965 : 1981	Dimensions for wrought aluminium and aluminium alloys, bar, rod and section (*first revision*)
6477 : 1983	Dimensions for wrought aluminium and aluminium alloys, extruded hollow sections (*first revision*)
IS/ISO 7452 : 2002	Hot-rolled structural steel plates — Tolerances on dimensions and shape
12778 : 2004	Hot rolled parallel flange steel sections for beams, columns and bearing piles — Dimensions and section properties (*first revision*)
12779 : 1989	Rolling and cutting tolerances for hot rolled parallel flange beam and column sections
IS/ISO 16124 : 2004	Steel wire rod — Dimensions and tolerances
IS/ISO 16160 : 2012	Continuously hot rolled steel sheet products — Dimensional and shape tolerances (*first revision*)
IS/ISO 16162 : 2012	Continuously cold-rolled steel sheet products — Dimensional and shape tolerances (*first revision*)
IS/ISO 16163 : 2012	Continuously hot dipped coated steel products — Dimensional and shape tolerances (*first revision*)

24. THERMAL INSULATION MATERIALS

IS No.	*Title*
3144 : 1992	Methods of test for mineral wool thermal insulation material (*second revision*)
3346 : 1980	Methods for the determination of thermal conductivity of thermal insulation materials (two slab, guarded hot-plate method (*first revision*)
3677 : 1985	Specification for unbonded rock and slag wool for thermal insulation (*second revision*)
4671 : 1984	Specification for expanded polystyrene for thermal insulation purposes (*first revision*)
5688 : 1982	Methods of test for preformed block-type and pipe-covering type thermal insulation (*first revision*)
5724 : 1970	Methods of test for thermal insulating cement
6598 : 1972	Specification for cellular concrete for thermal insulation

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IS No.	*Title*
7509 : 1993	Specification for thermal insulating cement (*first revision*)
8154 : 1993	Specification for preformed calcium silicate insulation for temperature up to 650°C (*first revision*)
8183 : 1993	Specification for bonded mineral wool (*first revision*)
9403 : 1980	Method of test for thermal conductance and transmittance of built up sections by means of guarded hot box
9489 : 1980	Method of test for thermal conductivity of materials by means of heat flow meter
9490 : 1980	Method of determination for thermal conductivity of insulation materials (water calorimeter method)
9742 : 1993	Specification for sprayed mineral wool thermal insulation (*first revision*)
9743 : 1990	Specification for thermal insulation finishing cements (*first revision*)
9842 : 1994	Specification for preformed fibrous pipe insulation (*first revision*)
11128 : 1994	Specification for spray applied hydrated calcium silicate thermal insulation
11129 : 1984	Method of test for tumbling friability of preformed block-type thermal insulation
11239	Method of test for rigid cellular thermal insulation materials
(Part 1) : 2009	Dimensions (*first revision*)
(Part 2) : 2009	Apparent density (*first revision*)
(Part 3) : 2009	Dimensional stability (*first revision*)
(Part 4) : 1985	Water vapour transmission rate (*first revision*)
(Part 5) : 2009	Volume percent of open and closed cells (*first revision*)
(Part 6) : 1985	Heat distortion temperature
(Part 7) : 1985	Coefficient of linear thermal expansion at low temperatures
(Part 8) : 1985	Flame height, time of burning and loss of mass
(Part 9) : 1988	Water absorption
(Part 10) : 1985	Flexural strength
(Part 11) : 1985	Compressive strength
(Part 12) : 1988	Horizontal burning characteristics
(Part 13) : 1992	Determination of flammability by oxygen index
11307 : 1985	Specification for cellular glass block and pipe thermal insulating
11308 : 1985	Specification for thermal insulating castables (hydraulic setting) for temperatures up to 1 250°C
12436 : 1988	Specification for preformed rigid polyurethane (PUR) and polyisocyanurate (PIR) foams for thermal insulation
13204 : 1991	Specification for rigid phenolic foams for thermal insulation
13286 : 1992	Methods of test for surface spread of flame for thermal insulation materials
14656 : 1999	Ceramic fibre products — Methods of test

25. THREADED FASTENERS, RIVETS AND NAILS

IS No.	*Title*
207 : 1964	Specification for gate and shutter hooks and eyes (*revised*)
451 : 1999	Specification for technical supply conditions for wood screws (*third revision*)
554 : 1999	Specification for pipe threads where pressure-tide joints are made on the threads — Dimensions, tolerances and designation (*fourth revision*)
723 : 1972	Specification for steel countersunk head wire nails (*second revision*)
724 : 1964	Specification for mild steel and brass cup, ruler and square hooks and screw eyes (*revised*)
725 : 1961	Specification for copper wire nails (*revised*)
730 : 1978	Specification for hook bolts for corrugated sheet roofing (*second revision*)
1120 : 1975	Specification for coach screws (*first revision*)
1363	Specification for hexagon head bolts, screws and nuts of product grade C
(Part 1) : 2002	Hexagon head bolts (Size range M5 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (Size range M5 to M64) (*fourth revision*)
(Part 3) : 2002	Hexagon nuts (Size range M5 to M64) (*fourth revision*)
1364	Specification for hexagon head bolts,

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IS No.	*Title*
	screws and nuts of product Grades A and B
(Part 1) : 2002	Hexagon head bolts (Size range M1.6 to M64) (*fourth revision*)
(Part 2) : 2002	Hexagon head screws (Size range M1.6 to M64) (*fourth revision*)
(Part 3) : 2002	Hexagon nuts (Size range M1.6 to M64) (*fourth revision*)
(Part 4) : 2003	Hexagon thin nuts (chamfered) (Size range M1.6 to M64) (*fourth revision*)
(Part 5) : 2002	Hexagon thin nuts (unchamfered) (Size range M1.6 to M10) (*fourth revision*)
(Part 6) : 2002	Hexagon nuts, style 2
1365 : 2005	Slotted countersunk flat head screws (Common head style) — Product Grade A (*fourth revision*)
1366 : 2002	Specification for slotted cheese head screws (*third revision*)
1367	Specification for technical supply conditions for threaded steel fasteners
(Part 1) : 2014	Introduction and general information (*fourth revision*)
(Part 2) : 2002	Product grades and tolerances (*third revision*)
(Part 3) : 2002	Mechanical properties and test methods for bolts, screws and studs with full loadability (*fourth revision*)
(Part 5) : 2002	Mechanical properties and test methods for set screws and similar threaded fasteners not under tensile stresses (*third revision*)
(Part 6) : 1994	Mechanical properties and test methods for nuts with specified proof loads (*third revision*)
(Part 7) : 1980	Mechanical properties and test methods for nuts without specified proof loads (*second revision*)
(Part 8) : 2014	Mechanical and performance properties for prevailing torque type steel hexagon nuts (*fourth revision*)
(Part 9/Sec 1) : 1993	Surface discontinuities, Section 1 Bolts, screws and studs for general applications (*third revision*)
(Part 9/Sec 2) : 1993	Surface discontinuities, Section 2 Bolts, screws and studs for special applications (*third revision*)
(Part 10) : 2002	Surface discontinuities on nuts (*third revision*)
(Part 11) : 2002	Electroplated coatings (*third revision*)
(Part 12) : 1981	Phosphate coatings on threaded fasteners (*second revision*)
(Part 13) : 1983	Hot dip galvanized coatings on threaded fasteners (*second revision*)
(Part 14/Sec 1) : 2002	Mechanical properties of corrosion resistance stainless stainless steel fasteners, Section 1 Bolts, screws and studs (*third revision*)
(Part 14/Sec 2) : 2002	Mechanical properties of corrosion resistance stainless stainless steel fasteners, Section 2 Nuts (*third revision*)
(Part 14/Sec 3) : 2002	Mechanical properties of corrosion resistance stainless stainless steel fasteners, Section 3 Set screws and similar fasteners not under tensile stress (*third revision*)
(Part 16) : 2002	Designation system and symbols (*third revision*)
(Part 17) : 2005	Inspections, sampling and acceptance procedure (*fourth revision*)
(Part 18) : 1996	Packaging (*third revision*)
(Part 19) : 1996	Axial fatigue testing of bolts, screws and studs
(Part 20) : 1996	Torsional test and minimum torques for bolts and screws with nominal diameters 1mm to 10 mm
1929 : 1982	Specification for hot forged steel rivets for hot closing (12 to 36 mm diameter) (*first revision*)
2016 : 1967	Specification for plain washers (*first revision*)
2155 : 1982	Specification for cold forged solid steel rivets for hot closing (6 to 16 mm diameter) (*first revision*)
2269 : 2006	Hexagon socket head cap screws (*fifth revision*)
2585 : 2006	Specification for square head bolts, screws and square nuts of product grade C (*second revision*)
2609 : 1972	Specification for coach bolts (*first revision*)
2643 : 2005	Pipe threads where pressure-tight joints are not made on the threads — Dimensions, tolerances and designation (*third revision*)
2687 : 1991	Specification for cap nuts (*second revision*)

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IS No.	*Title*
2769 : 1969	Sizes for squares and square holes for general engineering purposes (*first revision*)
2907 : 1998	Specification for non-ferrous rivets (*first revision*)
2998 : 1982	Specification for cold forged steel rivets for cold closing (1 to 16 mm diameter) (*first revision*)
3063 : 1994	Specification for fasteners single coil rectangular section spring lock washers (*second revision*)
3121 : 1981	Specification for rigging screws and stretching screws (*first revision*)
3468 : 1991	Specification for pipe nuts (*second revision*)
3640 : 1982	Specification for hexagon fit bolts (*first revision*)
3757 : 1985	Specification for high strength structural bolts (*second revision*)
4206 : 1987	Dimensions for nominal lengths, and thread lengths for bolts, screws and studs (*first revision*)
4762 : 2002	Specification for worm drive hose clips for general purposes (*second revision*)
5369 : 1975	General requirements for plain washers and lock washers (*first revision*)
5370 : 1969	Specification for plain washers with outside diameter 3 × inside diameter
5372 : 1975	Specification for taper washer for channels (ISMC) (*first revision*)
5373 : 1969	Specification for square washers for wood fastenings
5374 : 1975	Specification for taper washers for l-beam (ISMB) (*first revision*)
5624 : 1993	Specification for foundation bolts (*first revision*)
6113 : 1970	Specification for aluminium fasteners for building purposes
6610 : 1972	Specification for heavy washers for steel structures
6623 : 2004	Specification for high strength structural nuts (*second revision*)
6639 : 2005	Specification for hexagon head bolts for general steel structures (*first revision*)
6649 : 1985	Specification for hardened and tempered washers for high strength structural bolts and nuts (*first revision*)
6733 : 1972	Specification for wall and roofing nails
6736 : 1972	Specification for slotted raised countersunk head wood screws
6739 : 1972	Specification for slotted round head wood screws
6760 : 1972	Specification for slotted countersunk head wood screws
8033 : 1976	Specification for washers with square hole for wood fastenings
8412 : 1977	Specification for slotted countersunk head bolts for steel structures
8822 : 1978	Specification for slotted mushroom head roofing bolts
8869 : 1978	Specification for washers for corrugated sheet roofing
8911 : 2005	Countersunk slotted raised head screws (common head style) — Product Grade A (*first revision*)
10102 : 1982	Specification for technical supply conditions for rivets
10238 : 2001	Specification for step bolts for steel structures
12427 : 2001	Specification for threaded steel fasteners — hexagon head transmission tower bolts (*first revision*)

26. TIMBER, BAMBOO AND OTHER LIGNOCELLULOSIC BUILDING MATERIALS

a) Timber and Bamboo

i) *Timber Classification*

IS No.	*Title*
287 : 1993	Permissible moisture content for timber used for different purposes— Recommendations (*third revision*)
399 : 1963	Classification of commercial timbers and their zonal distribution (*revised*)
1150 : 2000	Trade names and abbreviated symbols for timber species (*third revision*)
4970 : 1973	Key for identification of commercial timber (*first revision*)

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ii) *Timber Conversion and Grading*

IS No.	*Title*
190 : 1991	Specification for coniferous sawn timber (baulks and scantlings) (*fourth revision*)
1326 : 1992	Specification for non-coniferous sawn timber (baulks and scantlings) (*second revision*)
1331 : 1971	Specification for cut sizes of timber (*second revision*)
2377 : 1967	Tables for volumes of cut sizes of timber (*first revision*)
3337 : 1978	Specification for ballies for general purposes (*first revision*)
3386 : 1979	Specification for wooden fence posts (*first revision*)
5966 : 1993	Specification for non-coniferous timber in converted form for general purpose (*first revision*)
14960 : 2001	Specification for preservative treated and seasoned sawn timber from rubberwood (Hevea brasiliensis)

iii) *Timber Testing*

IS No.	*Title*
1708	Methods of testing small clear specimens of timber
(Part 1) : 1986	Determination of moisture content (*second revision*)
(Part 2) : 1986	Determination of specific gravity (*second revision*)
(Part 3) : 1986	Determination of volumetric shrinkage (*second revision*)
(Part 4) : 1986	Determination of radial and tangential shrinkage and fibre saturation point (*second revision*)
(Part 5) : 1986	Determination of static bending strength (*second revision*)
(Part 6) : 1986	Determination of static bending strength under two point loading (*second revision*)
(Part 7) : 1986	Determination of impact bending strength (*second revision*)
(Part 8) : 1986	Determination of compressive strength parallel to grain (*second revision*)
(Part 9) : 1986	Determination of compressive strength perpendicular to grain (*second revision*)
(Part 10) : 1986	Determination of hardness under static indentation (*second revision*)
(Part 11) : 1986	Determination of shear strength parallel to grain (*second revision*)
(Part 12) : 1986	Determination of tensile strength parallel to grain (*second revision*)
(Part 13) : 1986	Determination of tensile strength perpendicular to grain (*second revision*)
(Part 14) : 1986	Determination of cleavage strength parallel to grain (*second revision*)
(Part 15) : 1986	Determination of nail and screw holding power (*second revision*)
(Part 16) : 1986	Determination of brittleness by izod impact (*second revision*)
(Part 17) : 1986	Determination of brittleness by Charpy impact (*second revision*)
(Part 18) : 1986	Determination of torsional strength (*second revision*)
2408 : 1963	Methods of static tests of timbers in structural sizes
2455 : 1990	Method of sampling of model trees and logs for timber testing and their conversion (*second revision*)
2753	Methods for estimation of preservatives in treated timber and treating solutions
(Part 1) : 1991	Determination of copper, arsenic, chromium, zinc, boron, creosote and fuel oil (*first revision*)
(Part 2) : 2014	Determination of copper in copper organic preservative salt (*second revision*)
4907 : 2004	Method of testing timber connectors (*first revision*)
8292 : 1992	Methods for evaluation of working quality of timber under different wood operations — Method of test (*first revision*)
8720 : 1978	Methods of sampling of timber scantlings from depots and their conversion for testing
8745 : 1994	Methods of presentation of data of physical and mechanical properties of timber (*first revision*)
10420 : 1982	Method of determination of sound absorption coefficient of timber by standing wave method
10754 : 1983	Method of determination of thermal conductivity of timber
11215 : 1991	Methods for determination of moisture content of timber and timber products (*first revision*)

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IS No.	*Title*
13621 : 1993	Method of test for determination of dielectric constant of wood under microwave frequencies

iv) *Structural Timber and Tests*

IS No.	*Title*
3629 : 1986	Specification for structural timber in building (*first revision*)
4891 : 1988	Specification for preferred cut sizes of structural timber (*first revision*)
4924	Method of test for nail jointed timber trusses
(Part 1) : 1968	Destructive test
(Part 2) : 1968	Proof test

v) *Logs*

IS No.	*Title*
3364	Method of measurement and evaluation of defects in timber
(Part 1) : 1976	Logs (*first revision*)
(Part 2) : 1976	Converted timber (*first revision*)
4895 : 1985	Specification for teak logs (*first revision*)
5246 : 2000	Specification for coniferous logs (*first revision*)
7308 : 1999	Specification for non-coniferous logs (*first revision*)

vi) *Bamboo*

IS No.	*Title*
6874 : 2008	Method of tests for bamboos (*first revision*)
8242 : 1976	Methods of tests for split bamboos

(b) Reconstituted Products

i) *Plywood*

IS No.	*Title*
303 : 1989	Specification for plywood for general purposes (*third revision*)
710 : 2010	Specification for marine plywood (*second revision*)
1328 : 1996	Specification for veneered decorative plywood (*third revision*)
1734	Methods of test for plywood
(Part 1) : 1983	Determination of density and moisture content (*second revision*)
(Part 2) : 1983	Determination of resistance of dry heat (*second revision*)
(Part 3) : 1983	Determination of fire resistance (*second revision*)
(Part 4) : 1983	Determination of glue shear strength (*second revision*)
(Part 5) : 1983	Test for adhesion of plies (*second revision*)
(Part 6) : 1983	Determination of water resistance (*second revision*)
(Part 7) : 1983	Mycological test (*second revision*)
(Part 8) : 1983	Determination of *p*H value (*second revision*)
(Part 9) : 1983	Determination of tensile strength (*second revision*)
(Part 10 : 1983	Determination of compressive strength (*second revision*)
(Part 11) : 1983	Determination of static bending strength (*second revision*)
(Part 12) : 1983	Determination of scarf joint strength (*second revision*)
(Part 13) : 1983	Determination of panel shear strength (*second revision*)
(Part 14) : 1983	Determination of plate shear strength (*second revision*)
(Part 15) : 1983	Central loading of plate test (*second revision*)
(Part 16) : 1983	Vibration of plywood plate test (*second revision*)
(Part 17) : 1983	Long time loading test of plywood strips (*second revision*)
(Part 18) : 1983	Impact resistance test on the surface of plywood (*second revision*)
(Part 19) : 1983	Determination of nail and screw holding power (*second revision*)
(Part 20) : 1983	Acidity and alkalinity resistance test (*second revision*)
4990 : 2011	Specification for plywood for concrete shuttering work (*third revision*)
5509 : 2000	Specification for fire retardant plywood (*second revision*)
5539 : 1969	Specification for preservative treated plywood
7316 : 1974	Specification for decorative plywood using plurality of veneers for decorative faces
10701 : 2012	Specification for structural plywood (*first revision*)
13957 : 1994	Specification for metal faced plywood
15791 : 2007	Specification for museum plywood

ii) *Blockboards, Particle Boards and Fibre Boards*

IS No.	*Title*
1658 : 2006	Specification for fibre hardboards (*third revision*)

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IS No.	*Title*
1659 : 2004	Specification for block boards (*fourth revision*)
2380	Methods of test for wood particle boards and boards from other lignocellulosic materials
(Part 1) : 1977	Preparation and conditioning of test specimens (*first revision*)
(Part 2) : 1977	Accuracy of dimensions of boards (*first revision*)
(Part 3) : 1977	Determination of moisture content and density (*first revision*)
(Part 4) : 1977	Determination of static bending strength (*first revision*)
(Part 5) : 1977	Determination of tensile strength perpendicular to surface (*first revision*)
(Part 6) : 1977	Determination of tensile strength parallel to surface (*first revision*)
(Part 7) : 1977	Determination of compression-perpendicular to plane of the board (*first revision*)
(Part 8) : 1977	Compression parallel to surface test (*first revision*)
(Part 9) : 1977	Determination of resistance to shear in plane of the board (*first revision*)
(Part 10) : 1977	Falling hammer impact test (*first revision*)
(Part 11) : 1977	Surface hardness (*first revision*)
(Part 12) : 1977	Central loading of plate test (*first revision*)
(Part 13) : 1977	Long time loading bending test (*first revision*)
(Part 14) : 1977	Screw and nail withdrawal test (*first revision*)
(Part 15) : 1977	Lateral nail resistance (*first revision*)
(Part 16) : 1977	Determination of water absorption (*first revision*)
(Part 17) : 1977	Determination of swelling in water (*first revision*)
(Part 18) : 1977	Determination of mass and dimensional changes caused by moisture changes (*first revision*)
(Part 19) : 1977	Durability cyclic test for interior use (*first revision*)
(Part 20) : 1977	Accelerated weathering cyclic test for exterior use (*first revision*)
(Part 21) : 1977	Planeness test under uniform moisture content (*first revision*)
(Part 22) : 1981	Determination of surface glueability test
(Part 23) : 1981	Vibration test for particle boards
3087 : 2005	Specification for particle boards of wood and other lignocellulosic materials (medium density) for general purposes (*second revision*)
3097 : 2006	Specification for veneered particle boards (*second revision*)
3129 : 1985	Specification for low density particle boards (*first revision*)
3308 : 1981	Specification for wood wool building slabs (*first revision*)
3348 : 1965	Specification for fibre insulation boards
3478 : 1966	Specification for high density wood particle boards
12406 : 2003	Specification for medium density fibreboards for general purposes (*first revision*)
12823 : 2015	Specification for wood products — Prelaminated particle boards (*first revision*)
13745 : 1993	Method for determination of formaldehyde content in particle board by extraction method called perforator method
14276 : 1995	Specification for cement bonded particle boards
14587 : 1998	Specification for prelaminated medium density fibre board
15786 : 2008	Specification for prelaminated cement bonded particle boards

iii) *Wood-Based Laminates and Lumber*

IS No.	*Title*
3513 (Part 3) : 1989	Specification for resin treated compressed wood laminates (compregs): Part 3 For general purposes (*first revision*)
3513 (Part 4) : 1966	Specification for high and medium density wood laminates (compregs): Part 4 Sampling and tests
7638 : 1999	Methods of sampling for wood/ lignocellulosic based panel products (*second revision*)
9307	Methods of tests for wood-based structural sandwich construction
(Part 1) : 1979	Flexure test
(Part 2) : 1979	Edgewise compression test
(Part 3) : 1979	Flatwise compression test

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IS No.	*Title*
(Part 4) : 1979	Shear test
(Part 5) : 1979	Flatwise tension test
(Part 6) : 1979	Flexure creep test
(Part 7) : 1979	Cantilever vibration test
(Part 8) : 1979	Weathering test
14315 : 1995	Specification for commercial veneers
14616 : 1999	Specification for laminated veneer lumber
16171 : 2014	Specification for veneer laminated lumber

iv) *Bamboo and Coir Board Products*

IS No.	*Title*
13958 : 1994	Specification for bamboo mat board for general purposes
14588 : 1999	Specification for bamboo mat veneer composite for general purposes
14842 : 2000	Specification for coir veneer board for general purposes
15476 : 2004	Specification for bamboo mat corrugated sheets
15491 : 2004	Specification for medium density coir boards for general purposes
15877 : 2010	Specification for coir faced block boards
15878 : 2010	Specification for coir hardboard for general purposes
15972 : 2012	Specification for bamboo-jute corrugated and semi-corrugated sheets

v) *Adhesives*

IS No.	*Title*
848 : 2006	Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) (*second revision*)
851 : 1978	Specification for synthetic resin adhesives for construction work (non-structural) in wood (*first revision*)
852 : 1994	Specification for animal glue for general wood-working purposes (*second revision*)
1508 : 1972	Specification for extenders for use in synthetic resin adhesives (urea-formaldehyde) for plywood (*first revision*)
4835 : 1979	Specification for polyvinyl acetate dispersion-based adhesives for wood (*first revision*)
9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition

27. UNIT WEIGHTS OF BUILDING MATERIALS

IS No.	*Title*
875 (Part 1) : 1987	Code of Practice for design loads (other than earthquake) for buildings and structures : Part 1 Dead loads — Unit weights of building material and stored materials (*second revision*)

28. WATERPROOFING AND DAMP-PROOFING MATERIALS

IS No.	*Title*
1322 : 1993	Specification for bitumen felts for waterproofing and damp-proofing (*fourth revision*)
1580 : 1991	Specification for bituminous compound for waterproofing and caulking purposes (*second revision*)
3037 : 1986	Specification for bitumen mastic for use in waterproofing of roofs (*first revision*)
3384 : 1986	Specification for bitumen primer for use in waterproofing and damp-proofing (*first revision*)
5871 : 1987	Specification for bitumen mastic for tanking and damp-proofing (*first revision*)
7193 : 2013	Specification for glass fibre base bitumen felts (*second revision*)
12027 : 1987	Specification for silicone-based water repellents
13435	Method of tests for acrylic based polymer waterproofing materials
(Part 1) : 1992	Determination of solid content
(Part 2) : 1992	Determination of coarse particle
(Part 3) : 1992	Determination of capillary water take-up
(Part 4) : 1992	Determination of *p*H value
13826	Method of test for bitumen based felts
(Part 1) : 1993	Breaking strength test
(Part 2) : 1993	Pliability test
(Part 3) : 1993	Storage sticking test
(Part 4) : 1993	Pressure head test
(Part 5) : 1993	Heat resistance test
(Part 6) : 1993	Water absorption test
(Part 7) : 1993	Determination of binder content
14695 : 1999	Specification for glass fibre base coal tar pitch outer wrap

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29. WELDING ELECTRODES AND WIRES

IS No.	*Title*
814 : 2004	Specification for covered electrodes for manual metal arc welding of carbon and carbon manganese steel (*sixth revision*)
1278 : 1972	Specification for filler rods and wires for gas welding (*second revision*)
1395 : 1982	Specification for low and medium alloy steel covered electrodes for manual metal arc welding (*third revision*)
2879 : 1998	Mild steel for metal arc welding electrodes (*third revision*)
4972 : 1968	Specification for resistance spot-welding electrodes
5206 : 1983	Covered electrodes for manual arc welding of stainless steel and other similar high alloy steels (*first revision*)
5511 : 1991	Specification for covered electrodes for manual metal arc welding of cast iron (*first revision*)
5897 : 1985	Specification for aluminium and aluminium alloy welding rods and wires and magnesium alloy welding rods (*first revision*)
5898 : 1970	Specification for copper and copper alloy bare solid welding rods and electrodes
6419 : 1996	Specification for welding rods and bare electrodes for gas shielded arc welding of structural steel (*first revision*)
6560 : 1996	Specification for molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding (*first revision*)
8363 : 1976	Specification for bare wire electrodes for electroslag welding of steels
10631 : 1983	Stainless steel for welding electrode core wire
15977 : 2013	Specification for classification and acceptance tests for bare solid wire electrodes and wire flux combination for submerged arc welding of structural steel
8666 : 1977	Specification for copper and copper alloy covered electrodes for manual metal arc welding

30. WIRE ROPES AND WIRE PRODUCTS (INCLUDING WIRE FOR FENCING)

IS No.	*Title*
278 : 2009	Specification for galvanized steel barbed wire for fencing (*fourth revision*)
2140 : 1978	Specification for stranded galvanized steel wire for fencing (*first revision*)
2266 : 2002	Specification for steel wire ropes for general engineering purposes (*fourth revision*)
2365 : 1977	Specification for steel wire suspension ropes for lifts, elevators and hoists (*first revision*)
2721 : 2003	Specification for galvanized steel chain link fences fabric (*second revision*)
6594 : 2001	Technical supply conditions for steel wire ropes and strands (*second revision*)
16013 : 2012	Specification for welded wire gabions (metallic-coated or metallic-coated with PVC coating)
16014 : 2012	Specification for mechanically woven, double-twisted, hexagonal wire mesh gabions, revet mattresses and rock fall netting (galvanized steel wire or galvanized steel wore with PVC coating)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 1 Loads, Forces and Effects

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Section 1) covers the various loads, forces and effects which are to be taken into account for structural design of buildings. The various loads that are covered under this Section are dead load, imposed load, wind load, seismic force, snow load, special loads and load combinations.

This Code was first published in 1970 and subsequently revised in 1983 and 2005. The first revision of this Section was modified in 1987 through Amendment No. 2 to the 1983 version of the Code to bring this Section in line with the latest revised loading code. Thereafter, in view of the revision of the important Indian Standard on earthquake resistant design of structure, that is, IS 1893 a need to revise this part was felt again. The second revision of 2005 was therefore formulated to take into account the revised standard, IS 1893 (Part 1) : 2002 'Criteria for earthquake resistant design of structures: Part 1 General provision and buildings (*fifth revision*)' and to also incorporate latest information on additional loads, forces and effects as also the details regarding multi- hazard risk in various districts of India.

The significant changes incorporated in the second revision of 2005 included: the revision of the seismic zone map providing only four zones, instead of five, with erstwhile Zone I being merged into Zone II; changing of the values of seismic zone factors to reflect more realistic values of effective peak ground acceleration considering Maximum Considered Earthquake (MCE) and service life of structure in each seismic zone; specifying of response spectra for three types of founding strata, namely rock and hard soil, medium soil and soft soil; the revision of empirical expression for estimating the fundamental natural period T_a of multistoreyed buildings with regular moment resisting frames; adoption of the procedure of first calculating the actual force that may be experienced by the structure during the probable maximum earthquake, if it were to remain elastic, also bringing in the concept of response reduction due to ductile deformation or frictional energy dissipation in the cracks by introducing the 'response reduction factor' in place of the earlier performance factor; specifying a lower bound for the design base shear of buildings, based on empirical estimate of the fundamental natural period T_a; deletion of the soil-foundation system factor and instead, introduction of a clause to restrict the use of foundations vulnerable to differential settlements in severe seismic zones; revision of torsional eccentricity values upwards in view of serious damages observed in buildings with irregular plans; revision of modal combination rule in dynamic analysis of buildings; inclusion of a new clause on multi-hazard risk in various districts of India and a list of districts identified as multi-hazard prone districts; incorporation of latest amendments issued to IS 875; introduction of a clause on vibration in buildings for general guidance; and inclusion of reference to the Indian Standards on landslide control and design of retaining walls which were formulated after the first revision of the Section.

In this revision, following significant modifications/inclusions taking into account the recent developments, R & D efforts nationally and internationally, have been made:

1) Provisions on parapets and balustrades have been updated by including concentrated horizontal loads, wherever applicable, and modification in horizontal load per unit length. Also, new use areas covering appurtenances fixed to the structure have been included.
2) Aerodynamic roughness heights for individual terrain categories have been explicitly included, and are used to derive turbulence intensity and mean hourly wind speed profiles.
3) The previous classification of structures into B and C Classes has been deleted and accordingly the modification factor, k_2 is renamed as terrain roughness and height factor.
4) The values of k_2 factor corresponding to previous Class A type structure only, are retained in this Section.
5) An additional modification factor, k_4, termed as importance factor has been included for cyclonic regions.
6) Simple empirical expressions have been suggested for height variations of hourly mean wind speed and also turbulence intensity in different terrains.
7) Provisions to account for effects of directionality, area averaging and correlation of pressures on the design wind pressure have been included.
8) Guidelines to account for the wind induced interference for tall buildings and buildings less than 20 m

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have been included for use in preliminary design. It is however recommended to carry out detailed boundary layer wind tunnel tests/computational fluid dynamics (CFD) studies for final design of important structures.

9) In the gust factor method for evaluating along wind response, equations have been suggested for background factor, size reduction factor, energy ratio and length scale of turbulence.
10) A method for computing across wind response of tall buildings and lattice towers has been included.
11) The basic wind speed map of India has been updated based on the R&D studies in the country.
12) Provisions relating to design imposed load due to helipad have been included.
13) Provisions related to design imposed load due to fire tenders and emergency vehicle have been included.
14) Provisions relating to loads due to collision between vehicle and structural and non-structural elements in car parking and stilts.
15) Design spectra are defined for natural period up to 6 s.
16) Same design response spectra are specified for all buildings, irrespective of the material of construction.
17) Bases of various load combinations to be considered have been made consistent for earthquake effects, with those specified in the other codes.
18) Temporary structures are brought under the purview of this Section.
19) Importance factor provisions have been modified to introduce intermediate importance category of buildings, to acknowledge the density of occupancy of buildings.
20) A provision is introduced to ensure that all buildings are designed for at least a minimum lateral force.
21) Buildings with flat slabs are brought under the purview of this Section.
22) Additional clarity is brought in on how to handle different types of irregularity of structural system.
23) Effect of masonry infill walls has been included in analysis and design of frame buildings.
24) Method is introduced for arriving at the approximate natural period of buildings with basements, step back buildings and buildings on hill slopes.
25) Torsional provisions are simplified.
26) Provisions relating to simplified method of evaluation of liquefaction potential have been included in Annex J.
27) Provisions relating to design for blast loads have been included in Annex N.

There has been a growing awareness among the consultants, academicians, researchers and practice engineers for design and construction of wind sensitive structures. In order to augment the available limited good quality meteorological wind data and structural response data, it is necessary to conduct full scale measurements in the field. Thus as emphasized in the previous revision, all individuals and organizations responsible for putting up of tall structures are encouraged to provide instrumentation in their existing and new structures (transmission towers, chimneys, cooling towers, buildings, etc) at different elevations (at least at two levels) to continuously measure and monitor wind data. The instruments are required to collect data on wind direction, wind speed and structural response of the structure due to wind (with the help of accelerometer, strain gauges, etc). Such instrumentation in tall structures shall not in any way affect or alter the functional behaviour of such structures. The data so collected shall be very valuable in evolving more accurate wind loading of structures.

The information contained in this Section is largely based on the following Indian Standards:

IS 875	Code of practice for design loads (other than earthquake) for building and structure:
(Part 2) : 1987	Imposed loads (*second revision*)
(Part 3) : 2015	Wind loads (*third revision*)
(Part 4) : 1987	Snow loads (*second revision*)
(Part 5) : 1987	Special loads and load combinations (*second revision*)
IS 1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)

This Section has to be read together with Sections 2 to 8 of Part 6 ‘Structural Design’ of this Code.

A special publication, SP 64 (S&T) : 2001 ‘Explanatory Handbook on Indian Standard Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures IS 875 (Part 3) : 1987’ is also available. This publication gives detailed background information on the provisions for wind loads and also the use of these provisions for arriving at the wind loads on buildings and structures while evaluating their structural safety.

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However, in view of revision of IS 875 (Part 3) in 2015, applicability of this revised standard and this Section of the Code shall be taken as final in case of conflict of provisions with SP 64.

Reference may also be made to the Vulnerability Atlas of India, 2011 and Landslide Hazard Zonation Map of India, 2003 by Building Materials and Technology Promotion Council, Ministry of Urban Development and Poverty Alleviation, Government of India. The Vulnerability Atlas contains information pertaining to each State and Union Territory of India, on (a) seismic hazard map, (b) cyclone, and wind map, (c) flood prone area map, and (d) housing stock vulnerability table for each district indicating for each house type the level of risk to which it could be subjected. The Atlas can be used to identify areas in each district of the country which are prone to high risk from more than one hazard. The information will be useful in establishing the need of developing housing designs to resist the combination of such hazards.

In the formulation of this Section, inputs were also derived from the Heliport Manual, 1995 of the International Civil Aviation Organization.

For guidelines on risk reduction against tsunami for buildings and structures which are near-shore and on-shore within the expected run-up zone of the tsunami, reference may be made to the Indian Standard ‘Guidelines for Risk Reduction of Structures against Tsunami’ (*under preparation*). The standard deals also with the strategies for protection against tsunami and the design of structures located on coastal sites and in addition, includes special criteria for design of buildings that are to be used for vertical evacuation during a tsunami.

For criteria on structural safety of tall reinforced concrete (RC) buildings of heights greater than 45 m and less than 250 m, normally intended for use as residential, office and other commercial buildings, reference may be made to the Indian Standard ‘Criteria for Structural Safety of Tall Buildings’ (*under preparation*).

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding of numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 1 Loads, Forces and Effects

1 SCOPE

1.1 This Code (Part 6/Section 1) covers basic design loads to be assumed in the design of buildings. The imposed loads, wind loads, seismic forces, snow loads and other loads, which are specified herein, are minimum working loads which should be taken into consideration for purposes of design.

1.2 This Section does not take into consideration loads incidental to construction.

2 DEAD LOAD

2.1 Assessment of Dead Load

The dead load in a building shall comprise the weight of all walls, partitions, floors and roofs, and shall include the weights of all other permanent constructions (including built-in partitions, finishes, cladding and other similarly incorporated architectural and structural items, weight of fixed service equipment) in the building and shall conform to good practice [6-1(1)].

3 IMPOSED LOAD

3.1 This clause covers imposed loads to be assumed in the design of buildings. The imposed loads specified herein are minimum loads which should be taken into consideration for the purpose of structural safety of buildings.

NOTE — This Section does not cover detailed provisions for loads incidental to construction and special cases of vibration, such as moving machinery, heavy acceleration from cranes, hoists and the like. Such loads shall be dealt with individually in each case.

3.2 Terminology

3.2.1 For the purpose of imposed loads specified herein, the definitions given below shall apply.

3.2.1.1 *Assembly buildings* — These shall include any building or part of a building where groups of people congregate or gather for amusement, recreation, social, religious, patriotic, civil, travel and similar purposes; for example, theatres, motion picture houses, assembly halls, city halls, marriage halls, town halls, auditoria, exhibition halls, museums, skating rinks, gymnasiums, restaurants (also used as assembly halls), place of worship, dance halls, club rooms, passenger stations and terminals of air, surface and other public transportation services, recreation piers and stadia, etc.

3.2.1.2 *Business buildings* — These shall include any building or part of a building, which is used for transaction of business (other than that covered by mercantile buildings); for keeping of accounts and records for similar purposes; offices, banks, professional establishments, court houses, and libraries shall be classified in this group so far as principal function of these is transaction of public business and the keeping of books and records.

3.2.1.3 *Dwellings* — These shall include any building or part occupied by members of single/multi-family units with independent cooking facilities. These shall also include apartment houses (flats).

3.2.1.4 *Educational buildings* — These shall include any building used for school, college or day-care purposes involving assembly for instruction, education or recreation and which is not covered by assembly buildings.

3.2.1.5 *Imposed load* — The load assumed to be produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, loads due to impact and vibration, and dust loads but excluding wind, seismic, snow and other loads due to temperature changes, creep, shrinkage, differential settlement, etc.

3.2.1.6 *Industrial buildings* — These shall include any building or a part of a building or structure, in which products or materials of various kinds and properties are fabricated, assembled, manufactured or processed, for example, assembly plants, industrial laboratories, dry cleaning plants, power plants, generating units, pumping stations, fumigation chambers, laundries, buildings or structures in gas plants, refineries, dairies and saw-mills, etc.

3.2.1.7 *Institutional buildings* — These shall include any building or a part thereof, which is used for purposes such as medical or other treatment in case of persons suffering from physical and mental illness, disease or infirmity; care of infants, convalescents or aged persons and for penal or correctional detention in which the liberty of the inmates is restricted. Institutional buildings ordinarily provide sleeping accommodation for the occupants. It includes hospitals, sanatoria, custodial institutions or penal institutions like jails, prisons and reformatories.

3.2.1.8 *Occupancy or use group* — The principal occupancy for which a building or part of a building is used or intended to be used; for the purpose of classification of a building according to occupancy, an occupancy shall be deemed to include subsidiary

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occupancies which are contingent upon it.

3.2.1.9 *Office buildings* — The buildings primarily to be used as an office or for office purposes; 'office purposes' include the purpose of administration, clerical work, handling money, telephone and telegraph operating, and operating computers, calculating machines, 'clerical work' includes writing, book-keeping, sorting papers, typing, filing, duplicating, drawing of matter for publication and the editorial preparation of matter for publication, etc.

3.2.1.10 *Mercantile buildings* — These shall include any building or a part of a building which is used as shops, stores, market for display and sale of merchandize either wholesale or retail. Office, storage and service and facilities incidental to the sale of merchandize and located in the same building shall be included under this group.

3.2.1.11 *Residential buildings* — These shall include any building in which sleeping accommodation is provided for normal residential purposes with or without cooking or dining or both facilities (except buildings under institutional buildings). It includes lodging or rooming houses, one or two-family private dwellings, dormitories, apartment houses (flats) and hotels.

3.2.1.12 *Storage buildings* — These shall include any building or part of a building used primarily for the storage or sheltering of goods, wares or merchandize, like warehouses, cold storages, freight depots, transit sheds, store houses, garages, hangers, truck terminals, grain elevators, barns and stables.

3.3 Imposed Loads on Floors Due to Use and Occupancy

3.3.1 *Imposed Loads*

The imposed loads to be assumed in the design of buildings shall be the greatest loads that probably will be produced by the intended use or occupancy, but shall not be less than the equivalent minimum loads specified in Table 1 subject to any reductions permitted in **3.3.2**.

Floors shall be investigated for both the uniformly distributed load (UDL) and the corresponding concentrated load specified in Table 1, and designed for the most adverse effects but they shall not be considered to act simultaneously. The concentrated loads specified in Table 1 may be assumed to act over an area of 0.3 m × 0.3 m. However, the concentrated loads need not be considered where the floors are capable of effective lateral distribution of this load.

All other structural elements shall be investigated for the effects of uniformly distributed loads on the floors specified in Table 1.

NOTES

1 Where, in Table 1, no values are given for concentrated load, it may be assumed that the tabulated distributed load is adequate for design purposes.

2 The loads specified in Table 1 are equivalent uniformly distributed loads on the plan area and provide for normal effects of impact and acceleration. They do not take into consideration special concentrated loads and other loads.

3 Where the use of an area or floor is not provided in Table 1, the imposed load due to the use and occupancy of such an area shall be determined from the analysis of loads resulting from,

a) weight of the probable assembly of persons;

b) weight of the probable accumulation of equipment and furnishing;

c) weight of the probable storage materials; and

d) impact factor, if any.

4 While selecting a particular loading, the possible change in use or occupancy of the building should be kept in view. Designers should not necessarily select in every case the lower loading appropriate to the first occupancy. In doing this they might introduce considerable restrictions in the use of the building at a later date, and thereby reduce its utility.

5 The loads specified herein, which are based on estimations, may be considered as the characteristic loads for the purpose of limit state method of design till such time statistical data are established based on load surveys to be conducted in the country.

6 When an existing building is altered by an extension in height or area, all existing structural parts affected by the addition shall be strengthened where necessary, and all new structural parts shall be designed to meet the requirements for building hereafter erected.

7 The loads specified in the Section does not include loads incidental to construction. Therefore, close supervision during construction is essential to ensure that overloading of the building due to loads by way of stacking of building materials or use of equipment (for example, cranes and trucks) during construction or loads which may be induced by floor to floor propping in multi-storeyed construction, does not occur. However, if construction loads were of short duration, permissible increase in stresses in the case of working stress method or permissible decrease in load factors in limit state method, as applicable to relevant design codes, may be allowed for.

8 The loads in Table 1 are grouped together as applicable to buildings having separate principal occupancy or use. For a building with multiple occupancies, the loads appropriate to the occupancy with comparable use shall be chosen from other occupancies.

9 Regarding loading on lift machine rooms including storage space used for repairing lift machines, designers should go by the recommendations of lift manufacturers for the present. Regarding loading due to false ceiling, the same should be considered as imposed loads on the roof/floor to which it is fixed.

3.3.1.1 *Load application*

The uniformly distributed loads specified in Table 1 shall be applied as static loads over the entire floor area under consideration or a portion of the floor area, whichever arrangement produces critical effects on the structural elements as provided in respective design codes.

In the design of floors, the concentrated loads are

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Table 1 Imposed Floor Loads for Different Occupancies
(*Clause* 3.3.1)

Sl No.	Occupancy Classification	Uniformly Distributed Load (UDL) kN/m^2	Concentrated Load kN
(1)	(2)	(3)	(4)
i)	Residential Buildings		
	a) Dwelling houses:		
	1) All rooms and kitchens	2.0	1.8
	2) Toilets and bath rooms	2.0	—
	3) Corridors, passages, staircases including fire escapes and store rooms	3.0	4.5
	4) Balconies	3.0	1.5 per metre run concentrated at the outer edge
	b) Dwelling units planned and executed in accordance with good practice [6-1(2)] only:		
	1) Habitable rooms, kitchens, and toilets and bath rooms	1.5	1.4
	2) Corridors, passages and staircases including fire escapes	1.5	1.4
	3) Balconies	3.0	1.5 per metre run concentrated at the outer edge
	c) Hotels, hostels, boarding houses, lodging houses, dormitories and residential clubs:		
	1) Living rooms, bed rooms and dormitories	2.0	1.8
	2) Kitchen and laundries	3.0	4.5
	3) Billiards room and public lounges	3.0	2.7
	4) Store rooms	5.0	4.5
	5) Dining rooms, cafeterias and restaurants	4.0	2.7
	6) Office rooms	2.5	2.7
	7) Rooms for indoor games	3.0	1.8
	8) Baths and toilets	2.0	—
	9) Corridors, passages staircases including fire escapes and lobbies – as per the floor serviced (excluding stores and the like) but not less than	3.0	4.5
	10) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
	d) Boiler rooms and plant rooms– to be calculated but not less than	5.0	6.7
	e) Garages:		
	1) Garage floors (including parking area and repair workshops for passenger cars and vehicles not exceeding 2.5 tonne gross weight, including access ways and ramps – to be calculated but not less than	2.5	9.0
	2) Garage floors for vehicles not exceeding 4.0 tonne gross weight (including access ways and ramps) – to be calculated but not less than	5.0	9.0
ii)	Educational Buildings		
	a) Class rooms and lecture rooms (not used for assembly purposes)	3.0	2.7
	b) Dining rooms, cafeterias and restaurants	3.0[1)]	2.7
	c) Offices, lounges and staff rooms	2.5	2.7
	d) Dormitories	2.0	2.7
	e) Projection rooms	5.0	–
	f) Kitchens	3.0	4.5
	g) Toilets and bath rooms	2.0	–
	h) Store rooms	5.0	4.5
	j) Libraries and archives:		
	1) Stack room/stack area	6.0 kN/m^2 for a minimum height of 2.2 m + 2.0 kN/m^2 per metre height beyond 2.2 m	4.5

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Table 1 — (*Continued*)

(1)	(2)	(3)	(4)
	2) Reading rooms (without separate storage)	4.0	4.5
	3) Reading rooms (with separate storage)	3.0	4.5
	k) Boiler rooms and plant rooms – to be calculated but not less than	4.0	4.5
	m) Corridors, passages, lobbies, staircases including fire escapes – as per the floor serviced (without accounting for storage and projection rooms) but not less than	4.0	4.5
	n) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
iii)	Institutional Buildings		
	a) Bed rooms, wards, dressing rooms, dormitories and lounges	2.0	1.8
	b) Kitchens, laundries and laboratories	3.0	4.5
	c) Dining rooms, cafeterias and restaurants	3.0[1)]	2.7
	d) Toilets and bathrooms	2.0	–
	e) X-ray rooms, operating rooms and general storage areas – to be calculated but not less than	3.0	4.5
	f) Office rooms and O.P.D. rooms	2.5	2.7
	g) Corridors, passages, lobbies, staircases including fire escapes – as per the floor serviced (without accounting for storage and projection rooms) but not less than	4.0	4.5
	h) Boiler rooms and plant rooms – to be calculated but not less than	5.0	4.5
	j) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
iv)	Assembly Buildings		
	a) Assembly areas :		
	1) With fixed seats[2)]	4.0	–
	2) Without fixed seats	5.0	3.6
	b) Restaurants (subject to assembly), museums and art galleries and gymnasia	4.0	4.5
	c) Projection rooms	5.0	—
	d) Stages	5.0	4.5
	e) Office rooms, kitchens and laundries	3.0	4.5
	f) Dressing rooms	2.0	1.8
	g) Lounges and billiards rooms	2.0	2.7
	h) Toilets and bathrooms	2.0	—
	j) Corridors, passages and staircases including fire escapes	4.0	4.5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
	m) Boiler rooms and plant rooms including weight of machinery	7.5	4.5
	n) Corridors, passages, subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like corridors, staircases and passages in grandstands	5.0	4.5
v)	Business and Office Buildings (*see also* **3.2.1**)		
	a) Rooms for general use with separate storage	2.5	2.7
	b) Rooms without separate storage	4.0	4.5
	c) Banking halls	3.0	2.7
	d) Business computing machine rooms (with fixed computers or similar equipment)	3.5	4.5
	e) Records/files store rooms and storage space	5.0	4.5
	f) Vaults and strong rooms – to be calculated but not less than	5.0	4.5
	g) Cafeterias and dining rooms	3.0[1)]	2.7
	h) Kitchens	3.0	2.7
	j) Corridors, passages, lobbies, staircases including fire escapes – as per the floor serviced (excluding stores) but not less than	4.0	4.5
	k) Bath and toilets rooms	2.0	—

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Table 1 — (*Concluded*)

(1)	(2)	(3)	(4)
	m) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
	n) Stationary stores	4.0 for each metre of storage height	9.0
	p) Boiler rooms and plant rooms – to be calculated but not less than	5.0	6.7
	q) Libraries	*See* Sl No. (ii)	
vi)	Mercantile Buildings		
	a) Retail shops	4.0	3.6
	b) Wholesale shops – to be calculated but not less than	6.0	4.5
	c) Office rooms	2.5	2.7
	d) Dining rooms, restaurants and cafeterias	3.0[1)]	2.7
	e) Toilets	2.0	–
	f) Kitchens and laundries	3.0	4.5
	g) Boiler rooms and plant rooms – to be calculated but not less than	5.0	6.7
	h) Corridors, passages, staircases including fire escapes and lobbies	4.0	4.5
	j) Corridors, passages, staircases subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5.0	4.5
	k) Balconies	Same as rooms to which they give access but with a minimum of 4.0	1.5 per metre run concentrated at the outer edge
vii)	Industrial Buildings[3)]		
	a) Work areas without machinery/equipment	2.5	4.5
	b) Work areas with machinery/equipment[4)]		
	1) Light duty (To be calculated but not less than)	5.0	4.5
	2) Medium duty (To be calculated but not less than)	7.0	4.5
	3) Heavy duty (To be calculated but not less than)	10.0	4.5
	c) Boiler rooms and plant rooms – to be calculated but not less than	5.0	6.7
	d) Cafeterias and dining rooms	3.0[1)]	2.7
	e) Corridors, passages, stair cases including fire escapes	4.0	4.5
	f) Corridors, passages, lobbies, staircases subject to machine loads and wheeled vehicles – to be calculated but not less than	5.0	4.5
	g) Kitchens	3.0	4.5
	h) Toilets and bathrooms	2.0	—
viii)	Storage Buildings[4)]		
	a) Storage rooms (other than cold storage) and warehouses — to be calculated based on the bulk density of materials stored but not less than	2.4 kN/m^2 per metre of storage height with a minimum of 7.5 kN/m^2	7.0
	b) Cold storage – to be calculated but not less than	5.0 kN/m^2 per metre of storage height with a minimum of 15 kN/m^2	9.0
	c) Corridors, passages, staircases including fire escapes – as per the floor serviced but not less than	4.0	4.5
	d) Corridors, passages subject to loads greater than from crowds, such as wheeled vehicles, trolleys and the like	5.0	4.5
	e) Boiler rooms and plant rooms	7.5	4.5

[1)] Where unrestricted assembly of persons is anticipated, the value of UDL should be increased to 4.0 kN/m^2.

[2)] With fixed seats implies that the removal of the seating and the use of the space for other purposes is improbable. The maximum likely load in this case is, therefore, closely controlled.

[3)] The loading in industrial buildings (workshops and factories) varies considerably and so three loadings under the terms 'light', 'medium' and 'heavy' are introduced in order to allow for more economical designs but the terms have no special meaning in themselves other than the imposed load for which the relevant floor is designed. It is, however important particularly in the case of heavy weight loads, to assess the actual loads to ensure that they are not in excess of 10 kN/m^2; in case where they are in excess, the design shall be based on the actual loadings.

[4)] For various mechanical handling equipment which are used to transport goods, as in warehouses, workshops, store rooms, etc, the actual load coming from the use of such equipment shall be ascertained and design should cater to such loads.

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considered to be applied in the positions which produce the maximum stresses and where deflection is the main criterion in the positions which produce the maximum deflections. Concentrated load, when used for the calculation of bending and shear, are assumed to act at a point. When used for the calculation of local effects such as crushing or punching, they are assumed to act over an actual area of application of 0.3 m × 0.3 m.

3.3.1.2 *Loads due to light partitions*

In office and other buildings, where actual loads due to light partitions cannot be assessed at the time of planning the floors and the supporting structural members shall be designed to carry, in addition to other loads, uniformly distributed loads per square metre of not less than 33.33 percent of weight per metre run of finished partitions, subject to a minimum of 1 kN/m^2, provided total weight of partition walls per m^2 of the wall area does not exceed 1.5 kN/m^2 and the total weight per metre length is not greater than 4.0 kN.

3.3.2 *Reduction in Imposed Loads on Floors*

3.3.2.1 *For members supporting floors*

Except as provided for in **3.3.2.1**(a), the following reductions in assumed total imposed loads on the floors may be made in designing columns, load bearing walls, piers, their supports and foundations:

Number of Floors (Including the Roof) to be Carried by Member Under Consideration	*Reduction in Total Distributed Imposed Load on All Floors to be Carried by the Member Under Consideration*
	Percent
1	0
2	10
3	20
4	30
5 to 10	40
Over 10	50

a) No reduction shall be made for any plant or machinery which is specifically allowed for, or for buildings for storage purposes, warehouses and garages. However, for other buildings, where the floor is designed for an imposed floor load of 5.0 kN/m^2 or more, the reductions shown in **3.3.2.1** may be taken provided that the loading assumed is not less than it would have been, if all the floors had been designed for 5.0 kN/m^2 with no reductions.

NOTE — In case, if the reduced load in the lower floor is lesser than the reduced load in the upper floor, then the reduced load of the upper floor will be adopted.

b) An example is given in Annex A illustrating the reduction of imposed loads in a multi-storeyed building in the design of column members.

3.3.2.2 *For beams in each floor level*

Where a single span of beam, girder or truss supports not less than 50 m^2 of floor at one general level, the imposed floor load may be reduced in the design of the beams, girders or trusses by 5 percent for each 50 m^2 area supported subject to a maximum reduction of 25 percent. However, no reduction shall be made in any of the following types of loads:

a) Any superimposed moving load,
b) Any actual load due to machinery or similar concentrated loads,
c) The additional load in respect of partition walls; and
d) Any impact or vibration.

NOTE — The above reduction does not apply to beams, girders or trusses supporting roof loads.

3.3.3 *Posting of Floor Capacities*

Where a floor or part of a floor of a building has been designed to sustain a uniformly distributed load exceeding 3.0 kN/m^2 and in assembly, business, mercantile, industrial or storage buildings, a permanent notice in the form shown below indicating the actual uniformly distributed and/or concentrated loadings for which the floor has been structurally designed shall be posted in a conspicuous place in a position adjacent to such floor or on such part of a floor.

DESIGNED IMPOSED FLOOR LOADING

Distributed……..kN/m^2

Concentrated……kN

Label Indicating Designed Imposed Floor Loading

NOTES

1 The lettering of such notice shall be embossed or cast suitably on a tablet whose least dimension shall not be less than 0.25 m and located not less than 1.5 m above floor level with lettering of a minimum size of 25 mm.

2 If a concentrated load or a bulk load has to occupy a definite position on the floor, the same could also be indicated in the table.

3.4 Imposed Loads on Roofs

3.4.1 *Imposed Loads on Various Types of Roofs*

On flat roofs, sloping roofs and curved roofs, the imposed loads due to use and occupancy of the buildings and the geometry of the types of roofs shall be as given in Table 2.

3.4.1.1 Roofs of buildings used for promenade or

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Table 2 Imposed Loads on Various Types of Roofs
(*Clause* 3.4.1)

Sl No.	Type of Roof	Imposed Load Measured on Plan Area	Minimum Imposed Load Measured on Plan
(1)	(2)	(3)	(4)
i)	Flat, sloping or curved roof with slopes up to and including 10°:		
	a) Access provided	1.5 kN/m^2	3.75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span of any beam or truss or wall
	b) Access not provided except for maintenance	0.75 kN/m^2	1.9 kN uniformly distributed over any span of one metre width of the roof slab and 4.5 kN uniformly distributed over the span of any beam or truss or wall
ii)	Sloping roof with slope greater than 10°	For roof membrane sheets or purlins – 0.75 kN/m^2 less 0.02 kN/m^2 for every degree increase in slope over 10°	Subject to a minimum of 0.4 kN/m^2
iii)	Curved roof with slope of line obtained by joining springing point to the crown with the horizontal, greater than 10°	$(0.75 - 0.52\ \alpha^2)$ kN/m^2 where α = h/l h = height of the highest point of the structure measured from its springing; and l = chord width of the roof if singly curved and shorter of the two sides if doubly curved. Alternatively, where structural analysis can be carried out for curved roofs of all slopes in a simple manner applying the laws of statistics, the curved roofs shall be divided into minimum 6 equal segments and for each segment imposed load shall be calculated appropriate to the slope of the chord of each segment as given in Sl No. (i) and (ii).	Subject to a minimum of 0.4 kN/m^2

NOTES

1 The loads given above do not include loads due to snow, rain, dust collection, etc. The roof shall be designed for imposed loads given above or for snow/rain load, whichever is greater.

2 For special types of roofs with highly permeable and absorbent material, the contingency of roof material increasing in weight due to absorption of moisture shall be provided for.

incidental to assembly purposes shall be designed for the appropriate imposed floor loads given in Table 1 for the occupancy.

3.4.2 *Concentrated Load on Roof Coverings*

To provide for loads incidental to maintenance, unless otherwise specified by the Engineer-in-Charge, all roof coverings (other than glass or transparent sheets made of fibre glass) shall be capable of carrying an incidental load of 0.90 kN concentrated on an area of 1 250 mm^2 so placed as to produce maximum stresses in the covering. The intensity of the concentrated load may be reduced with the approval of the Engineer-in-Charge, where it is ensured that the roof coverings would not be traversed without suitable aids. In any case, the roof coverings shall be capable of carrying the loads in accordance with **3.4.1**, **3.4.3** and **3.4.4** and wind load.

3.4.3 *Loads Due to Rain*

On surfaces whose positioning, shape and drainage system are such as to make accumulation of rain water possible, loads due to such accumulation of water and the imposed loads for the roof as given in Table 2 shall be considered separately and the more critical of the two shall be adopted in the design.

3.4.4 *Dust Loads*

In areas prone to settlement of dust on roofs (for example, steel plants, cement plants), provision for dust load equivalent to probable thickness of accumulation of dust may be made.

3.4.5 *Loads on Members Supporting Roof Coverings*

Every member of the supporting structure which is directly supporting the roof covering(s) shall be designed to carry the more severe of the following loads except as provided in **3.4.5.1**:

a) The load transmitted to the members from the roof covering(s) in accordance with **3.4.1**, **3.4.3** and **3.4.4**; and

b) An incidental concentrated load of 0.90 kN concentrated over a length of 125 mm placed at the most critical positions on the member.

NOTE — Where it is ensured that the roofs would be traversed only with the aid of planks and ladders capable of distributing

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the loads on them to two or more supporting members, the intensity of concentrated load indicated in **3.4.5** (b) may be reduced to 0.5 kN with the approval of the Engineer-in-Charge.

3.4.5.1 In case of sloping roofs with slope greater than 10°, members supporting the roof purlins, such as trusses, beams, girders, etc, may be designed for two-thirds of the imposed load on purlin or roofing sheets.

3.5 Imposed Horizontal Loads on Parapets, Balustrades and Other Appurtenances Fixed to Structure, and on Grandstands

3.5.1 *Parapets, Parapet Walls, Balustrades and other Appurtenances Fixed to the Structure such as Grab Bars, Fixed Ladders and Guardrails in Stilt Parking*

Parapets, parapet walls, balustrades and other appurtenances fixed to the structure such as grab bars, fixed ladders and guardrails in stilt parking, together with the members which give them structural support, shall be designed for the minimum loads given in Table 3. These are expressed as horizontal forces acting at handrail or coping level. These loads shall be considered to act vertically also but not simultaneously with the horizontal forces. The values given in Table 3 are minimum values and where values for actual loadings are available, they shall be used instead.

3.5.2 *Grandstands and the Like*

Grandstands, stadia, assembly platforms, reviewing stands and the like shall be designed to resist a horizontal force applied to seats of 0.35 kN per linear metre along the line of seats and 0.15 kN per linear metre perpendicular to the line of the seats. These loadings need not be applied simultaneously. Platforms without seats shall be designed to resist a minimum horizontal force of 0.25 kN/m^2 of plan area.

3.6 Loading Effects Due to Impact and Vibration

The crane loads to be considered under imposed loads shall include the vertical loads, eccentricity effects induced by vertical loads, impact factors, lateral and longitudinal braking forces acting across and along the crane rails, respectively.

3.6.1 *Impact Allowance for Lifts, Hoists and Machinery*

The imposed loads specified in **3.3.1** shall be assumed to include adequate allowance for ordinary impact conditions. However, for structures carrying loads which induce impact or vibration, as far as possible, calculations shall be made for increase in the imposed load due to impact or vibration. In the absence of sufficient data for such calculation, the increase in the imposed loads shall be as follows:

	Structures	*Impact Allowance* Percent *Min*
i)	For frames supporting lifts and hoists	100
ii)	For foundations, footings and piers supporting lifts and hoisting apparatus	40
iii)	For supporting structures and foundations for light machinery, shaft or motor units	20
iv)	For supporting structures and foundations for reciprocating machinery or power units	50

Table 3 Horizontal Loads on Parapets, Parapet Walls and Balustrades
(*Clause* 3.5.1)

Sl No.	Usage Area	Intensity of Horizontal Load kN/m Run	Concentrated load (For Each 3m length) kN
(1)	(2)	(3)	(4)
i)	Light access stairs, gangways and like, not more than 600 mm wide	0.25	—
ii)	Light access stairs, gangways and like, more than 600 mm wide; stairways, landings, balconies and parapet walls (private and part of dwellings)	0.35	—
iii)	a) All other stairways, landings and balconies and all parapets and handrails to roofs [except those subject to overcrowding covered under Sl No. (iv)]	0.75	0.89
	b) Panel fillers	0.20	0.22
iv)	Parapets and balustrades:		
	a) In places of assembly, such as restaurants and bars, retail and public areas, not likely to be overcrowded	1.5	1.5
	b) In places of assembly, such as retail areas, theatres, cinemas, bars, auditoria, shopping malls, discothèques, places of worship, likely to be overcrowded	3.0	1.5
v)	Grab bars	—	1.11
vi)	Fixed ladders	—	1.33
vii)	Guardrail systems and handrail assemblies	0.73	0.89

NOTE — In the case of guard parapets on a floor of multi-storeyed car park or crash barriers provided in certain buildings for fire escape, the value of imposed horizontal load (together with impact load) may be determined. For (vii), this load need not be considered for (a) one- and two-family dwellings, and (b) factory, industrial and storage occupancies, in areas that serve occupant load not greater than 22 kN.

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3.6.2 *Concentrated Imposed Loads with Impact and Vibration*

Concentrated imposed loads with impact and vibration which may be due to installed machinery shall be considered and provided for in the design. The impact factor shall not be less than 20 percent which is the amount allowable for light machinery.

3.6.2.1 Provision shall also be made for carrying any concentrated equipment loads while the equipment is being installed or moved for servicing and repairing.

3.6.3 *Impact Allowance for Crane Girders*

For crane gantry girders and supporting columns, the impact allowances (given below) shall be deemed to cover all forces set up by vibration, shock from slipping of slings, kinetic action of acceleration, and retardation and impact of wheel loads:

Forces specified in (c) and (d) shall be considered as acting at the rail level and being appropriately transmitted to the supporting system. Gantry girders and their vertical supports shall be designed on the assumption that either of the horizontal forces in (c) and (d) may act at the same time as the vertical load.

NOTE — *See* good practice [6-1(3)] for classification (Class I to Class IV) of cranes.

3.6.3.1 *Overloading factors in crane supporting structures*

For all ladle cranes and charging cranes where there is possibility of overloading from production considerations, an overloading factor of 10 percent of the maximum wheel loading shall be taken.

3.6.4 *Crane Load Combinations*

In the absence of any specific indications, the load combinations shall be as indicated below.

	Type of Load	*Additional Load*
a)	Vertical loads for electric overhead cranes	25 percent of maximum static loads for crane girders for all class of cranes 25 percent for columns supporting Class III and Class IV cranes 10 percent for columns supporting Class I and Class II cranes No additional load for design of foundations
b)	Vertical loads for hand operated cranes	10 percent of maximum wheel loads for crane girders only
c)	Horizontal forces transverse to rails:	
	1) For electric overhead cranes with trolley having rigid mast for suspension of lifted weight (such as soaker crane, stripper crane, etc)	10 percent of weight of crab and the weight lifted by the cranes, acting on any one crane track rail, acting in either direction and equally distributed amongst all the wheels on one side of rail track For frame analysis, this force, calculated as above, shall be applied on one side of the frame at a time in either direction
	2) For all other electric overhead cranes and hand operated cranes	5 percent of weight of crab and the weight lifted by the cranes, acting on any one crane track rail, acting in either direction and equally distributed amongst the wheels on one side of rail track For the frame analysis, the force, calculated as above, shall be applied on one side of the frame at a time in either direction
d)	Horizontal traction forces along the rails for overhead cranes, either electrically operated or hand operated	5 percent of all static wheel loads

3.6.4.1 *Vertical loads*

In an aisle, where more than one crane is in operation or has provision for more than one crane in future, the following load combinations shall be taken for vertical loading:

a) Two adjacent cranes working in tandem with full load and with overloading according to **3.6.3.1**; and

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b) For long span gantries, where more than one crane can come in the span, the girder shall be designed for one crane fully loaded with overloading according to **3.6.3.1** plus as many loaded cranes as can be accommodated on the span but without taking into account overloading according to **3.6.3** (a) to give the maximum effect.

3.6.4.2 *Lateral surge*

For design of columns and foundations, supporting crane girders, the following crane combinations shall be considered:

a) *For single bay frames* — Effect of one crane in the bay giving the worst effect shall be considered for calculation of surge force; and

b) *For multi-bay frames* — Effect of two cranes working, one each in any of two bays in the cross-section to give the worst effect shall be considered for calculation of surge force.

3.6.4.3 *Tractive force*

3.6.4.3.1 Where one crane is in operation with no provision for future crane, tractive force from only one crane shall be taken.

3.6.4.3.2 Where more than one crane is in operation or there is provision for future crane, tractive force from two cranes giving maximum effect shall be considered.

NOTE — Lateral surge force and longitudinal tractive force acting across and along the crane rail respectively shall not be assumed to act simultaneously. However, if there is only one crane in the bay, the lateral and longitudinal forces may act together simultaneously with vertical loads.

3.7 Rooftop Helipad

Elevated helipad structures shall be designed as per the latest guidelines of Directorate General of Civil Aviation and International Civil Aviation Organization's Heliport Manual.

3.7.1 *Structural Design*

Elevated helipads may be designed for a specific helicopter type though greater operational flexibility will be obtained from a classification system of design. The final approach and take-off area (FATO) should be designed for the largest or heaviest type of helicopter that is anticipated to use the helipad, and account taken of other types of loading such as personnel, freight, snow, refueling equipment, etc. For the purpose of design, it is to be assumed that the helicopter will land on two main wheels, irrespective of the actual number of wheels in the undercarriage, or on two skids, if they are fitted. The loads imposed on the structure should be taken as point loads at the wheel centres as shown below:

Helicopter Category	*Maximum Take-off Mass*		*Point Load for Each Wheel*	*Under-Carriage Wheel Centres*	*Super-imposed Load* S_{Ha}	*Super-imposed Load* S_{Hb}
	kg	kN	kN	m	kN/m^2	kN/m^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Up to 2 300	Up to 22.6	12.0	1.75	0.5	1.5
2	2 301-5 000	22.6-49.2	25.0	2.0	0.5	2.0
3	5 001-9 000	49.2-88.5	45.0	2.5	0.5	2.5
4	9 001-13 500	88.5-133.0	67.0	3.0	0.5	3.0
5	13 501-19 500	133.0-192.0	96.0	3.5	0.5	3.0
6	19 501-27 000	192.0-266.0	133.0	4.5	0.5	3.0

3.7.2 The FATO should be designed for the worse condition derived from consideration of the following two cases.

3.7.3 *Case A — Helicopter on Landing*

When designing a FATO on an elevated helipad, and in order to cover the bending and shear stresses that result from a helicopter touching down, the following

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should be taken into account:

a) *Dynamic load due to impact on touch-down* — This should cover the normal touchdown, with a rate of descent of 1.8 m/s, which equates to the serviceability limit state. The impact load is then equal to 1.55 times the maximum take-off mass of the helicopter.

The emergency touchdown should also be covered at a rate of descent of 3.6 m/s (12 ft/s), which equates to the ultimate limit state. The partial safety factor in this case should be taken as 1.66. Therefore,

Ultimate design load = 1.66 × service load
= (1.66 × 1.5) maximum take-off mass
= 2.5 maximum take-off mass

The sympathetic response factor discussed at **3.7.3** (b) below should be applied.

b) *Sympathetic response on the FATO* — The dynamic load should be increased by a structural response factor dependent upon the natural frequency of the platform slab when considering the design of supporting beams and columns. This increase in loading will usually apply only to slabs with one or more freely supported edges. It is recommended that the average structural response factor (R) of 1.3 should be used in determining the ultimate design load.

c) *Over-all superimposed load on the FATO* (S_{Ha}) — To allow for snow load, personnel, freight and equipment loads, etc, in addition to wheel loads, an allowance of 0.5 kN/m^2 should be included in the design.

d) *Lateral load on the platform supports* — The supports of the platform should be designed to resist a horizontal point load equivalent to 0.5 maximum take-off mass of the helicopter, together with the wind loading [*see* (*f*)], applied in the direction which will provide the greater bending moments.

e) *Dead load of structural members* — The partial safety factor to be used for the dead load should be taken as 1.4.

f) *Wind loading* — Shall be as per **4**.

g) *Punching shear* — Check for the punching shear of an undercarriage wheel or skid using the ultimate design load with a contact area of 64.5 × 10^3 mm^2.

3.7.4 *Case B — Helicopter at Rest*

When designing a FATO on an elevated helipad, and in order to cover the bending and shear stresses from a helicopter at rest, the following should be taken into account:

a) *Dead load of the helicopter* — Each structural element shall be designed to carry the point load, in accordance with the table under **3.7.1**, from the two main wheels or skids applied simultaneously in any position on the FATO so as to produce the worst effect from both bending and shear.

b) *Over-all superimposed load* (S_{Hb}) — In addition to wheel loads, an allowance for over-all superimposed load given in the table under **3.7.1**, over the area of the FATO, should be included in the design.

c) *Dead load on structural members and wind loading* — The same factors should be included in the design for these items as given for Case A.

NOTE — The above design loads for helicopters at rest are summarized below:

Design Load for Helicopter on Landing — Case A

i)	Superimposed loads:	
	a) Helicopter	2.5 L_H distributed as two point loads at the wheel centres for the helicopter category given in the informal table under **3.7.1** Average value for R = 1.3.
	b) Lateral load	$1.6\frac{L_H}{2}$ applied horizontally in any direction
	c) Over-all superimposed load	Load at platform level together with the maximum wind loading. 1.4 S_{Ha} over the whole area of the platform (S_{Ha} given in the informal table under **3.7.1**)
ii)	Dead load	1.4G
iii)	Wind loading	1.4W
iv)	Punching shear check	2.5 $L_H R$ load over tyre skid contact area of 64.5 × 10^3 mm^2

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Design Load for Helicopter at Rest — Case B

i)	Superimposed loads:	
	a) Helicopter	1.6 L_H distributed as two point loads at the wheel centres for the helicopter category given in the informal table under **3.7.1**
	b) Over-all superimposed load (Personnel, freight, etc)	1.6 S_{Hb} over the whole area of the platform. S_{Hb} given in the informal table under **3.7.1**
ii)	Shear check	Check as appropriate

Symbol	*Meaning*
L_H	Maximum take-off mass of helicopter
G	Dead load of structure
W	Wind loading
R	Structural response factor
S_{Ha}	Superimposed load — Case A
S_{Hb}	Superimposed load — Case B

Load Type	*Partial Load Factors*
Dynamic load (ultimate design load)	2.5
Live load	1.6
Dead load	1.4
Wind loading	1.4

3.7.5 Normally, the upper load limit of the helicopter category selected should be used for design purposes except as follows:

In order to avoid over-design in the platform the upper limit in any band may be exceeded by 10 percent should be the maximum take-off mass of a helicopter fall just into the next higher category.

3.8 Fire Tenders and Emergency Vehicles

Where a structure or portions of a structure are accessed and loaded by fire department access vehicles and other similar emergency vehicles, the structure shall be designed for the greater of the following loads:

a) The actual operational loads, including outrigger reactions and contact areas of the vehicles as stipulated and provided by the building official.

b) The contact area of wheel dimensions to be used considering 45° distribution at the reinforcement of slab considering the bear coat on the slab and any soil filling.

or

In absence of any data the bare slab loading may be considered as 15 to 20 kN/m^2.

c) When the fire tender load is combined with gravity loads and the same can be considered as accidental load with the partial load factor of 1.05.

d) Fire tender load need not be combined with lateral loads.

4 WIND LOAD

4.1 General

4.1.1 This clause gives wind forces and their effects (static and dynamic) that should be taken into account when designing buildings, structures and components thereof.

4.1.2 Wind speeds vary randomly both in time and space and hence assessment of wind loads and response predictions are very important in the design of several buildings and structures. A large majority of structures met with in practice do not however, suffer wind induced oscillations and generally do not require to be examined for the dynamic effects of wind. For such normal, short and heavy structures, estimation of loads using static wind analysis has proved to be satisfactory. The details of this method involving important wind characteristics such as the basic wind speeds, terrain categories, modification factors, wind pressure and force coefficients, etc, are given in **4.4** and **4.5**.

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4.1.3 Nevertheless, there are various types of structures or their components such as some tall buildings which require investigation of wind induced oscillations. The influence of dynamic velocity fluctuations on the along wind loads (drag loads) for these structures shall be determined using Gust Factor Method, included in **4.8**. A method for calculation of across wind response of tall buildings is included in **4.8.3**.

4.1.4 This Section also applies to buildings or other structures during erection/construction and the same shall be considered carefully during various stages of erection/construction. In locations where the strongest winds and icing may occur simultaneously, loads on structural members, cables and ropes shall be calculated by assuming an ice covering based on climatic and local experience.

4.1.5 Wind is air in motion relative to the surface of the earth. The primary cause of wind is traced to earth's rotation and differences in terrestrial radiation. The radiation effects are primarily responsible for convection either upwards or downwards. The wind generally blows horizontal to the ground at high wind speeds. Since vertical components of atmospheric motion are relatively small, the term 'wind' denotes almost exclusively the horizontal wind; vertical winds are always identified as such. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at heights generally varying from 10 to 30 m above ground.

4.1.6 Very strong winds (more than 80 km/h) are generally associated with cyclonic storms, thunderstorms, dust storms or vigorous monsoons. A feature of the cyclonic storms over the Indian area is that they rapidly weaken after crossing the coasts and move as depressions/lows inland. The influence of a severe storm after striking the coast does not; in general exceed about 60 km, though sometimes, it may extend even up to 120 km. Very short duration hurricanes of very high wind speeds called *Kal Baisaki* or Norwesters occur fairly frequently during summer months over North East India.

4.1.7 The wind speeds recorded at any locality are extremely variable and in addition to steady wind at any time, there are effects of gusts which may last for a few seconds. These gusts cause increase in air pressure but their effect on stability of the building may not be so important; often, gusts affect only part of the building and the increased local pressures may be more than balanced by a momentary reduction in the pressure elsewhere. Because of the inertia of the building, short period gusts may not cause any appreciable increase in stress in main components of the building although the walls, roof sheeting and individual cladding units (glass panels) and their support-ing members such as purlins, sheeting rails and glazing bars may be more seriously affected. Gusts can also be extremely important for design of structures with high slenderness ratios.

4.1.8 The liability of a building to high wind pressures depends not only upon the geographical location and proximity of other obstructions to air flow but also upon the characteristics of the structure itself.

4.1.9 The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

4.1.10 The stability calculations as a whole shall be done considering the combined effect, as well as separate effects of imposed loads and wind loads on vertical surfaces, roofs and other part of the building above general roof level.

4.1.11 Buildings shall also be designed with due attention to the effects of wind on the comfort of people inside and outside the buildings.

NOTES

1 This Section does not apply to buildings or structures with unconventional shapes, unusual locations, and abnormal environmental conditions that have not been covered in this Code. Special investigations are necessary in such cases to establish wind loads and their effects. Wind tunnel studies may also be required in such situations.

2 In the case of tall structures with unsymmetrical geometry, the designs may have to be checked for torsional effects due to wind pressure.

3 The provisions given in good practice [6-1(4)] may be suitably referred by the design engineer/planner for reference.

4.2 Notations

The notations to be followed unless otherwise specified in relevant clauses under wind loads are given in Annex B.

4.3 Terminology

4.3.1 For the purpose of wind loads, the definitions given below shall apply.

4.3.1.1 *Angle of attack* — An angle between the direction of wind and a reference axis of the structure.

4.3.1.2 *Breadth* — It means horizontal dimension of the building measured normal to the direction of wind.

4.3.1.3 *Depth* — It means the horizontal dimension of the building measured in the direction of the wind.

NOTE — Breadth and depth are dimensions measured in relation to the direction of wind, whereas length and width are dimensions related to the plan.

4.3.1.4 *Developed height* — It is the height of upward penetration of the velocity profile in a new

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terrain. At large fetch lengths, such penetration reaches the gradient height, above which the wind speed may be taken to be constant. At lesser fetch lengths, a velocity profile of a smaller height but similar to that of the fully developed profile of that terrain category has to be taken, with the additional provision that the velocity at the top of this shorter profile equal to that of the un-penetrated earlier velocity profile at that height.

4.3.1.5 *Effective frontal area* — The projected area of the structure normal to the direction of wind.

4.3.1.6 *Element of surface area* — The area of surface over which the pressure coefficient is taken to be constant.

4.3.1.7 *Force coefficient* — A non-dimensional coefficient such that the total wind force on a body is the product of the force coefficient, the dynamic pressure of the incident design wind speed and the reference area over which the force is required.

NOTE — When the force is in the direction of the incident wind, the non-dimensional coefficient will be called as 'drag coefficient'. When the force is perpendicular to the direction of incident wind, the non-dimensional coefficient will be called as 'lift coefficient'.

4.3.1.8 *Ground roughness* — The nature of the earth's surface as influenced by small scale obstructions such as trees and buildings (as distinct from topography) is called ground roughness.

4.3.1.9 *Gust* — A positive or negative departure of wind speed from its mean value, lasting for not more than, say, 2 min over a specified interval of time.

4.3.1.10 *Peak gust* — A peak gust or peak gust speed is the wind speed associated with the maximum amplitude.

4.3.1.11 *Fetch length* — It is the distance measured along the wind from a boundary at which a change in the type of terrain occurs. When the changes in terrain types are encountered (such as, the boundary of a town or city, forest, etc), the wind profile changes in character but such changes are gradual and start at ground level, spreading or penetrating upwards with increasing fetch length.

4.3.1.12 *Gradient height* — It is the height above the mean ground level at which the gradient wind blows as a result of balance among pressure gradient force, Coriolis force and centrifugal force. For the purpose of this Section, the gradient height is taken as the height above the mean ground level, above which the variation of wind speed with height need not be considered.

4.3.1.13 *Tall building* — A building with a height more than or equal to 50 m or having a height to smaller lateral dimension more than 6.

4.3.1.14 *Mean ground level* — The mean ground level is the average horizontal plane of the area enclosed by the boundaries of the structure.

4.3.1.15 *Pressure coefficient* — It is the ratio of the difference between the pressure acting at a point on the surface and the static pressure of the incident wind to the design wind pressure, where the static and design wind pressures are determined at the height of the point considered after taking into account the geographical location, terrain conditions and shielding effect. The pressure coefficient is also equal to $[1 - (V_p/V_z)^2]$, where V_p is the actual wind speed at any point on the structure at a height corresponding to that of V_z.

NOTE — Positive sign of the pressure coefficient indicates pressure acting towards the surface and negative sign indicates pressure acting away from the surface.

4.3.1.16 *Return period* — It is the number of years, reciprocal of which gives the probability of extreme wind exceeding a given wind speed in anyone year.

4.3.1.17 *Shielding effect* — Shielding effect or shielding refers to the condition where wind has to pass along some structure(s) or structural element(s) located on the upstream wind side, before meeting the structure or structural element under consideration. A factor called 'shielding factor' is used to account for such effects in estimating the force on the shielded structures.

4.3.1.18 *Suction* — It means pressure less than the atmospheric (static) pressure and is taken to act away from the surface.

4.3.1.19 *Solidity ratio* — It is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

NOTE — Solidity ratio is to be calculated for individual frames.

4.3.1.20 *Terrain category* — It means the characteristics of the surface irregularities of an area which arise from natural or constructed features. The categories are numbered in increasing order of roughness.

4.3.1.21 *Topography* — The nature of the earth's surface as influenced by the hill and valley configurations.

4.3.1.22 *Velocity profile* — The variation of the horizontal component of the atmospheric wind speed at different heights above the mean ground level is termed as velocity profile.

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4.4 Wind Speed

4.4.1 *Nature of Wind in Atmosphere*

In general, wind speed in the atmospheric boundary layer increases with height from zero at ground level to maximum at a height called the gradient height. There is usually a slight change in direction (Ekman effect) but this is ignored in this Section. The variation with height depends primarily on the terrain conditions. However, the wind speed at any height never remains constant and it has been found convenient to resolve its instantaneous magnitude into an average or mean value and a fluctuating component around this average value. The average value depends on the average time employed in analyzing the meteorological data and this averaging time varies from few seconds to several minutes. The magnitude of fluctuating component of the wind speed, which is called gust, depends on the averaging time. In general, smaller the averaging interval more is the magnitude of the gust speed.

4.4.2 *Basic Wind Speed*

Figure 1 gives basic wind speed map of India, as applicable to 10 m height above mean ground level for different zones of the country. Basic wind speed is based on peak gust velocity averaged over a short time interval of about 3 s and corresponds to mean heights above ground level in an open terrain (Category 2). Basic wind speeds presented in Fig. 1 have been worked out for a 50 year return period. Basic wind speed for some important cities/towns is also given in Annex C.

4.4.3 *Design Wind Speed* (V_z)

The basic wind speed (V_b) for any site shall be obtained from Fig. 1 and shall be modified to include the following effects to get design wind speed, V_z at any height z, for the chosen structure:

a) Risk level,
b) Terrain roughness and height of structure,
c) Local topography, and
d) Importance factor for the cyclonic region.

It can be mathematically expressed as follows:

$$V_z = V_b\, k_1\, k_2\, k_3\, k_4$$

where

V_z = design wind speed at height z, in m/s;
k_1 = probability factor (risk coefficient) (*see* **4.4.3.1**);
k_2 = terrain roughness and height factor (*see* **4.4.3.2**);
k_3 = topography factor (*see* **4.4.3.3**); and
k_4 = importance factor for the cyclonic region (*see* **4.4.3.4**).

NOTE — Wind speed may be taken as constant up to a height of 10 m. However, pressures for buildings less than 10 m high may be reduced by 20 percent for evaluating stability and design of the framing.

4.4.3.1 *Risk coefficient* (k_1 *factor*)

Figure 1 gives basic wind speeds for Terrain Category 2 as applicable at 10 m above ground level based on 50 years mean return period. The suggested life period to be assumed in design and the corresponding k_1 factors for different class of structures for the purpose of design are given in Table 4. In the design of buildings and structures, a regional basic wind speed having a mean return period of 50 years shall be used except as specified in Note of Table 4.

4.4.3.2 *Terrain, height factor* (k_2 *factor*)

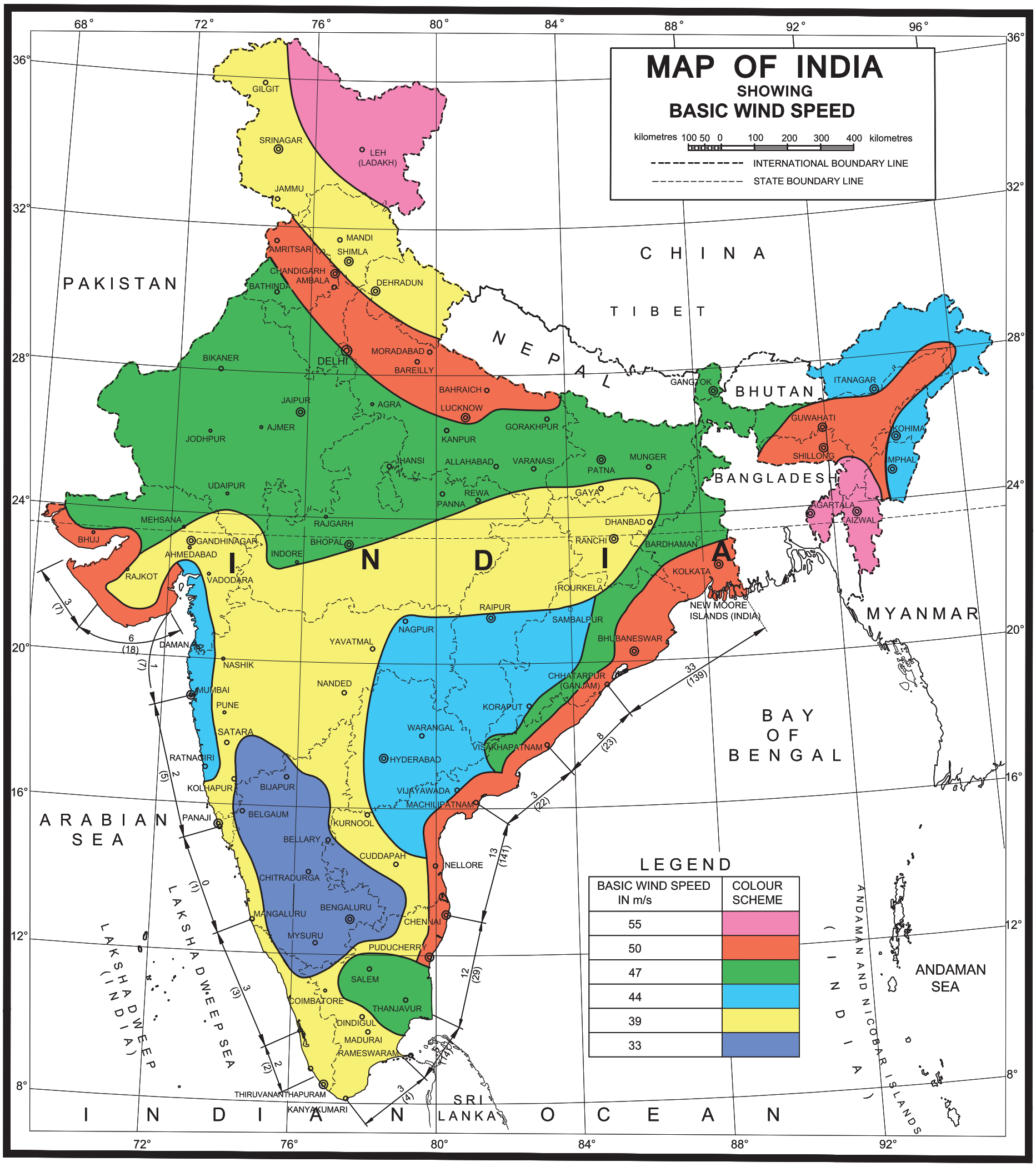
4.4.3.2.1 *Terrain*

Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the orientation of any building or structure may be suitably planned.

Terrain in which a specific structure stands shall be assessed as being one of the following terrain categories:

a) *Category 1* — Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5 m. The equivalent aerodynamic roughness height, ($z_{0,1}$) for this terrain is 0.002 m. Typically this category represents open sea-coasts and flat plains without trees.
b) *Category 2* — Open terrain with well scattered obstructions having heights generally between 1.5 m and 10 m. The equivalent aerodynamic roughness height, ($z_{0,2}$) for this terrain is 0.02 m. This is the criterion for measurement of regional basic wind speeds and represents airfields, open park lands and undeveloped spar-sely built-up outskirts of towns and suburbs. Open land adjacent to sea coast may also be classified as Category 2 due to roughness of large sea waves at high winds.
c) *Category 3* — Terrain with numerous closely spaced obstructions having the size of buildings/structures up to 10 m in height with or without a few isolated tall structures. The equivalent aerodynamic roughness height, ($z_{0,3}$) for this terrain is 0.2 m. This category represents well wooded areas, and shrubs, towns and industrial areas full or partially

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The state boundaries between Uttarakhand & Uttar Pradesh, Bihar & Jharkhand, and Chhattisgarh & Madhya Pradesh have not been verified by the Governments concerned.

The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

The responsibility for the correctness of internal details rests with the publisher.

NOTES

1 The occurrence of a tornado is possible in virtually any part of India. They are particularly more severe in the northern parts of India. The recorded number of these tornados is too small to assign any frequency. The devastation caused by a tornado is due to exceptionally high winds about its periphery, and the sudden reduction in atmospheric pressure at its centre, resulting in an explosive outward pressure on the elements of the structure. The regional basic wind speeds do not include any specific allowance for tornados. It is not the usual practice to allow for the effect of tornados unless special requirements are called for as in the case of important structures such as, nuclear power reactors and satellite communication towers.

2 The total number of cyclonic storms that have struck different sections of east and west coasts are included in Fig. 1, based on available records for the period from 1877 to 1982. The figures above the lines (between the stations) indicate the total number of severe cyclonic storms with or without a core of hurricane winds (speeds above 87 km/h) and the figures in the brackets below the lines indicate the total number of cyclonic storms. Their effect on land is already reflected in the basic wind speeds specified in Fig. 1. These have been included only as additional information.

FIG. 1 BASIC WIND SPEED IN m/s (BASED ON 50-YEARS RETURN PERIOD)

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Table 4 Risk Coefficients for Different Classes of Structures in Different Wind Speed Zones
(*Clause* 4.4.3.1)

Sl No.	Class of Structure	Mean Probable Design Life of Structure in Years	K_1 Factor for Basic Wind Speed (in m/s) of					
			33	39	44	47	50	55
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	All general buildings and structures	50	1.0	1.0	1.0	1.0	1.0	1.0
ii)	Temporary sheds, structures such as those used during construction operations (for example form-work and false work), structures during construction stages and boundary walls	5	0.82	0.76	0.73	0.71	0.70	0.67
iii)	Buildings and structures presenting a low degree of hazard to life and property in the event of failure, such as isolated towers in wooded areas, farm buildings other than residential buildings	25	0.94	0.92	0.91	0.90	0.90	0.89
iv)	Important buildings and structures, such as hospitals, communication buildings/towers, and power plant structures	100	1.05	1.06	1.07	1.07	1.08	1.08

NOTE — The factor k_1 is based on statistical concepts which take into account the degree of reliability required and period of time in years during which there will be exposure to wind, that is, life of the structure. Whatever wind speed is adopted for design purposes, there is always a probability (however small) that it may be exceeded in a storm of exceptional violence; more the period of years over which there is exposure to the wind, more is the probability. Larger return periods ranging from 100 to 1 000 years (implying lower risk level) in association with larger periods of exposure may have to be selected for exceptionally important structures, such as, nuclear power reactors and satellite communication towers. Equation given below may be used in such cases to estimate k_1 factors for different periods of exposure and chosen probability of exceedance (risk level). The probability level of 0.63 is normally considered sufficient for design of buildings and structures against wind effects and the values of k_1 corresponding to this risk level are given above.

$$k_1 = \frac{X_{N,P}}{X_{50,0.63}} = \frac{A - B\left[\ln\left\{-\frac{1}{N}\ln\left(1-P_N\right)\right\}\right]}{A+4B}$$

where

N = mean probable design life of structure in years;
P_N = risk level in N consecutive years (probability that the design wind speed is exceeded at least once in N successive years), nominal value = 0.63;
$X_{N,P}$ = extreme wind speed for given values of N and P_N; and
$X_{50,0.63}$ = extreme wind speed for N = 50 years and P_N = 0.63

A and B have the following values for different basic wind speed zones:

Zone m/s	*A** m/s	*B** m/s
33	23.1 (83.2)	2.6 (9.2)
39	23.3 (84.0)	3.9 (14.0)
44	24.4 (88.0)	5.0 (18.0)
47	24.4 (88.0)	5.7 (20.5)
50	24.7 (88.8)	6.3 (22.8)
55	25.2 (90.8)	7.6 (27.3)

* Values of A and B, in km/h are given within bracket

developed. It is likely that the, next higher category than this will not exist in most design situations and that selection of a more severe category will be deliberate.

d) *Category 4* — Terrain with numerous large high closely spaced obstructions. The equivalent aerodynamic roughness height, ($z_{0,4}$) for this terrain is 2.0 m. This category represents large city centers, generally with obstructions above 25 m and well developed industrial complexes.

4.4.3.2.2 *Variation of wind speed with height in different terrains (k_2)*

Table 5 gives multiplying factors (k_2) by which the basic wind speed given in Fig. 1 shall be multiplied to obtain the wind speed at different heights, in each terrain category.

4.4.3.2.3 *Terrain categories in relation to the direction of wind*

The terrain category used in the design of a structure

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Table 5 Factors to Obtain Design Wind Speed Variation with Height in Different Terrains
(*Clause* 4.4.3.2.2)

Sl No.	Height (z)	Terrain and Height Multiplier (k_2)			
	m	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	1.05	1.00	0.91	0.80
ii)	15	1.09	1.05	0.97	0.80
iii)	20	1.12	1.07	1.01	0.80
iv)	30	1.15	1.12	1.06	0.97
v)	50	1.20	1.17	1.12	1.10
vi)	100	1.26	1.24	1.20	1.20
vii)	150	1.30	1.28	1.24	1.24
viii)	200	1.32	1.30	1.27	1.27
ix)	250	1.34	1.32	1.29	1.28
x)	300	1.35	1.34	1.31	1.30
xi)	350	1.35	1.35	1.32	1.31
xii)	400	1.35	1.35	1.34	1.32
xiii)	450	1.35	1.35	1.35	1.33
xiv)	500	1.35	1.35	1.35	1.34

NOTE — For intermediate values of height (z) in a given terrain category, use linear interpolation.

may vary depending on the direction of wind under consideration. Where sufficient meteorological information is available, the basic wind speed may be varied for specific wind direction.

4.4.3.2.4 *Changes in terrain categories*

The velocity profile for a given terrain category does not develop to full height immediately with the commencement of that terrain category but develop gradually to height (h_x) which increases with the fetch or upwind distance (x).

a) *Fetch and developed Height relationship* — The relation between the developed height (h_x) and the fetch (x) for wind-flow over each of the four terrain categories may be taken as given in Table 6.

b) For structures of heights more than the developed height (h_x) in Table 6, the velocity profile may be determined in accordance with the following:

   1) The less or least rough terrain, or
   2) The method described in Annex D.

4.4.3.3 *Topography (k_3 factor)*

The basic wind speed V_b given in Fig. 1 takes into account the general level of site above sea level. This does not allow for local topographic features such as hills, valleys, cliffs, escarpments, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

Table 6 Fetch and Developed Height Relationship
(*Clause* 4.4.3.2.4)

Sl No.	Fetch (x)	Developed Height (h_x) m			
	km	Terrain Category 1	Terrain Category 2	Terrain Category 3	Terrain Category 4
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.2	12	20	35	60
ii)	0.5	20	30	35	95
iii)	1	25	45	80	130
iv)	2	35	65	110	190
v)	5	60	100	170	300
vi)	10	80	140	250	450
vii)	20	120	200	350	500
viii)	50	180	300	400	500

The effect of topography shall be significant at a site when the upwind slope (θ) is more than about 3°, and below that, the value of k_3 may be taken to be equal to 1.0. The value of k_3 is confined in the range of 1.0 to 1.36 for slopes more than 3°. A method of evaluating the value of k_3 for values more than 1.0 is given in Annex E. It may be noted that the value of k_3 varies with height above ground level, with a maximum near the ground, and reducing to 1.0 at higher levels.

4.4.3.4 *Importance factor for cyclonic region (k_4 factor)*

The east coast of India is relatively more vulnerable for occurrences of severe cyclones. On the west coast, Gujarat is vulnerable for severe cyclones. Studies of wind speed and damage to buildings and structures point to the fact that the speeds given in the basic wind speed map are often exceeded during the cyclones. The effect of cyclonic storms is largely felt in a belt of approximately 60 km width at the coast. In order to ensure better safety of structures in this region (60 km wide on the east coast as well as on the Gujarat Coast), the following values of k_4, as recommended in good practice [6-1(5)] are stipulated as applicable according to the importance of the structure:

	k_4
Structures of post-cyclone importance for emergency services (such as cyclone shelters, hospitals, schools, communication towers, etc)	1.30
Industrial structures	1.15
All other structures	1.00

4.4.4 *Hourly Mean Wind Speed*

The hourly mean wind speed at height z, for different terrains can be obtained as:

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$$\overline{V}_{z,H} = \bar{k}_{2,i} V_b$$

where

$\bar{k}_{2,i}$ = hourly mean wind speed factor for terrain category 'i'

$$= 0.142\,3\left[\ln\left(\frac{z}{z_{0,i}}\right)\right]\left(z_{0,i}\right)^{0.070\,6}$$

The design hourly mean wind speed at height z can be obtained as:

$$\overline{V}_{z,d} = \overline{V}_{z,H}\ k_1 k_3 k_4$$
$$= V_b k_1 \bar{k}_{2,i} k_3 k_4$$

4.4.5 *Turbulence Intensity*

The turbulence intensity variations with height for different terrains can be obtained using the relations given below:

a) *Terrain category 1*

$$I_{z,1} = 0.350\ 7 - 0.053\ 5 \log_{10}\left(\frac{z}{z_{0,1}}\right)$$

b) *Terrain category 2*

$$I_{z,2} = I_{z,1} + \frac{1}{7}\left(I_{z,4} - I_{z,1}\right)$$

c) *Terrain category 3*

$$I_{z,3} = I_{z,1} + \frac{3}{7}\left(I_{z,4} - I_{z,1}\right)$$

d) *Terrain category 4*

$$I_{z,4} = 0.466 - 0.135\ 8 \log_{10}\left(\frac{z}{z_{0,4}}\right)$$

4.4.6 *Off-Shore Wind Velocity*

Cyclonic storms form far away from the sea coast and gradually reduce in speed as they approach the sea coast. Cyclonic storms generally extend up to about 60 km inland after striking the coast. Their effect on land is already reflected in basic wind speeds specified in Fig. 1. The influence of wind speed off the coast up to a distance of about 200 km may be taken as 1.15 times the value on the nearest coast in the absence of any definite wind data. The factor 1.15 shall be used in addition to k_4.

4.5 Wind Pressures and Forces on Buildings/ Structures

4.5.1 *General*

The wind load on a building/structure shall be calculated for,

a) the building/structure as a whole;
b) individual structural elements as roofs and walls; and
c) Individual cladding units including glazing and their fixings.

4.5.2 *Design Wind Pressure*

The wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind speed:

$$p_z = 0.6 V_z^2$$

where

p_z = wind pressure at height z, in N/m^2; and

V_z = design wind speed at height z, in m/s.

The design wind pressure p_d can be obtained as,

$$p_d = K_d K_a K_c p_z$$

where

K_d = wind directionality factor,

K_a = area averaging factor, and

K_c = combination factor [*see* **4.5.3.3.13**].

The value of p_d, however shall not be taken as less than 0.70 p_z.

NOTES

1 The coefficient 0.6 (in SI units) in the above formula depends on a number of factors and mainly on the atmospheric pressure and air temperature. The value chosen corresponds to the average Indian atmospheric conditions.

2 K_d should be taken as 1.0 when considering local pressure coefficients.

4.5.2.1 *Wind directionality factor, K_d*

Considering the randomness in the directionality of wind and recognizing the fact that pressure or force coefficients are determined for specific wind directions, it is specified that for buildings, solid signs, open signs, lattice frameworks, and trussed towers (triangular, square, rectangular) a factor of 0.90 may be used on the design wind pressure. For circular or near-circular forms this factor may be taken as 1.0.

For the cyclone affected regions also the factor K_d shall be taken as 1.0.

4.5.2.2 *Area averaging factor, K_a*

Pressure coefficients given in **4.5.3** are a result of averaging the measured pressure values over a given area. As the area becomes larger, the correlation of measured values decrease and *vice-versa*. The decrease in pressures due to larger areas may be taken into account as given in Table 7.

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Table 7 Area Averaging Factor (K_a)
(*Clause* 4.5.2.2)

Sl No.	Tributary Area (A) m^2	Area Averaging Factor (K_a)[1)]
(1)	(2)	(3)
i)	≤ 10	1.0
ii)	25	0.9
iii)	≥ 100	0.8

[1)] Linear interpolation for intermediate values of tributary area, A is permitted.

4.5.2.2.1 *Tributary area*

a) *Overall structure* — For evaluating loads on frames the tributary area shall be taken as the centre-to-centre distances between frames multiplied by the individual panel dimension in the other direction together with overall pressure coefficients.

b) *Individual elements* — For beam type elements, purlins, etc, the tributary area shall be taken as effective span multiplied by spacing. The effective span is the actual span for mid span and cantilever load effects; and half the sum of adjacent spans for support moments and reactions.

c) For plate type elements, the area of individual plates between supports is taken as the tributary area.

d) For glass cladding, individual pane area of glass is the tributary area.

4.5.3 *Pressure Coefficients*

The pressure coefficients are always given for a particular surface or part of the surface of a building/ structure. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (C_p) and the design wind pressure at the height of the sur-face from the ground. The average values of these pressure coefficients for some building shapes are given in **4.5.3.2** and **4.5.3.3**.

Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building/structure, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been sub-divided and mean pressure coefficients given for each of its several parts.

In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edges of walls and roofs are separately shown. Coefficients for the local effects should only be used for calculation of forces on these local areas affecting roof sheeting, glass panels, and individual cladding units including their fixtures. They should not be used for calculating force on entire structural elements such as roof, walls or structure as a whole.

NOTES

1 The pressure coefficients given in different tables have been obtained mainly from measurements on models in wind tunnels, and the great majority of data available has been obtained in conditions of relatively smooth flow. Where sufficient field data exists as in the case of rectangular buildings, values have been obtained to allow for turbulent flow.

2 In recent years, wall glazing and cladding design has been a source of major concern. Although of less consequence than the collapse of main structures, damage to glass can be hazardous and cause considerable financial losses.

3 For pressure coefficients for structures not covered herein, reference may be made to specialist literature on the subject or advice may be sought from specialists in the subject.

4.5.3.1 *Wind load on individual members*

When calculating the wind load on individual structural elements such as roofs and walls, and individual cladding units and their fittings, it is essential to take account of the pressure difference between opposite faces of such elements or units. For clad structures, it is, therefore, necessary to know the internal pressure as well as the external pressure. Then the wind load, F (in N), acting in a direction normal to the individual structural element or cladding unit is:

$$F = (C_{pe} - C_{pi})\, A\, p_d$$

where

C_{pe} = external pressure coefficient;

C_{pi} = internal pressure coefficient;

A = surface area of structural element or cladding unit, in m^2; and

p_d = design wind pressure, in N/m^2.

NOTES

1 If the surface design pressure varies with height, the surface areas of the structural element may be sub-divided so that the specified pressures are taken over appropriate areas.

2 Positive wind load indicates the force acting towards the structural element and negative away from it.

4.5.3.2 *Internal pressure coefficients*

Internal air pressure in a building depends upon the degree of permeability of cladding to the flow of air. The internal air pressure may be positive or negative depending on the direction of flow of air in relation to openings in the buildings.

a) In the case of buildings where the claddings permit the flow of air with openings not more than about 5 percent of the wall area but where there are no large openings, it is necessary to consider the possibility of the internal pressure being positive or negative. Two design

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conditions shall be examined, one with an internal pressure coefficient of +0.2 and another with an internal pressure coefficient of –0.2.

The internal pressure coefficient is algebraically added to the external pressure coefficient and the analysis which indicates greater distress of the member shall be adopted. In most situations a simple inspection of the sign of external pressure will at once indicate the proper sign of the internal pressure coefficient to be taken for design.

NOTE — The term normal permeability relates to the flow of air commonly afforded by claddings not only through open windows and doors, but also through the slits round the closed windows and doors and through chimneys, ventilators and through the joints between roof coverings, the total open area being less than 5 percent of area of the walls having the openings.

b) *Buildings/structures with medium and large openings* — Buildings/structures with medium and large openings may also exhibit either positive or negative internal pressure depending upon the direction of wind. Buildings/structures with medium openings between about 5 to 20 percent of wall area shall be examined for an internal pressure coefficient of +0.5 and later with an internal pressure coefficient of –0.5, and the analysis which produces greater distress of the member shall be adopted. Buildings/structures with large openings, that is, openings larger than 20 percent of the wall area shall be examined once with an internal pressure coefficient of +0.7 and again with an internal pressure coefficient of –0.7, and the analysis which produces greater distress of the member shall be adopted.

Buildings/structures with one open side or opening exceeding 20 percent of wall area may be assumed to be subjected to internal positive pressure or suction similar to those of buildings with large openings. A few examples of buildings with one side openings are shown in Fig. 2 indicating values of internal pressure coefficients with respect to the direction of wind.

4.5.3.3 *External pressure coefficients*

4.5.3.3.1 *Walls*

The average external pressure coefficient for the walls of clad buildings of rectangular plan shall be as given in Table 8. In addition, local pressure concentration coefficients are also given.

4.5.3.3.2 *Pitched, hipped and monoslope roofs of clad buildings*

The average external pressure coefficients and pressure concentration coefficients for pitched roofs of rectangular clad building shall be as given in Table 9. Where no pressure concentration coefficients are given, the average coefficients shall apply. The pressure coefficients on the underside of any overhanging roof shall be taken in accordance with **4.5.3.3.5**.

NOTES

1 The pressure concentration shall be assumed to act outward (suction pressure) at the ridges, eaves, cornices and 90° corners of roofs.

2 The pressure concentration shall not be included with the net external pressure when computing overall loads.

3 For hipped roofs, pressure coefficients (including local values) may be taken on all the four slopes, as appropriate from Table 9, and be reduced by 20 percent for the hip slope.

For mono slope roofs of rectangular clad buildings, the average pressure coefficient and pressure concentration coefficient for monoslope (lean-to) roofs of rectangular clad buildings shall be as given in Table 10.

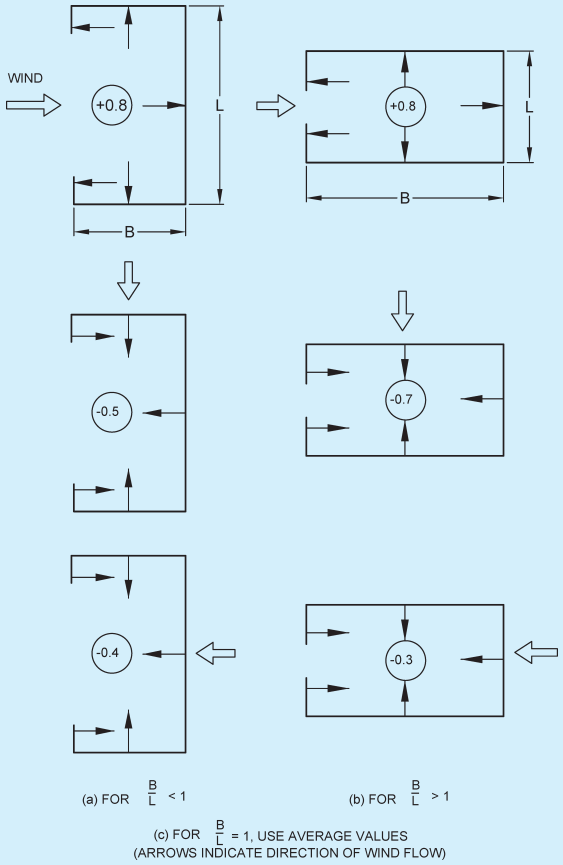
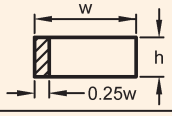
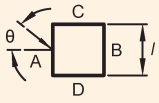
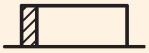
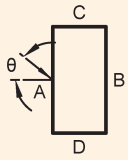
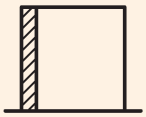
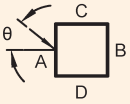
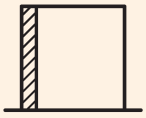
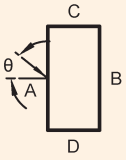
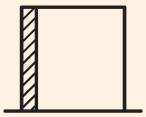
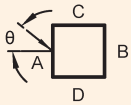
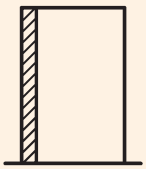
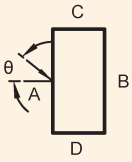
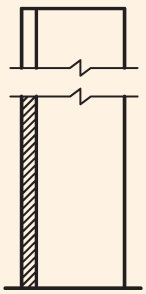
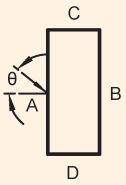


FIG. 2 VALUES OF INTERNAL PRESSURE COEFFICIENTS WITH RESPECT TO THE DIRECTION OF WIND FOR BUILDINGS WITH ONE SIDE OPENINGS

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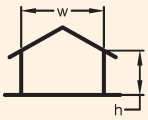
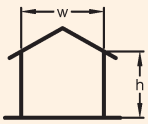
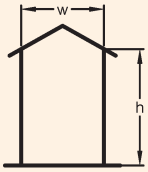
Table 8 External Pressure Coefficients (C_{pe}) for Walls of Rectangular Clad Buildings
(*Clause* 4.5.3.3.1)

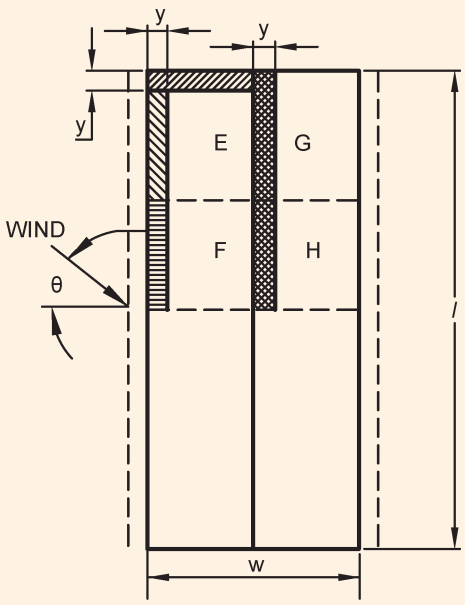
Building Height Ratio	Building Plan Ratio	Elevation	Plan	Wind Angle Θ	C_{pe} for Surface				Local C_{pe}
				Degree	A	B	C	D	
$\frac{h}{w} \leq \frac{1}{2}$	$1 < \frac{l}{w} \leq \frac{3}{2}$			0 90	+ 0.7 - 0.5	- 0.2 - 0.5	- 0.5 + 0.7	- 0.5 - 0.2	- 0.8
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+ 0.7 - 0.5	- 0.25 - 0.5	- 0.6 + 0.7	- 0.6 - 0.1	- 1.0
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$	$1 < \frac{l}{w} \leq \frac{3}{2}$			0 90	+ 0.7 - 0.6	- 0.25 - 0.6	- 0.6 + 0.7	- 0.6 - 0.25	- 1.1
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+ 0.7 - 0.5	- 0.3 - 0.5	- 0.7 + 0.7	- 0.7 - 0.1	- 1.1
$\frac{3}{2} < \frac{h}{w} < 6$	$1 < \frac{l}{w} \leq \frac{3}{2}$			0 90	+ 0.8 - 0.8	- 0.25 - 0.8	- 0.8 + 0.8	- 0.8 - 0.25	- 1.2
	$\frac{3}{2} < \frac{l}{w} < 4$			0 90	+ 0.7 - 0.5	- 0.4 - 0.5	- 0.7 + 0.8	- 0.7 - 0.1	- 1.2
$\frac{h}{w} \geq 6$	$\frac{l}{w} = \frac{3}{2}$			0 90	+ 0.95 - 0.8	- 1.85 - 0.8	- 0.9 + 0.9	- 0.9 - 0.85	1.25
	$\frac{l}{w} = 1.0$			0 90	+ 0.95 - 0.7	- 1.25 - 0.7	- 0.7 + 0.95	- 0.7 - 1.25	1.25
	$\frac{l}{w} = 2$			0 90	+ 0.85 - 0.75	- 0.75 - 0.75	- 0.75 + 0.85	- 0.75 - 0.75	1.25

NOTE — h is the height to eaves or parapet, l is the greater horizontal dimension of a building and w is the lesser horizontal dimension of a building.

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Table 9 External Pressure Coefficients (C_{pe}) for Pitched Roofs of Rectangular Clad Buildings
(*Clause* 4.5.3.3.2)

Building Height Ratio	Roof Angle α Degree	Wind Angle θ 0° EF	Wind Angle θ 0° GH	Wind Angle θ 90° EG	Wind Angle θ 90° FH	Local Coefficients			
$\frac{h}{w} \leq \frac{1}{2}$ 	0	- 0.8	- 0.4	- 0.8	- 0.4	- 2.0	- 2.0	- 2.0	-----
	5	- 0.9	- 0.4	- 0.8	- 0.4	- 1.4	- 1.2	- 1.2	- 1.0
	10	- 1.2	- 0.4	- 0.8	- 0.6	- 1.4	- 1.4		- 1.2
	20	- 0.4	- 0.4	- 0.7	- 0.6	- 1.0			- 1.2
	30	0	- 0.4	- 0.7	- 0.6	- 0.8			- 1.1
	45	+ 0.3	- 0.5	- 0.7	- 0.6				- 1.1
	60	+ 0.7	- 0.6	- 0.7	- 0.6				- 1.1
$\frac{1}{2} < \frac{h}{w} \leq \frac{3}{2}$ 	0	- 0.8	- 0.6	- 1.0	- 0.6	- 2.0	- 2.0	- 2.0	-----
	5	- 0.9	- 0.6	- 0.9	- 0.6	- 2.0	- 2.0	- 1.5	- 1.0
	10	- 1.1	- 0.6	- 0.8	- 0.6	- 2.0	- 2.0	- 1.5	- 1.2
	20	- 0.7	- 0.5	- 0.8	- 0.6	- 1.5	- 1.5		- 1.0
	30	- 0.2	- 0.5	- 0.8	- 0.8	- 1.0			- 1.0
	45	+ 0.2	- 0.5	- 0.8	- 0.8				
	60	+ 0.6	- 0.5	- 0.8	- 0.8				
$\frac{3}{2} < \frac{h}{w} < 6$ 	0	- 0.7	- 0.6	- 0.9	- 0.7	- 2.0	- 2.0	- 2.0	-----
	5	- 0.7	- 0.6	- 0.8	- 0.8	- 2.0	- 2.0	- 1.5	- 1.0
	10	- 0.7	- 0.6	- 0.8	- 0.8	- 2.0	- 2.0	- 1.5	- 1.2
	20	- 0.8	- 0.6	- 0.8	- 0.8	- 1.5	- 1.5		- 1.2
	30	- 1.0	- 0.5	- 0.8	- 0.7	- 1.5			
	40	- 0.2	- 0.5	- 0.8	- 0.7	- 1.0			
	50	+ 0.2	- 0.5	- 0.8	- 0.7				
	60	+ 0.5	- 0.5	- 0.8	- 0.7				



KEY PLAN

$y = h$ or $0.15\ w$

Whichever is the lesser.

NOTES

1 *h* is the height to eaves or parapet and *w* is the lesser horizontal dimension of a building.

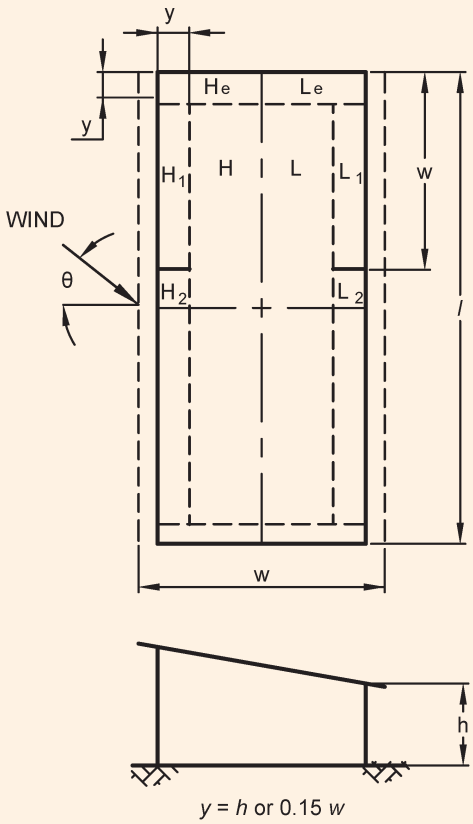
2 Where no local coefficients are given, the overall coefficient apply.

3 For hipped roofs the local coefficient for the hip ridge may be conservatively taken as the appropriate ridge value.

4 *w* and *l* are dimensions between the walls excluding overhangs.

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Table 10 External Pressure Coefficients (C_{pe}) for Monoslope Roofs for Rectangular Clad Buildings $\frac{h}{w} < 2$
(*Clause* 4.5.3.3.2)



y = *h* or 0.15 *w*
Whichever is the lesser.

NOTE :- Area *H* and area *L* refer to the whole quadrant.

Roof Angle α	Wind Angle θ									Local Coefficients (C_{pe})					
	0°		45°		90°		135°		180°						
Degree	*H*	*L*	*H*	*L*	*H* / *L* *	*H* / *L* **	*H*	*L*	*H*	*L*	H_1	H_2	L_1	L_2	H_e	L_e
5	- 1.0	- 0.5	- 1.0	- 0.9	- 1.0	- 0.5	- 0.9	- 1.0	- 0.5	- 1.0	- 2.0	- 1.5	- 2.0	- 1.5	- 2.0	- 2.0
10	- 1.0	- 0.5	- 1.0	- 0.8	- 1.0	- 0.5	- 0.8	- 1.0	- 0.4	- 1.0	- 2.0	- 1.5	- 2.0	- 1.5	- 2.0	- 2.0
15	- 0.9	- 0.5	- 1.0	- 0.7	- 1.0	- 0.5	- 0.6	- 1.0	- 0.3	- 1.0	- 1.8	- 0.9	- 1.8	- 1.4	- 2.0	- 2.0
20	- 0.8	- 0.5	- 1.0	- 0.6	- 0.9	- 0.5	- 0.5	- 1.0	- 0.2	- 1.0	- 1.8	- 0.8	- 1.8	- 1.4	- 2.0	- 2.0
25	- 0.7	- 0.5	- 1.0	- 0.6	- 0.8	- 0.5	- 0.3	- 0.9	- 0.1	- 0.9	- 1.8	- 0.7	- 0.9	- 0.9	- 2.0	- 2.0
30	- 0.5	- 0.5	- 1.0	- 0.6	- 0.8	- 0.5	- 0.1	- 0.6	0	- 0.6	- 1.8	- 0.5	- 0.5	- 0.5	- 2.0	- 2.0

* Applied to length *w* / 2 from wind-ward end.
** Applies to remainder

NOTES
1 *h* is the height of eaves at lower side, *l* is the greater horizontal dimensions of a building and w is the lesser horizontal dimension of a building.
2 *l* and *w* are overall length and width including overhangs.

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4.5.3.3.3 *Canopy roofs with* $(1/4 < h/w < 1$ *and* $1 < L/w < 3)$

The pressure coefficients are given in Tables 11 and 12 separately for monopitch and double pitch canopy roofs such as open-air parking garages, shelter areas, outdoor areas, railway platforms, stadiums and theatres. The coefficients take into account of the combined effect of the wind exerted on and under the roof for all wind directions; the resultant is to be taken normal to the canopy. Where the local coefficients overlap, the greater of the two given values should be taken. However, the effect of partial closures of one side and or both sides, such as those due to trains, buses and stored materials shall be foreseen and taken into account.

The solidity ratio, ϕ, is equal to the area of obstructions under the canopy divided by the gross area under the canopy, both areas normal to the wind direction. $\phi = 0$ represents a canopy with no obstructions underneath. $\phi = 1$ represents the canopy fully blocked with contents to the downwind eaves. Values of C_p for intermediate solidities may be linearly interpolated between these two extremes, and apply upwind of the position of maximum blockage only. For downwind of the position of maximum blockage, the coefficients for $\phi = 0$ may be used.

In addition to the forces due to the pressures normal to the canopy, there will be horizontal loads on the canopy due to the wind pressure on any fascia and to friction over the surface of the canopy. For any wind direction, only the greater of these two forces need to be taken into account. Fascia loads should be calculated on the area of the surface facing the wind, using a force coefficient of 1.3. Frictional drag should be calculated using the coefficients given in **4.5.4.1**.

NOTE — Tables 13 to 18 may be used to get internal and external pressure coefficients for pitches and troughed free roofs for some specific cases for which aspect ratios and roof slopes have been specified. However, while using Tables 13 to 18 any significant departure from it should be investigated carefully. No increase shall be made for local effects except as indicated.

4.5.3.3.4 *Pitched and saw-tooth roofs of multi-span buildings*

For pitched and saw-tooth roofs of multi-span buildings, the external average pressure coefficients shall be as given in Tables 19 and 20, respectively provided that all the spans shall be equal and the height to the eaves shall not exceed the span.

4.5.3.3.5 *Pressure coefficients on overhangs from roofs*

The pressure coefficients on the top over-hanging portion of the roofs shall be taken to be the same as that of the nearest top portion of the non-overhanging portion of the roofs. The pressure coefficients for the underside surface of the over-hanging portions shall be taken as follows and shall be taken as positive, if the overhanging portion is on the windward side:

1) 1.25, if the overhanging slopes downwards;
2) 1.00, if the overhanging is horizontal; and
3) 0.75, if the overhanging slopes upwards.

For overhanging portions on sides other than windward side, the average pressure coefficients on adjoining walls may be used.

4.5.3.3.6 *Curved roofs*

For curved roofs the external pressure coefficients shall be as given in Table 21. Allowance for local effects shall be made in accordance with Table 9. Two values of C_2 have been given for elevated curved roofs. Both the load cases have to be analysed, and critical load effects are to be considered in design.

4.5.3.3.7 *Cylindrical structures*

For the purpose of calculating the wind pressure distribution around a cylindrical structure of circular cross-section, the value of external pressure coefficients given in Table 22 may be used, provided that the Reynolds number is more than 10 000. They may be used for wind blowing normal to the axis of cylinders having axis normal to the ground plane and cylinders having their axis parallel to the ground plane. '*h*' is height of a vertical cylinder or length of a horizontal cylinder. Where there is a free flow of air around both ends, *h* is to be taken as half the length when calculating *h/D* ratio.

In the calculation of resultant load on the periphery of the cylinder, the value of C_{pi} shall be taken into account. For open ended cylinders, C_{pi} shall be taken as follows:

a) – 0.8, where *h*/*D* is more than or equal to 0.3; and
b) – 0.5, where *h*/*D* is less than 0.3.

4.5.3.3.8 *Roofs and bottoms of cylindrical elevated structures*

The external pressure coefficients for roofs and bottoms of cylindrical elevated structures shall be as given in Table 23. Alternately, the pressure distribution given in Fig. 3 can be used together with the force coefficients given in Table 28 for the cylindrical portion.

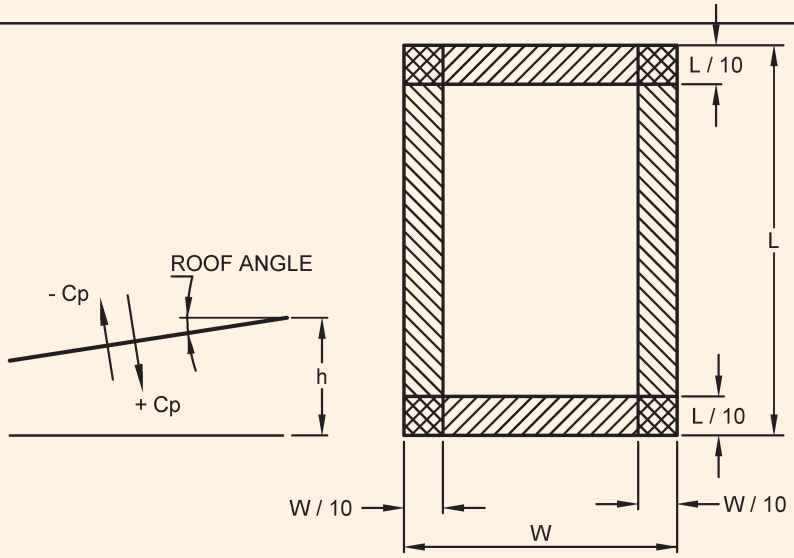
4.5.3.3.9 *Combined roofs*

The average external pressure coefficients for combined roofs are shown in Table 24.

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Table 11 Pressure Coefficients for Monoslope Free Roofs

(*Clause* 4.5.3.3.3)



Roof Angle α Degree	Solidity Ratio Φ	Maximum (Largest + ve) and Minimum (Largest - ve) Pressure Coefficients			
		Overall Coefficients	Local Coefficients		
			▭	▨	▨
0	All values of Φ	+ 0.2	+ 0.5	+ 1.8	+ 1.1
5		+ 0.4	+ 0.8	+ 2.1	+ 1.3
10		+ 0.5	+ 1.2	+ 2.4	+ 1.6
15		+ 0.7	+ 1.4	+ 2.7	+ 1.8
20		+ 0.8	+ 1.7	+ 2.9	+ 2.1
25		+ 1.0	+ 2.0	+ 3.1	+ 2.3
30		+ 1.2	+ 2.2	+ 3.2	+ 2.4
0	Φ = 0	- 0.5	- 0.6	- 1.3	- 1.4
	Φ = 1	- 1.0	- 1.2	- 1.8	- 1.9
5	Φ = 0	- 0.7	- 1.1	- 1.7	- 1.8
	Φ = 1	- 1.1	- 1.6	- 2.2	- 2.3
10	Φ = 0	- 0.9	- 1.5	- 2.0	- 2.1
	Φ = 1	- 1.3	- 2.1	- 2.6	- 2.7
15	Φ = 0	- 1.1	- 1.8	- 2.4	- 2.5
	Φ = 1	- 1.4	- 2.3	- 2.9	- 3.0
20	Φ = 0	- 1.3	- 2.2	- 2.8	- 2.9
	Φ = 1	- 1.5	- 2.6	- 3.1	- 3.2
25	Φ = 0	- 1.6	- 2.6	- 3.2	- 3.2
	Φ = 1	- 1.7	- 2.8	- 3.5	- 3.5
30	Φ = 0	- 1.8	- 3.0	- 3.8	- 3.6
	Φ = 1	- 1.8	- 3.0	- 3.8	- 3.6

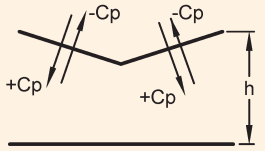
NOTES

1 For monopitch canopies the centre of pressure should be taken to act at 0.3*w* from the windward edge.

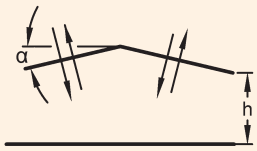
2 *W* and *L* are overall width and length including overhangs.

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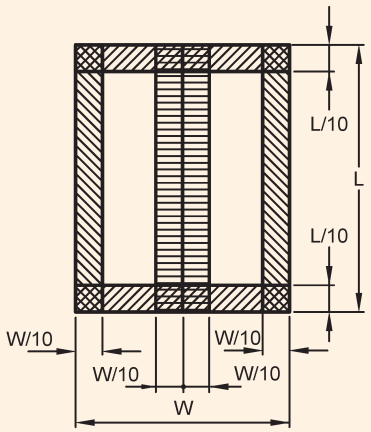
Table 12 Pressure Coefficients for Free Standing Double Sloped Roofs
(*Clause* 4.5.3.3.3)



- ve ROOF ANGLE



+ ve ROOF ANGLE



KEY PLAN

Roof Angle α Degree	Solidity Ratio Φ	Maximum (Largest + ve) and Minimum (Largest - ve) Pressure Coefficients				
		Overall Coefficients	Local Coefficients			
			▭	▨	▨	▬
- 20	All values of Φ	+ 0.7	+ 0.8	+ 1.6	+ 0.6	+ 1.7
- 15		+ 0.5	+ 0.6	+ 1.5	+ 0.7	+ 1.4
- 10		+ 0.4	+ 0.6	+ 1.4	+ 0.8	+ 1.1
- 5		+ 0.3	+ 0.5	+ 1.5	+ 0.8	+ 0.8
+ 5		+ 0.3	+ 0.6	+ 1.8	+ 1.3	+ 0.4
+ 10		+ 0.4	+ 0.7	+ 1.8	+ 1.4	+ 0.4
+ 15		+ 0.4	+ 0.9	+ 1.9	+ 1.4	+ 0.4
+ 20		+ 0.6	+ 1.1	+ 1.9	+ 1.5	+ 0.4
+ 25		+ 0.7	+ 1.2	+ 1.9	+ 1.6	+ 0.5
+ 30		+ 0.9	+ 1.3	+ 1.9	+ 1.6	+ 0.7
- 20	Φ = 0	- 0.7	- 0.9	- 1.3	- 1.6	- 0.6
	Φ = 1	- 0.9	- 1.2	- 1.7	- 1.9	- 1.2
- 15	Φ = 0	- 0.6	- 0.8	- 1.3	- 1.6	- 0.6
	Φ = 1	- 0.8	- 1.1	- 1.7	- 1.9	- 1.2
- 10	Φ = 0	- 0.6	- 0.8	- 1.3	- 1.5	- 0.6
	Φ = 1	- 0.8	- 1.1	- 1.7	- 1.9	- 1.3
- 5	Φ = 0	- 0.5	- 0.7	- 1.3	- 1.6	- 0.6
	Φ = 1	- 0.8	- 1.5	- 1.7	- 1.9	- 1.4
+ 5	Φ = 0	- 0.6	- 0.6	- 1.4	- 1.4	- 1.1
	Φ = 1	- 0.9	- 1.3	- 1.8	- 1.8	- 2.1
+ 10	Φ = 0	- 0.7	- 0.7	- 1.5	- 1.4	- 1.4
	Φ = 1	- 1.1	- 1.4	- 2.0	- 1.8	- 2.4
+ 15	Φ = 0	- 0.8	- 0.9	- 1.7	- 1.4	- 1.8
	Φ = 1	- 1.2	- 1.5	- 2.2	- 1.9	- 2.8
+ 20	Φ = 0	- 0.9	- 1.2	- 1.8	- 1.4	- 2.0
	Φ = 1	- 1.3	- 1.7	- 2.3	- 1.9	- 3.0
+ 25	Φ = 0	- 1.0	- 1.4	- 1.9	- 1.4	- 2.0
	Φ = 1	- 1.4	- 1.9	- 2.4	- 2.1	- 3.0
+ 30	Φ = 0	- 1.0	- 1.4	- 1.9	- 1.4	- 2.0
	Φ = 1	- 1.4	- 2.1	- 2.6	- 2.2	- 3.0

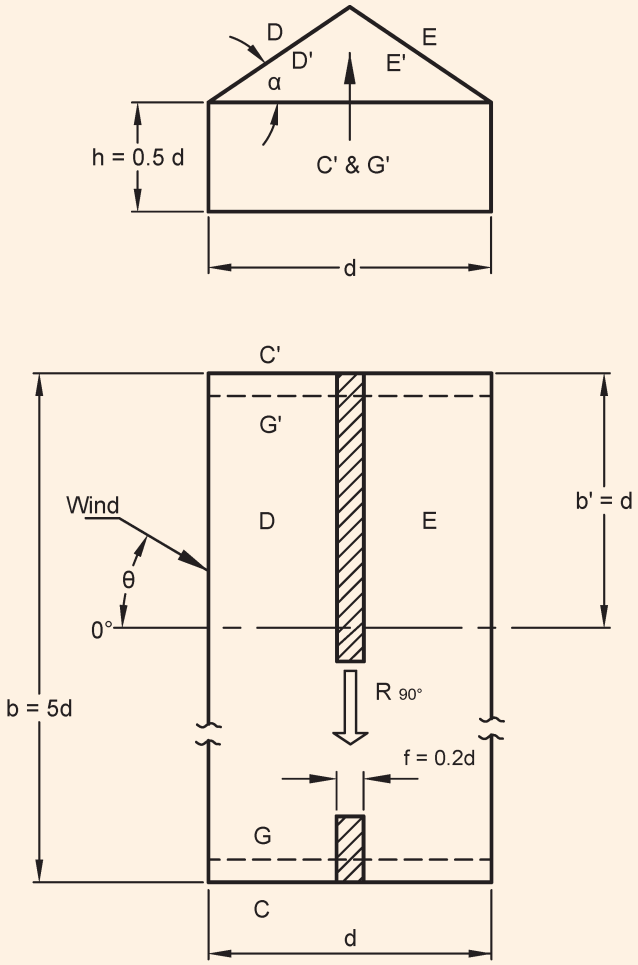
Each slope of a duopitch canopy should be able to withstand forces using both the maximum and the minimum coefficients, and the whole canopy should be able to support forces using one slope at the maximum coefficient with the other slope at the minimum coefficient. For duopitch canopies the centre of pressure should be taken to act at the centre of each slope.

NOTE—*W* and *L* are overall width and length including overhangs.

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Table 13 Pressure Coefficients (Top and Bottom) for Pitched Roofs, Roof Slope, α = 30°

(*Clause* 4.5.3.3.3)



Roof slope α = 30°

θ = 0°- 45°, *D, D', E, E'* full length.

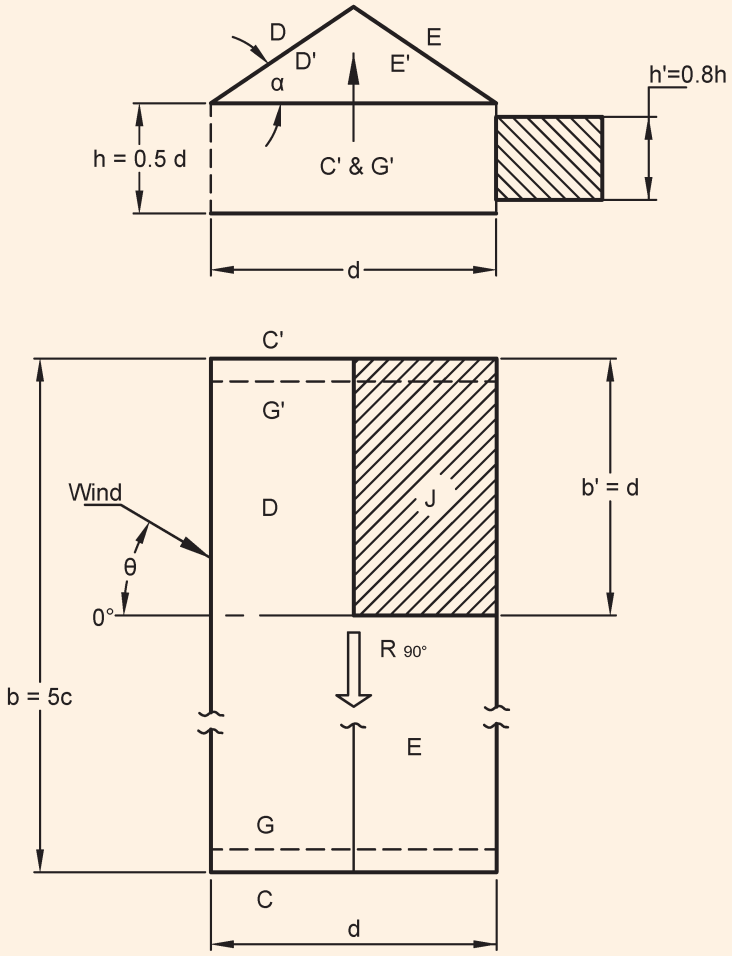
θ = 90°, *D, D', E, E'* part length *b',* thereafter C_p = 0.

Wind Angle θ	Pressure Coefficients, C_p							
	D	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	+ 0.6	- 1.0	- 0.5	- 0.9				
45°	+ 0.1	- 0.3	- 0.6	- 0.3				
90°	- 0.3	- 0.4	- 0.3	- 0.4	- 0.3	+ 0.8	+ 0.3	- 0.4
For all value of θ	For J : C_pTop = 1.0, $C_p$bottom = - 0.2 Tangentially acting friction : $R_{90°} = 0.05\, p_d bd$							

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Table 14 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs, α = 30° With Effects of Train or Stored Material

(*Clause* 4.5.3.3.3)



Roof slope α = 30°

Effects of trains or stored materials.

θ = 0°- 45°, or 135° - 180°, *D, D', E, E'* full length.

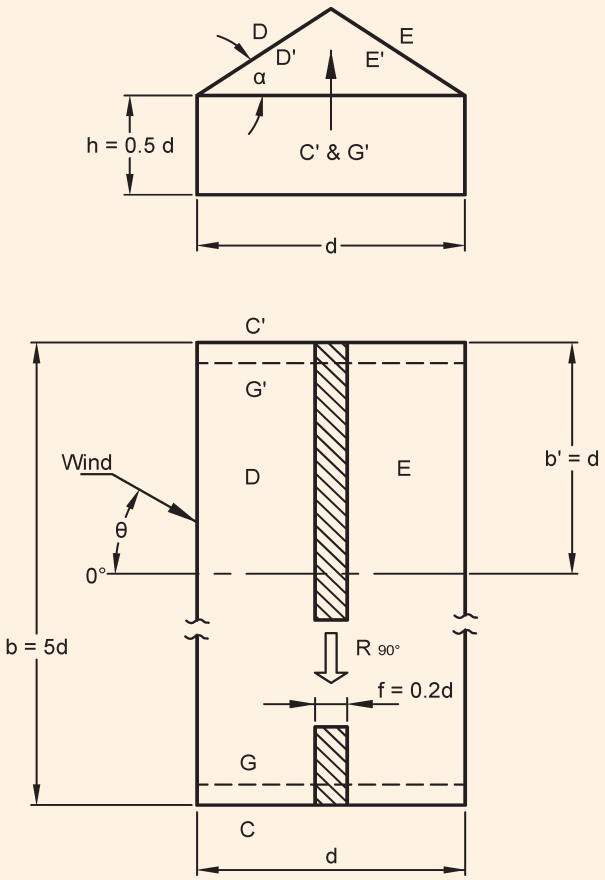
θ = 90°, *D, D', E, E'* part length *b',* thereafter C_p = 0.

Wind Angle θ	Pressure Coefficients, C_p							
	D	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	+ 0.1	+ 0.8	- 0.7	+ 0.9				
45°	- 0.1	+ 0.5	- 0.8	+ 0.5				
90°	- 0.4	- 0.5	- 0.4	- 0.5	- 0.3	+ 0.6	+ 0.3	- 0.4
180°	- 0.3	- 0.6	+ 0.4	- 0.6				
For all value of θ	For J : C_pTop = -1.5, C_p bottom = 0.5 Tangentially acting friction : $R_{90°} = 0.05\, p_d\, bd$							

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Table 15 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs, α = 10°

(*Clause* 4.5.3.3.3)



Roof slope α = 10°

θ = 0°- 45°, *D, D′, E, E′* full length.

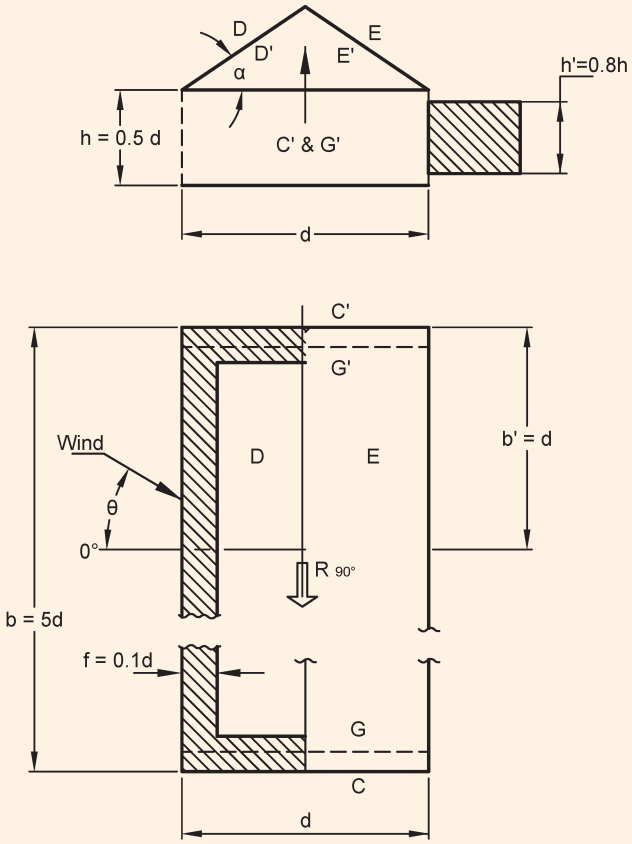
θ = 90°, *D, D′, E, E′* part length *b′*, thereafter C_p = 0.

Wind Angle θ	Pressure Coefficients, C_p							
	D	*D′*	*E*	*E′*	End Surfaces			
					C	*C′*	*G*	*G′*
0°	- 1.0	+ 0.3	- 0.5	+ 0.2				
45°	- 0.3	+ 0.1	- 0.3	+ 0.1				
90°	- 0.3	0	- 0.3	0	- 0.4	+ 0.8	+ 0.3	- 0.6
For all value of θ	For *f* : C_pTop = - 1.0, $C_p$bottom = 0.4 Tangentially acting friction : $R_{90°} = 0.1 p_d\, bd$							

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Table 16 Pressure Coefficients (Top and Bottom) for Pitched Free Roofs $\alpha = 10°$ With Effects of Train or Stored Materials

(*Clause* 4.5.3.3.3)



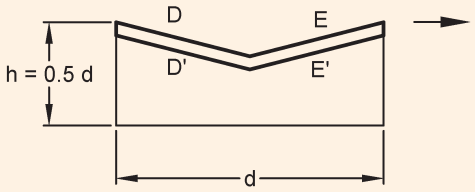
Roof slope $\alpha = 10°$
Effects of trains or stored materials.
$\theta = 0°$- 45°, or 135° - 180°, *D, D', E, E'* full length.
$\theta = 90°$, *D, D', E, E'* part length
b', thereafter $C_p = 0$.

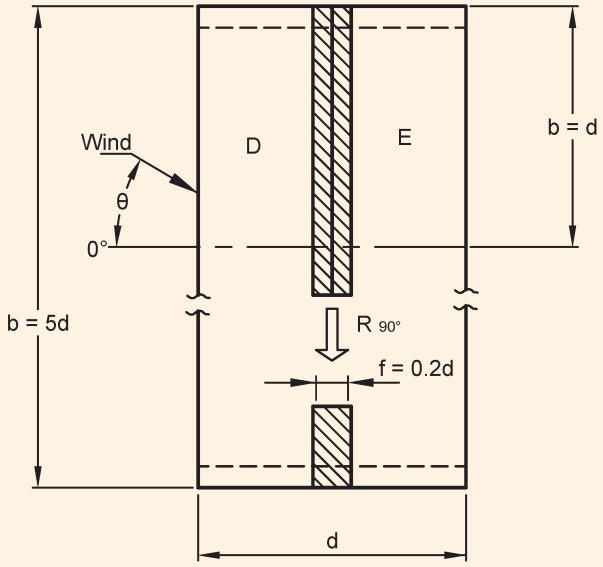
Wind Angle θ	Pressure Coefficients, C_p							
	D	*D'*	*E*	*E'*	End Surfaces			
					C	*C'*	*G*	*G'*
0°	- 1.3	+ 0.8	- 0.6	+ 0.7				
45°	- 0.5	+ 0.4	- 0.3	+ 0.3				
90°	- 0.3	0	- 0.3	0	- 0.4	+ 0.8	+ 0.3	- 0.6
180°	- 0.4	- 0.3	- 0.6	- 0.3				
For all value of θ	For *f* : C_p Top = -1.6, C_p bottom = - 0.9 Tangentially acting friction : $R_{90°} = 0.1 p_d bd$							

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Table 17 Pressure Coefficients for Troughed Free Roofs, $\alpha = 10°$

(*Clause* 4.5.3.3.3)





Roof slope $\alpha = 10°$

$\theta = 0°$- 45°, *D, D′, E, E′* full length.

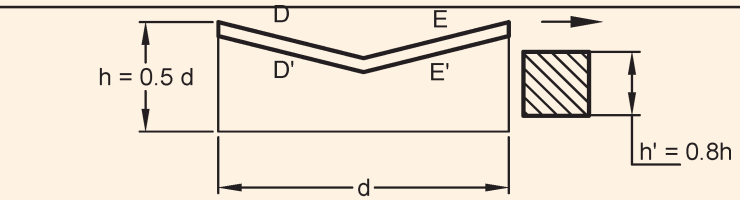
$\theta = 90°$, *D, D′, E, E′* part length *b′,* thereafter $C_p = 0$.

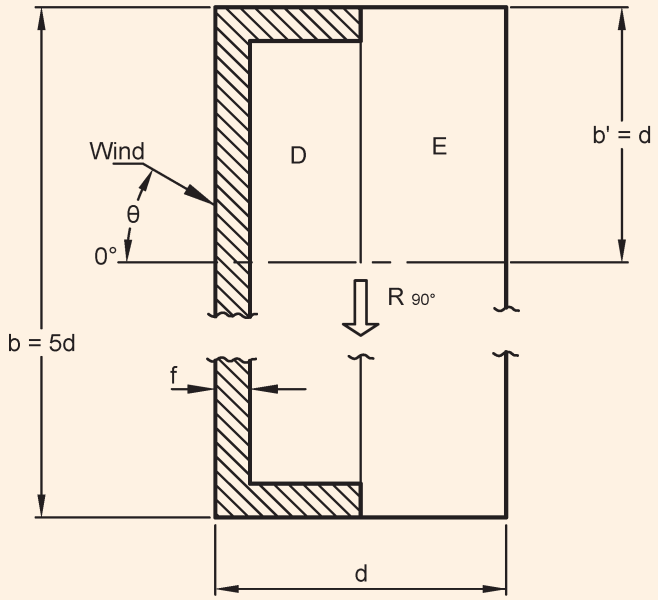
Wind Angle θ	Pressure Coefficients, C_p			
	D	*D′*	*E*	*E′*
0°	+ 0.3	- 0.7	+ 0.2	- 0.9
45°	0	- 0.2	+ 0.1	- 0.3
90°	- 0.1	+ 0.1	- 0.1	+ 0.1
For all value of θ	For *f* : C_pTop = 0.4, $C_p$bottom = - 1.5 Tangentially acting friction : $R_{90°} = 0.1 p_d bd$			

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Table 18 Pressure Coefficients (Top and Bottom) for Troughed Free Roofs $\alpha = 10°$ with Effects of Train or Stored Materials

(*Clause* 4.5.3.3.3)





Roof slope $\alpha = 10°$

Effects of trains or stored materials.

$\theta = 0°$- 45°, or 135° - 180°, *D, D′, E, E′* full length.

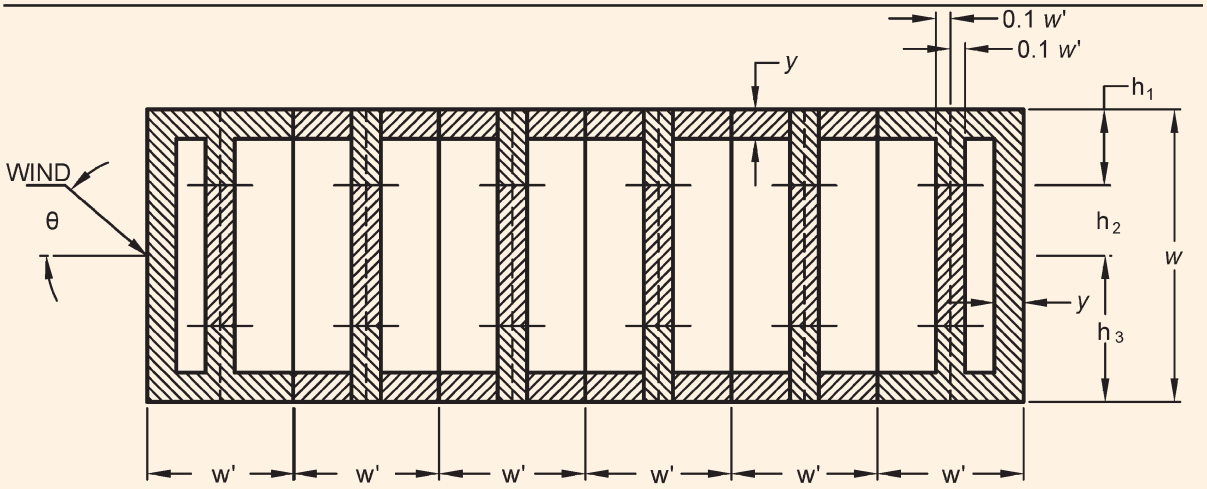
$\theta = 90°$, *D, D′, E, E′* part length *b′,* thereafter $C_p = 0$.

Wind Angle θ	Pressure Coefficients, C_p			
	D	*D′*	*E*	*E′*
0°	- 0.7	+ 0.8	- 0.6	+ 0.6
45°	- 0.4	+ 0.3	- 0.2	+ 0.2
90°	- 0.1	+ 0.1	- 0.1	+ 0.1
180°	- 0.4	- 0.2	- 0.6	- 0.3
For all value of θ	For *f* : C_pTop = -1.1, $C_p$bottom = 0.9 Tangentially acting friction : $R_{90°} = 0.1 p_d bd$			

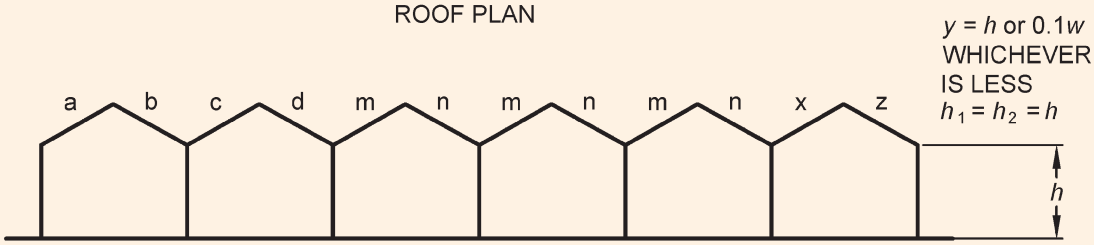
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Table 19 External Pressure Coefficients (C_{pe}) for Pitched Roofs of Multispan Buildings (All Spans Equal) with $h < w'$

(*Clause* 4.5.3.3.4)



ROOF PLAN



SECTION

Roof Angle	Wind Angle	First Span		First Intermediate Span		Other Intermediate Spans		End Span		Local Coefficient	
α Degree	θ Degree	a	b	c	d	m	n	x	z		
5	0	- 0.9	- 0.6	- 0.4	- 0.3	- 0.3	- 0.3	- 0.3	- 0.3		
10		- 1.1	- 0.6	- 0.4	- 0.3	- 0.3	- 0.3	- 0.3	- 0.4		
20		- 0.7	- 0.6	- 0.4	- 0.3	- 0.3	- 0.3	- 0.3	- 0.5	- 2.0	- 1.5
30		- 0.2	- 0.6	- 0.4	- 0.3	- 0.2	- 0.3	- 0.2	- 0.5		
45		+ 0.3	- 0.6	- 0.6	- 0.4	- 0.2	- 0.4	- 0.2	- 0.5		
DISTANCE											
Roof Angle α Degrees		Wind Angle θ Degrees		h_1		h_2		h_3			
up to 45		90		- 0.8		- 0.6		- 0.2			

Frictional drag : When wind angle $\theta = 0°$, horizontal forces due to frictional drag are allowed for in the above values, and

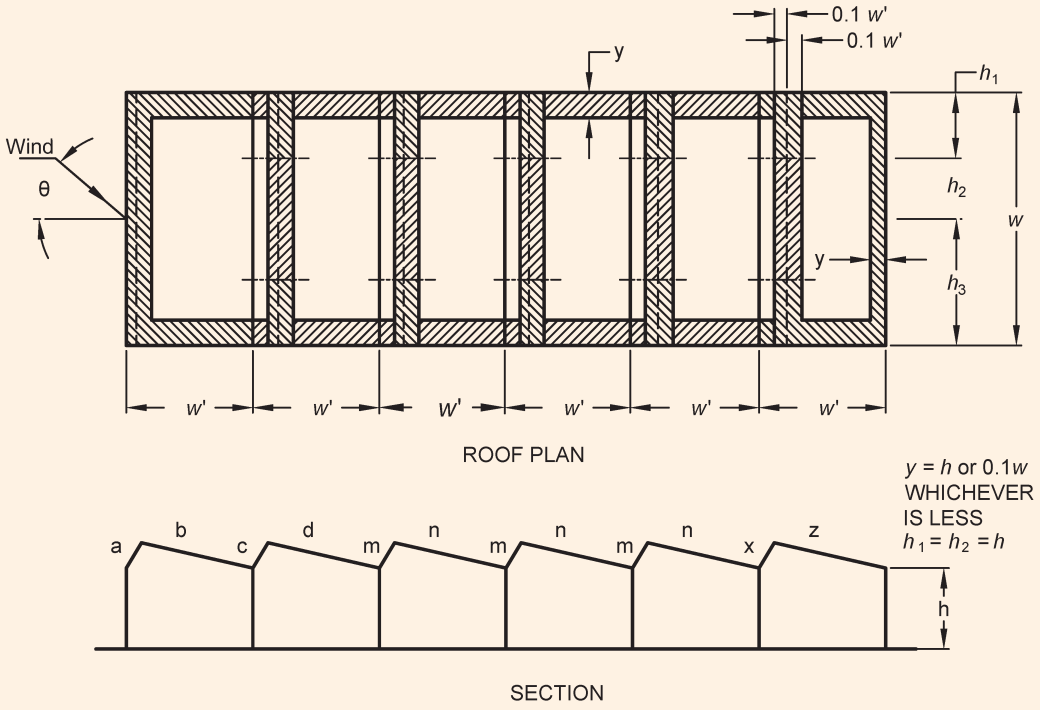
When wind angle $\theta = 90°$, allow for frictional drag in accordance with **4.5.4.1.**

NOTE — Evidence on these buildings is fragmentary and any departure from the cases given should be investigated separately.

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Table 20 External Pressure Coefficients (C_{pe}) for Saw Tooth Roofs of Multispan Buildings (All Spans Equal) with $h < w'$

(*Clause* 4.5.3.3.4)



Wind Angle	First Span		First Intermediate Span		Other Intermediate Spans		End Span		Local Coefficient	
θ Degree	a	b	c	d	m	n	x	z		
0	+ 0.6	- 0.7	- 0.7	- 0.4	- 0.3	- 0.2	- 0.1	- 0.3		
180	- 0.5	- 0.3	- 0.3	- 0.3	- 0.4	- 0.6	- 0.6	- 0.1	- 2.0	- 1.5

DISTANCE			
Wind Angle θ Degree	h_1	h_2	h_3
90	- 0.8	- 0.6	- 0.2
270	Similar to 90°, h_1, h_2, h_3, are needed to be reckoned from the windward edge in the same order		

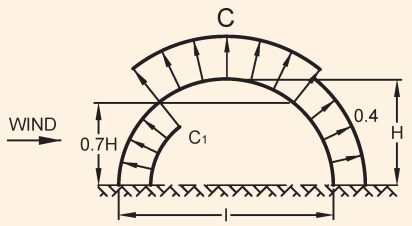
Frictional drag : When wing angle θ = 0°, horizontal forces due to frictional drag are allowed for in the above values, and

When wind angle θ = 90° , allow for frictional drag in accordance with **4.5.4.1.**

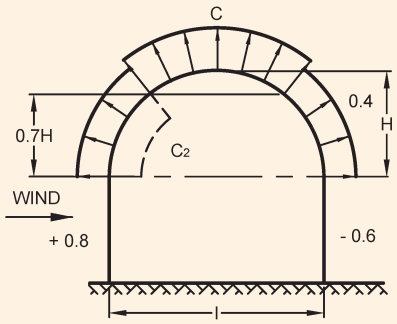
NOTE — Evidence on these buildings is fragmentary and any departure from the cases given should be investigated separately.

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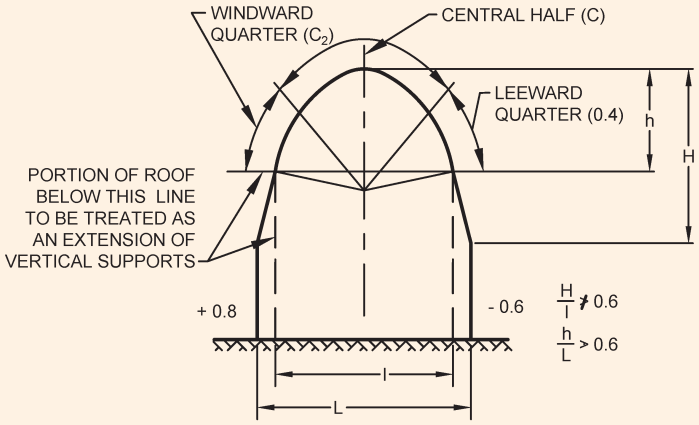
Table 21 External Pressure Coefficients (C_{pe}) for Curved Roofs
(*Clause* 4.5.3.3.6)



a) ROOF SPRINGING FROM GROUND LEVEL



b) ROOF ON ELEVATED STRUCTURE



c) DOUBLE CURVED ROOFS

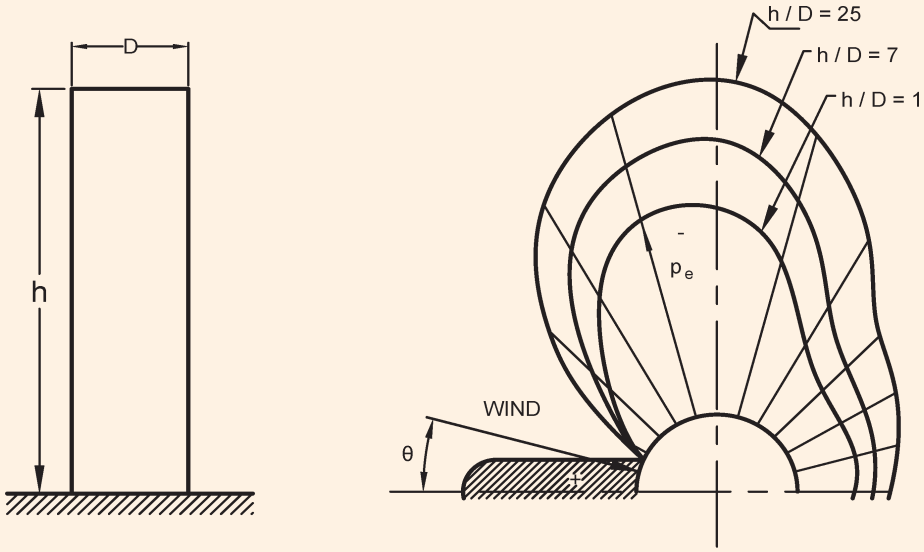
VALUES OF C, C_1 and C_2

H/l	C	C_1	C_2	C_2
0.1	- 0.8	+ 0.1	- 0.8	- 0.05
0.2	- 0.9	+ 0.3	- 0.7	+ 0.1
0.3	- 1.0	+ 0.4	- 0.3	+ 0.15
0.4	- 1.1	+ 0.6	+ 0.4	-
0.5	- 1.2	+ 0.7	+ 0.7	-

NOTE — When the wind is blowing normal to gable ends, C pe may be taken as equal to-0.7 for the full width of the roof over a length of//2 from the gable ends and - 0.5 for the remaining portion.

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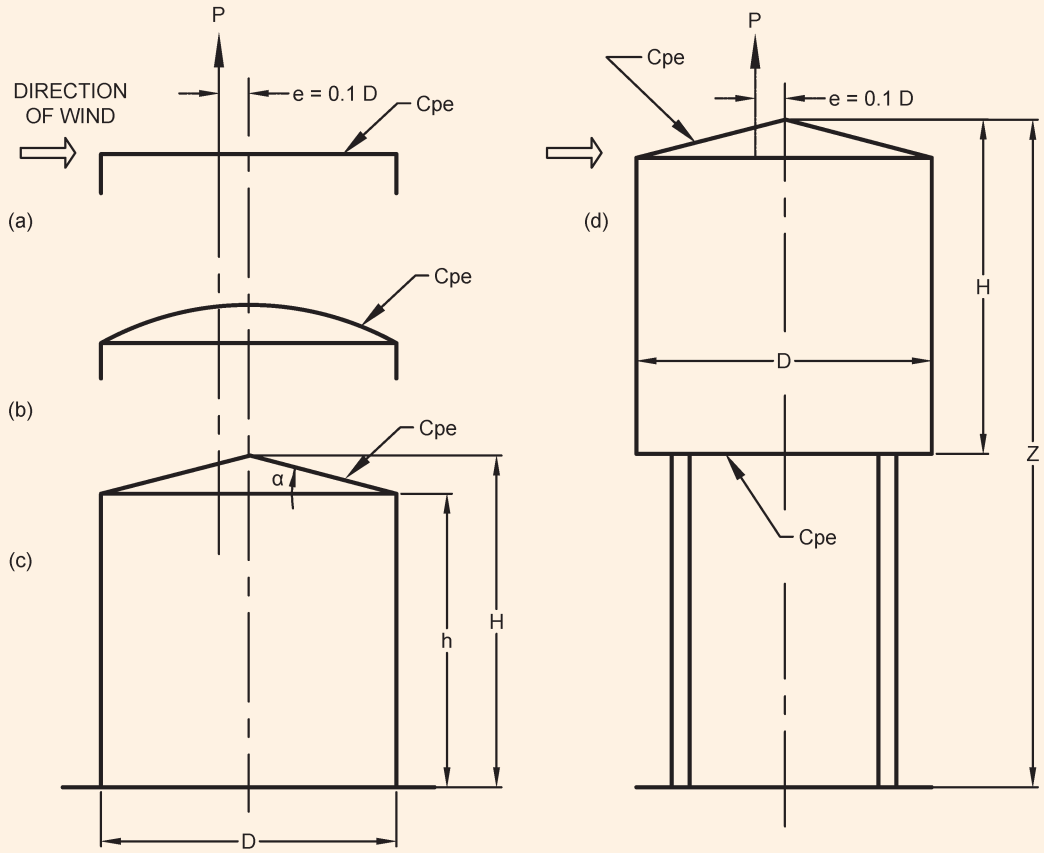
Table 22 External Pressure Coefficients (C_{pe}) around Cylindrical Structures
(*Clause* 4.5.3.3.7)



Position of Periphery, θ DEGREE	Pressure Coefficients (C_{pe})		
	h / *D* = 25	*h* / *D* = 7	*h* / *D* = 1
0	1.0	1.0	1.0
15	0.8	0.8	0.8
30	0.1	0.1	0.1
45	- 0.9	- 0.8	- 0.7
60	- 1.9	- 1.7	- 1.2
75	- 2.5	- 2.2	- 1.6
90	- 2.6	- 2.2	- 1.7
105	- 1.9	- 1.7	- 1.2
120	- 0.9	- 0.8	- 0.7
135	- 0.7	- 0.6	- 0.5
150	- 0.6	- 0.5	- 0.4
165	- 0.6	- 0.5	- 0.4
180	- 0.6	- 0.5	- 0.4

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Table 23 External Pressure Coefficients (C_{pe}) for Roofs and Bottoms of Cylindrical Structures
(*Clause* 4.5.3.3.8)



Coefficients of External Pressure (C_{pe})				
Structure According to Shape				
a, b and c		d		
H / D	Roof	(z / H) - 1	Roof	Bottom
0.5	- 0.65	1.00	- 0.75	- 0.8
1.00	- 1.00	1.25	- 0.75	- 0.7
2.00	- 1.00	1.50	- 0.75	- 0.6

Total force acting on the roof of the structure, $P = 0.785\ D^2\ (C_{pi} - C_{pe})\ p_d$
The resultant of P lies eccentrically, e = 0.1D

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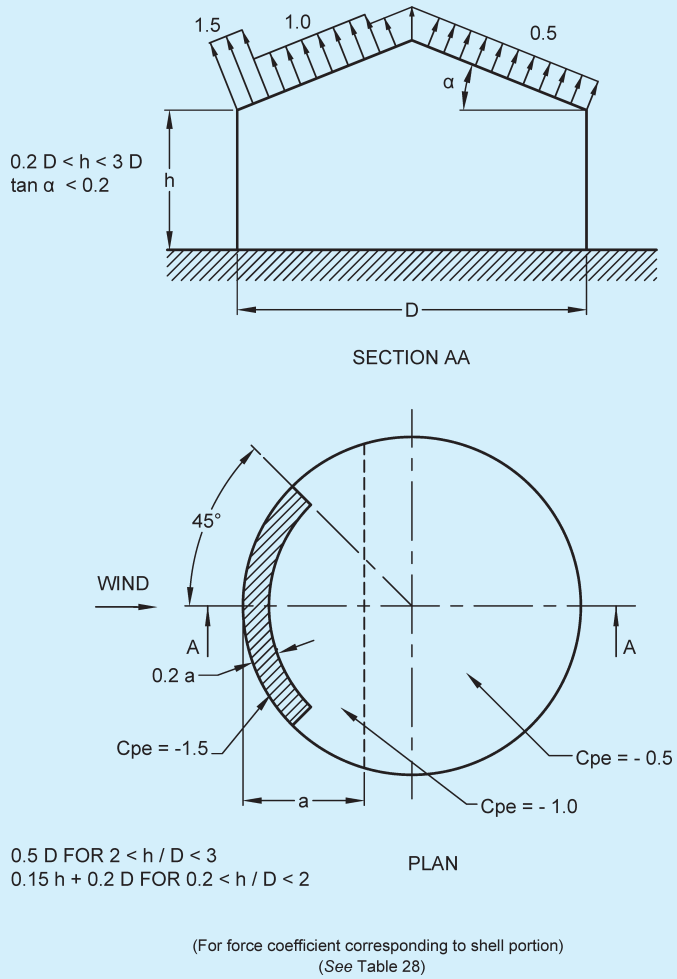


FIG. 3 EXTERNAL PRESSURE COEFFICIENTS ON THE UPPER ROOF SURFACE OF CYLINDRICAL STRUCTURES STANDING ON THE GROUND

4.5.3.3.10 *Roofs with skylight*

The average external pressure coefficients for roofs with skylight are shown in Table 25.

4.5.3.3.11 *Grandstands*

The pressure coefficients on the roof (top and bottom) and rear wall of a typical grandstand roof which is open on three sides are given in Table 26. The pressure coefficients are valid for a particular ratio of dimensions as specified in Table 24 but may be used for deviations up to 20 percent. In general, the maximum wind load occurs when the wind is blowing into the open front of the stand, causing positive pressure under the roof and negative pressure on the roof.

4.5.3.3.12 *Spheres*

The external pressure coefficients for spheres shall be as given in Table 27.

4.5.3.3.13 *Frames*

When taking wind loads on frames of clad buildings it is reasonable to assume that the pressures or suctions inside and outside the structure shall not be fully correlated. Therefore when taking the combined effect of wind loads on the frame, a reduction factor of $K_c = 0.90$ may be used over the building envelope when roof is subjected to pressure and internal pressure is suction, or *vice-versa*.

4.5.4 *Force Coefficients*

The value of force coefficients (C_f) apply to a building or structure as a whole, and when multiplied by the effective frontal area (A_e) of the building or structure and design wind pressure, p_d gives the total wind load (F) on that particular building or structure, expressed as:

$$F = C_f A_e p_d$$

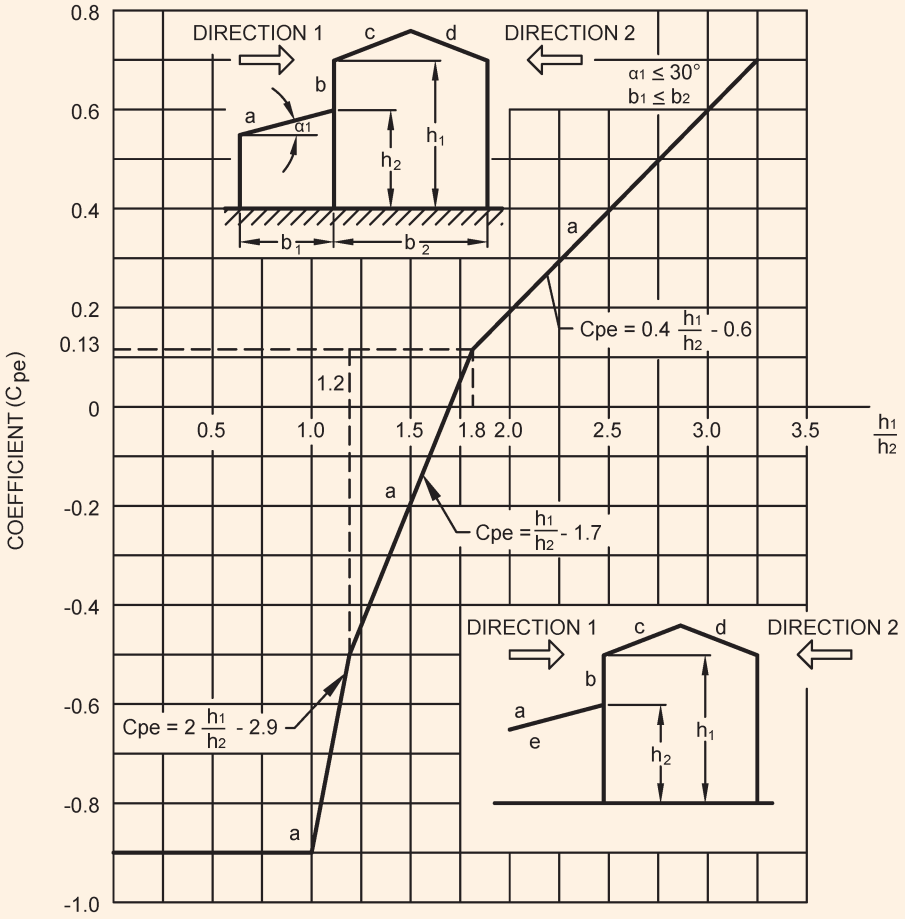
where F is the force acting in a direction specified in the respective tables and C_f is the force coefficient for the building.

NOTES

1 The value of the force coefficient differs for the wind acting

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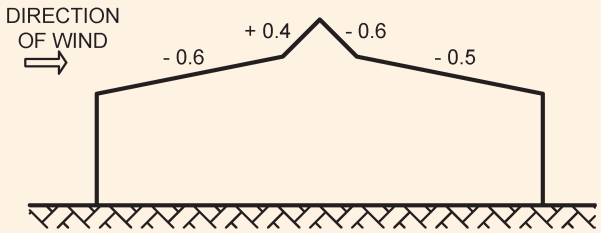
Table 24 External Pressure Coefficients (C_{pe}) for Combined Roofs
(*Clause* 4.5.3.3.9)

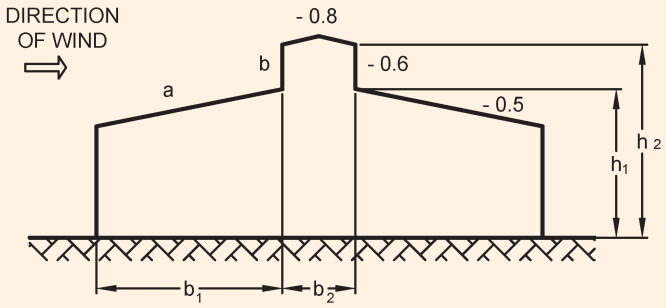


Values of Coefficients (C_{pe})		
Portion	Direction 1	Direction 2
a	From the Diagram	- 0.4
b	$C_{pe} = -0.5, \frac{h_1}{h_2} \leq 1.5$ $C_{pe} = +0.7; \frac{h_1}{h_2} > 1.5$	
c and d	*See* Table 9	
e	*See* **4.5.3.3**	

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Table 25 External Pressure Coefficients (C_{pe}) for Roofs with a Sky Light
(*Clause* 4.5.3.3.10)





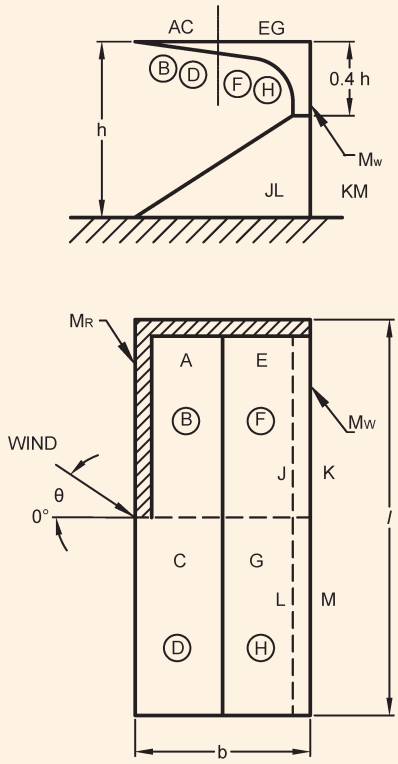
b) ROOFS WITH A SKY LIGHT

Values of Coefficients (C_{pe})			
Portion	$b_1 > b_2$		$b_1 \leq b_2$
	a	*b*	*a* and *b*
C_{pe}	- 0.6	+ 0.7	*See* Table 24 for combined roofs

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Table 26 Pressure Coefficients at Top and Bottom Roof of Grand Stands Open Three Sides (Roof Angle up to 5°)

(*Clause* 4.5.3.3.11)



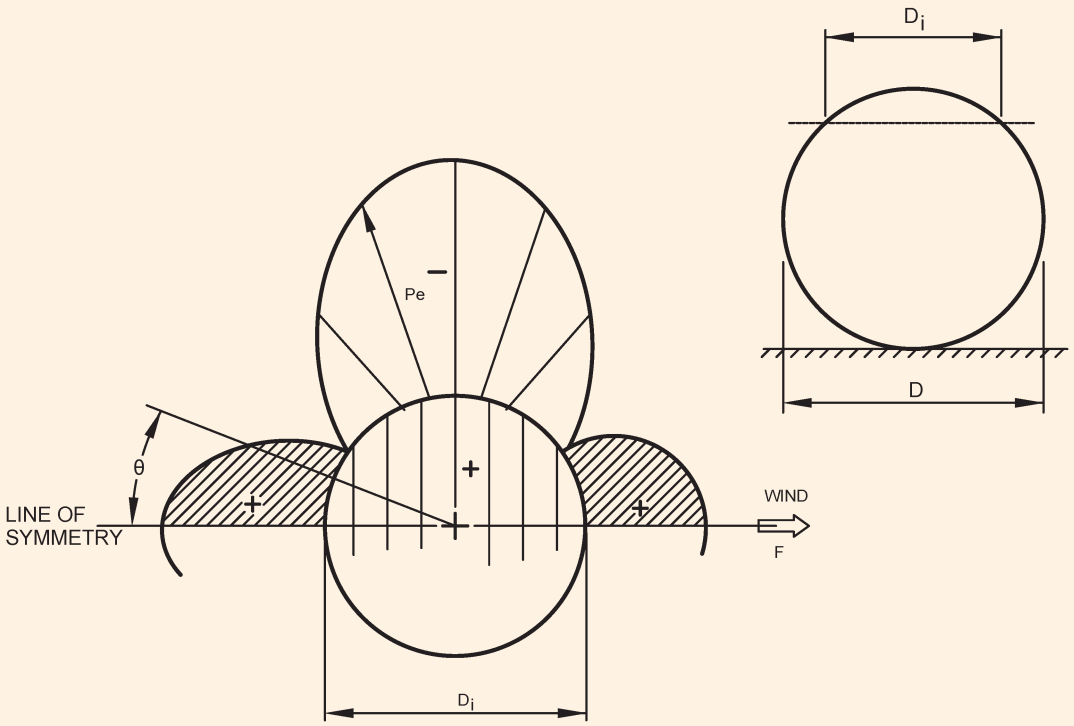
(Shaded area to scale)

Front and Back of Wall				
θ	*J*	*K*	*L*	*M*
0°	+ 0.9	- 0.5	+ 0.9	- 0.5
45°	+ 0.8	- 0.6	+ 0.4	- 0.4
135°	- 1.1	+ 0.6	- 1.0	+ 0.4
180°	- 0.3	+ 0.9	- 0.3	+ 0.9
60°	M_w - Cp of K = - 1.0			
60°	M_w - Cp of J = + 1.0			

Top and Bottom Roof								
θ	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*
0°	- 1.0	+ 0.9	- 1.0	+ 0.9	- 0.7	+ 0.9	+ 0.7	+ 0.9
45°	- 1.0	+ 0.7	- 0.7	+ 0.4	- 0.5	+ 0.8	- 0.5	+ 0.3
135°	- 0.4	- 1.1	- 0.7	- 1.0	- 0.9	- 1.1	- 0.9	- 1.0
180°	- 0.6	- 0.3	- 0.6	- 0.3	- 0.6	- 0.3	- 0.6	- 0.3
45°	'M_R' - Cp (top) = - 2.0							
45°	'M_R' - Cp (bottom) = + 1.0							

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Table 27 External Pressure Coefficients (C_{pe}) Around Spherical Structures
(*Clause* 4.5.3.3.12)



Position of Periphery, θ Degree	C_{pe}
0	+ 1.0
15	+ 0.9
30	+ 0.5
45	- 0.1
60	- 0.7
75	- 1.1
90	- 1.2
105	- 1.0
120	- 0.6
135	- 0.2
150	+ 0.1
165	+ 0.3
180	+ 0.4

on different faces of a building or structure. In order to determine the critical load, the total wind load should be calculated for each wind direction.

2 If surface design pressure varies with height, the surface area of the building/structure may be sub-divided so that specified pressures are taken over appropriate areas.

3 In tapered buildings/structures, the force coefficients shall be applied after sub-dividing the building/structure into suitable number of strips and the load on each strip calculated individually, taking the area of each strip as A_e.

4 For force coefficients for structures not covered herein, reference may be made to specialist literature on the subject or advice may be sought from specialist in the subject.

4.5.4.1 *Frictional drag*

In certain buildings of special shape, a force due to frictional drag shall be taken into account in addition to those loads specified in **4.5.3**. For rectangular clad buildings, this addition is necessary only where the ratio *d*/*h* or *d*/*b* is more than 4. The frictional drag force, *F'*, in the direction of the wind is given by the following

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formulae:

If $h \leq b$, $F' = C_f' (d - 4h)\, b\, p_d + C'_f (d - 4h)\, 2h\, p_d$, and

If $h > b$, $F' = C_f' (d - 4b)\, b\, p_d + C'_f (d - 4b)\, 2h\, p_d$

The first term in each case gives the drag on the roof and the second on the walls. The C_f' has the following values:

a) 0.01 for smooth surfaces without corrugations or ribs across the wind direction,
b) 0.02 for surfaces with corrugations across the wind direction, and
c) 0.04 for surfaces with ribs across the wind direction.

For other buildings, the frictional drag has been indicated, where necessary, in the tables of pressure coefficients and force coefficients.

4.5.4.2 *Force coefficients for clad buildings*

4.5.4.2.1 *Clad buildings of uniform section*

The overall force coefficients for rectangular clad buildings of uniform section with flat roofs in uniform flow shall be as given in Fig. 4 and for other clad buildings of uniform section (without projections, except where otherwise shown) shall be as given in Table 28.

NOTE — Structures that are in the supercritical flow regime, because of their size and design wind velocity, may need further calculation to ensure that the greatest loads do not occur at some wind speed below the maximum, when the flow will be sub-critical.

The coefficients are for buildings without projections, except where otherwise shown.

In Table 28, $\overline{V}_d b$ is used as an indication of the airflow regime.

4.5.4.2.2 *Buildings of circular shapes*

Force coefficients for buildings of circular cross-section shapes shall be as given in Table 28. However, more precise estimation of force coefficients for circular shapes of infinite length can be obtained from Fig. 5 taking into account the average height of surface roughness ε. When the length is finite the values obtained from Fig. 5 shall be reduced by the multiplication factor K (*see also* Table 31 and Annex F).

4.5.4.2.3 *Free standing walls and hoardings*

Force coefficients for free standing walls and hoardings shall be as given in Table 29.

To allow for oblique winds, the design shall also be checked for net pressure normal to the surface varying linearly from a maximum of 1.7 C_f at the windward edge to 0.44 C_f at the leeward edge.

The wind load on appurtenances and supports for hoardings shall be accounted for separately by using the appropriate net pressure coefficients. Allowance shall be made for shielding effects of one element on another.

4.5.4.2.4 *Solid circular shapes mounted on a surface*

The force coefficients for solid circular shapes mounted on a surface shall be as given in Table 30.

4.5.4.3 *Force coefficients for unclad buildings*

4.5.4.3.1 This Section applies to permanently unclad buildings and to frameworks of buildings while temporarily unclad. In the case of buildings whose surfaces are well-rounded, such as those with elliptic, circular or oval cross-sections, the total force can be more at a wind speed much less than maximum due to transition in the nature of boundary layer on them. Although this phenomenon is well known in the case of circular cylinders, the same phenomenon exists in the case of many other well-rounded structures, and this possibility shall be checked.

4.5.4.3.2 *Individual members*

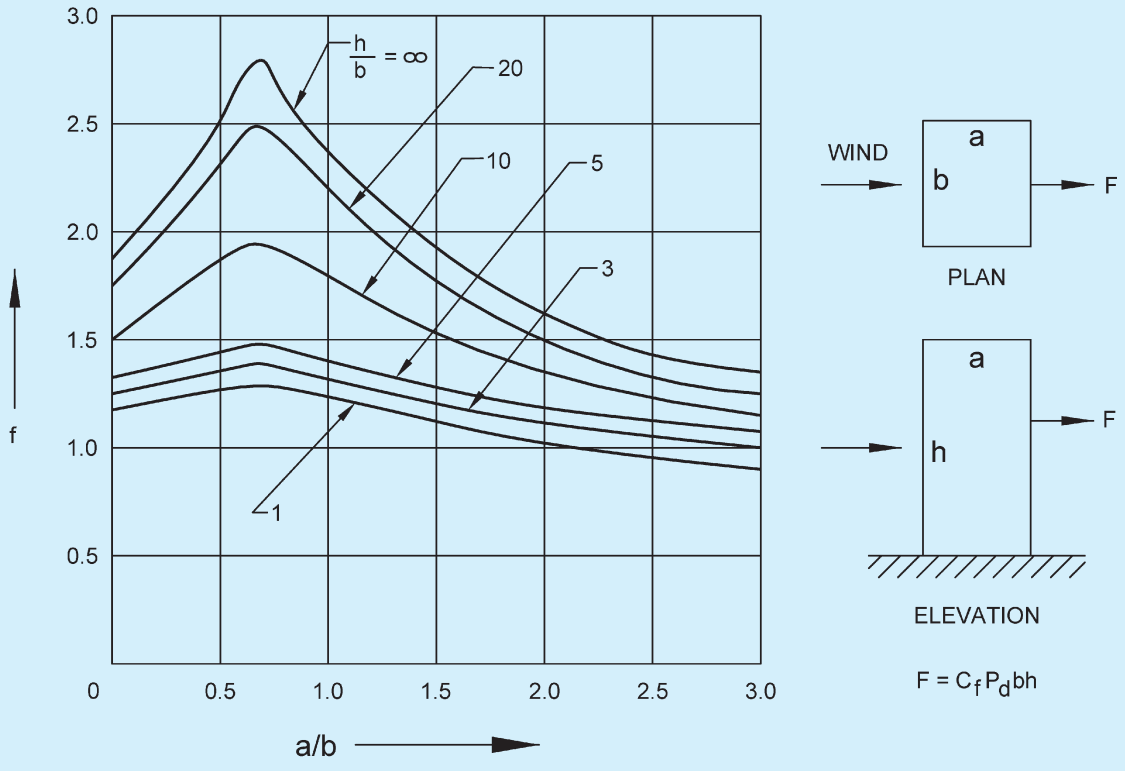
a) The force coefficient given in Table 32 refers to members of infinite length. For members of finite length, the coefficients should be multiplied by a factor K that depends on the ratio l/b where l is the length of the member and b is the width across the direction of wind. Table 31 gives the required values of K. The following special cases shall be noted while estimating K:
   1) When any member abuts on to a plate or wall in such a way that free flow of air around that end of the member is prevented, then the ratio of l/b shall be doubled for the purpose of determining K; and
   2) When both ends of a member are so obstructed, the ratio shall be taken as infinity for the purpose of determining K.
b) *Flat-sided members* — Force coefficients for wind normal to the longitudinal axis of flat-sided structural members shall be as given in Table 32.

   The force coefficients are given for two mutually perpendicular directions relative to a reference axis on the structural member. They are denoted by C_{fn} and C_{ft} and give the forces normal and transverse, respectively to the reference plane as shown in Table 32.

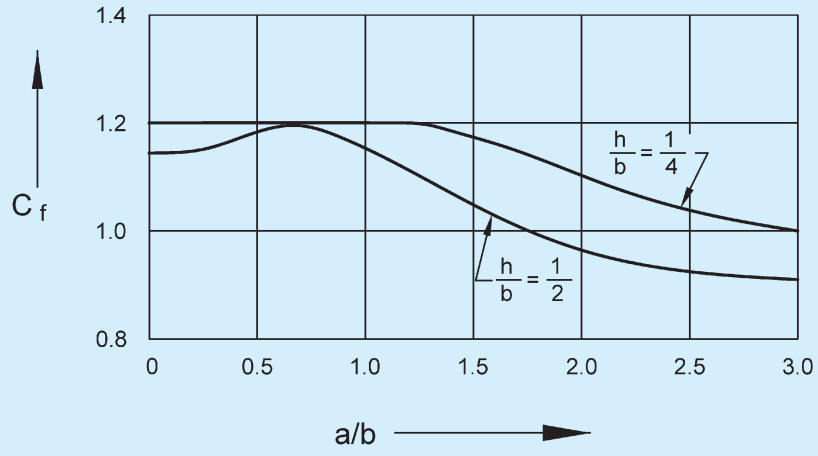
   Normal force, $F_n = (C_{fn}\, p_d\, K) / b$

   Transverse force, $F_t = (C_{ft}\, p_d\, K) / b$

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4A VALUES OF C_f *Versus* a / b for $h / b \geq 1$



4B VALUES OF C_f *Versus* a / b for $h / b < 1$

FIG. 4 FORCE COEFFICIENT FOR RECTANGULAR CLAD BUILDING IN UNIFORM FLOW

c) *Circular sections* — Force coefficients for members of circular section shall be as given in Table 28 (*see also* Annex F).

d) Force coefficients for wires and cables shall be as given in Table 33 according to the diameter (D), the design wind speed (V_d) and the surface roughness.

4.5.4.3.3 *Single frames*

Force coefficients for a single frame having either,

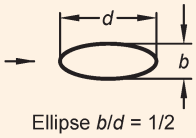
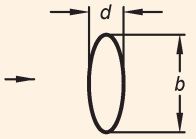
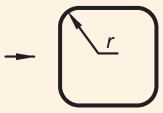
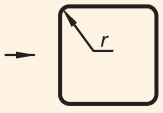
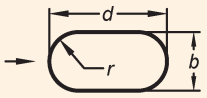
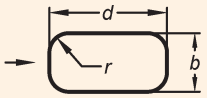
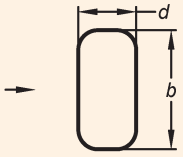
a) all flat sided members; or

b) all circular members in which all the members of the frame have either,

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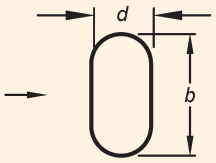
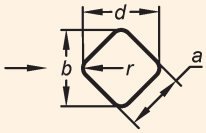
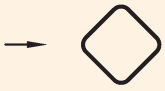
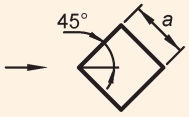
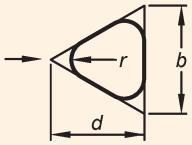
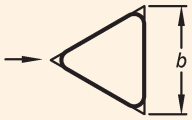
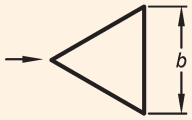
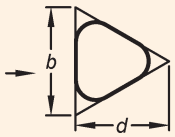
Table 28 Force Coefficients, C_f for Clad Buildings of Uniform Section (Acting in the Direction of Wind)

(*Clause* 4.5.4.2.1)

Plan Shape	$\overline{V}_d$ b m^2/s	C_f for Height / Breadth Ratio						
		Up to 1/2	1	2	5	10	20	∞
 *See also* Annex D	All Surfaces < 6	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	Rough or with Projection ≥ 6							
	Smooth ≥ 6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 Ellipse *b*/*d* = 1/2	< 10	0.5	0.5	0.5	0.5	0.6	0.6	0.7
	≥ 10	0.2	0.2	0.2	0.2	0.2	0.2	0.2
 Ellipse *b*/*d* = 2	< 8	0.8	0.8	0.9	1.0	1.1	1.3	1.7
	≥ 8	0.8	0.8	0.9	1.0	1.1	1.3	1.5
 *b*/*d* = 1 *r*/*b* = 1/3	< 4	0.6	0.6	0.6	0.7	0.8	0.8	1.0
	≥ 4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
 *b*/*d* = 1 *r*/*b* = 1/6	< 10	0.7	0.8	0.8	0.9	1.0	1.0	1.3
	≥ 10	0.5	0.5	0.5	0.5	0.6	0.6	0.6
 *b*/*d* = 1/2 *r*/*b* = 1/2	< 3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
	≥ 3	0.2	0.2	0.2	0.2	0.3	0.3	0.3
 *b*/*d* = 1/2 *r*/*b* = 1/6	All values	0.5	0.5	0.5	0.5	0.6	0.6	0.7
 *b*/*d* = 2 *r*/*b* = 1/12	All values	0.9	0.9	1.0	1.1	1.2	1.5	1.9

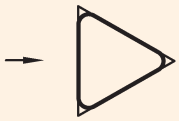
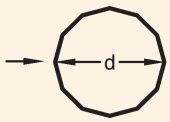
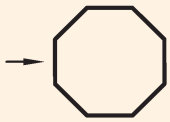
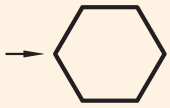
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Table 28 — (*Continued*)

Plan Shape	$\overline{V}_d b$ m^2/s	C_f for Height / Breadth Ratio						
		Up to 1/2	1	2	5	10	20	∞
 *b/d* = 2 *r/b* = 1/4	< 6	0.7	0.8	0.8	0.9	1.0	1.2	1.6
	≥ 6	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 *r/a* = 1/3	< 10	0.8	0.8	0.9	1.0	1.1	1.3	1.5
	≥ 10	0.5	0.5	0.5	0.5	0.5	0.6	0.6
 *r/a* = 1/12	All values	0.9	0.9	0.9	1.1	1.2	1.3	1.6
 *r/a* = 1/48	All values	0.9	0.9	0.9	1.1	1.2	1.3	1.6
 *r/b* = 1/4	< 11	0.7	0.7	0.7	0.8	0.9	1.0	1.2
	≥ 11	0.4	0.4	0.4	0.4	0.5	0.5	0.5
 *r/b* = 1/12	All values	0.8	0.8	0.8	1.0	1.1	1.2	1.4
 *r/b* = 1/48	All values	0.7	0.7	0.8	0.9	1.0	1.1	1.3
 *r/b* = 1/4	< 8	0.7	0.7	0.8	0.9	1.0	1.1	1.3
	≥ 8	0.4	0.4	0.4	0.4	0.5	0.5	0.5

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Table 28 — (*Concluded*)

Plan Shape	$\overline{V}_d$ b m^2/s	C_f for Height / Breadth Ratio						
		Up to 1/2	1	2	5	10	20	∞
 1/48 < *r*/*b* < 1/12	All values	1.2	1.2	1.2	1.4	1.6	1.7	2.1
 12 Sided Polygon	< 12	0.7	0.7	0.8	0.9	1.0	1.1	1.3
	≥ 12	0.7	0.7	0.7	0.7	0.8	0.9	1.1
 Octagon	All values	1.0	1.0	1.1	1.2	1.2	1.3	1.4
 Hexagon	All values	1.0	1.1	1.2	1.3	1.4	1.4	1.5

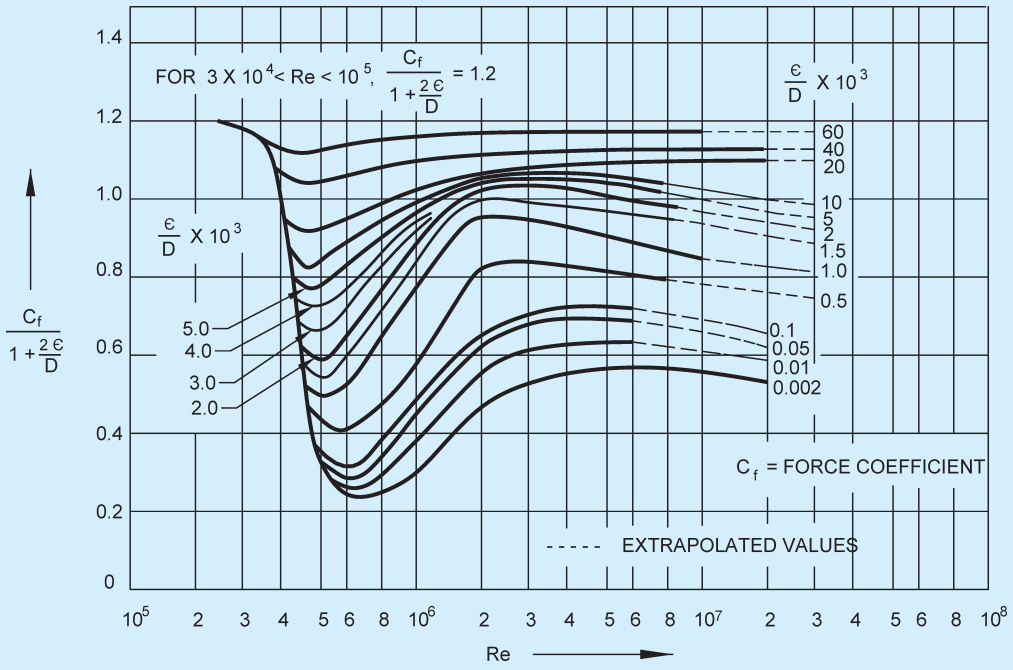
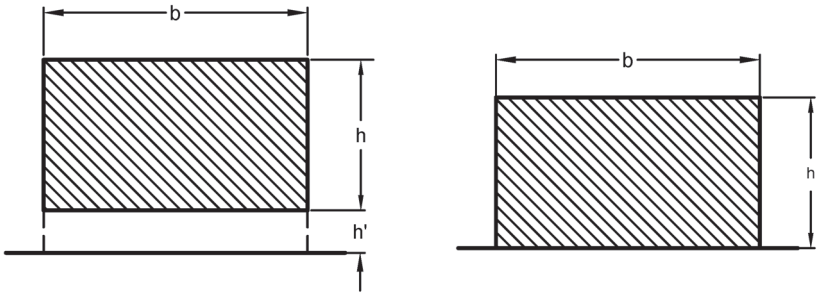


FIG. 5 VARIATION OF $\frac{C_f}{1+\frac{2\epsilon}{D}}$ WITH $R_e > 3 \times 10^4$ FOR CIRCULAR SECTIONS

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Table 29 Force Coefficients, C_f for Low Walls or Hoardings (< 15m High)
(*Clause* 4.5.4.2.3)



(WIND NORMAL TO FACE)

Width to Height Ratio, *b*/*h*		Force Coefficient C_f
Wall Above Ground	Wall on Ground	
From 0.5 TO 6	From 1 TO 12	1.2
10	20	1.3
16	32	1.4
20	40	1.5
40	80	1.75
60	120	1.8
80 or More	160 or More	2.0

1) $D\overline{V}_d$ less than 6 m²/s; or
2) $D\overline{V}_d$ more than or equal to 6 m²/s.

shall be as given in Table 31 according to the type of the member, the diameter (D), the design hourly mean wind speed ($D\overline{V}_d$) and the solidity ratio (Φ).

Force coefficients for a single frame not complying with the above requirements shall be calculated as follows:

$$C_f = \gamma\, C_{f\,super} + (1-\gamma)\frac{A_{circ\,sub}}{A_{sub}} C_{f\,sub} + (1-\gamma)\frac{A_{flat}}{A_{sub}} C_{f\,flat}$$

where

$C_{f\,super}$ = force coefficient for the supercritical circular members as given in Table 34 or Annex F,

$C_{f\,sub}$ = force coefficient for subcritical circular members as given in Table 34 or Annex F,

$C_{f\,flat}$ = force coefficient for the flat sided members as given in Table 34,

$A_{circ\,sub}$ = effective area of subcritical circular members,

A_{flat} = effective area of flat-sided members,

A_{sub} = $A_{circ\,sub} + A_{flat}$,

γ = (Area of the frame in a supercritical flow)/ A_e, and

A_e = Effective frontal area.

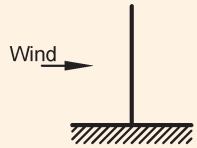
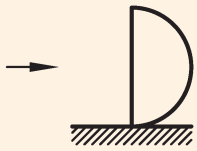
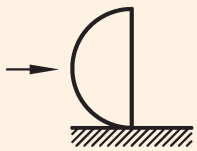
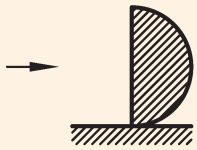
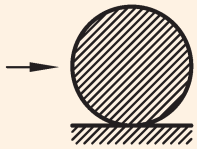
4.5.4.3.4 *Multiple frame buildings*

This Section applies to structures having two or more parallel frames where the windward frames may have a shielding effect upon the frames to leeward side. The windward frame and any unshielded parts of other frames shall be calculated in accordance with **4.5.4.3.3**, but the wind load on the parts of frames that are sheltered should be multiplied by a shielding factor which is dependent upon the solidity ratio of the windward frame, the types of members comprising the frame and the spacing ratio of the frames. The values of the shielding factors are given in Table 35.

Where there are more than two frames of similar geometry and spacing, the wind load on the third and subsequent frames should be taken as equal to that on

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Table 30 Force Coefficients, C_f for Solid Shapes Mounted on a Surface
(*Clause* 4.5.4.2.4)

Side Elevation	Description of Shape	C_f
	Circular disc	1.2
	Hemispherical bowl	1.4
	Hemispherical bowl	0.4
	Hemispherical solid	1.2
	Spherical solid	0.5 FOR V_z D < 7 0.2 FOR V_z D ≥ 7

the second frame. The loads on the various frames shall be added to obtain total load on the structure.

a) The frame spacing ratio is equal to the centre-to-centre distance between the frames, beams or girders divided by the least overall dimension of the frames, beam or girder measured in a direction normal to the direction of wind. For triangular framed structures or rectangular framed structures diagonal to the wind, the spacing ratio should be calculated from the mean distance between the frames in the direction of the wind.

b) Effective solidity ratio, Φe:

Φe = Φ for flat-sided members.

Φe is to be obtained from Fig. 6 for members of circular cross-sections.

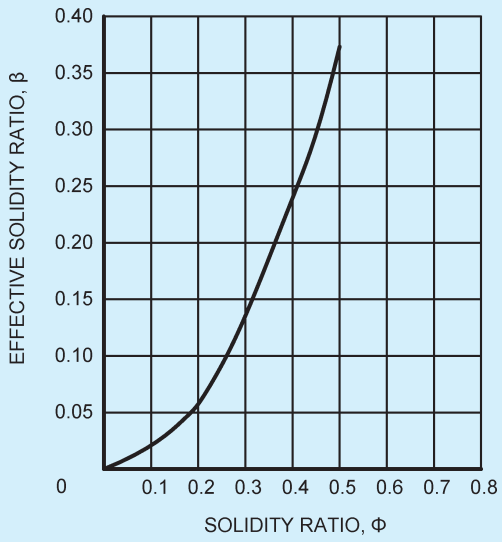


FIG. 6 EFFECTIVE SOLIDITY RATIO, FOR CIRCULAR SECTION MEMBERS

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Table 31 Reduction Factor *K* for Individual Members

[*Clauses* 4.5.4.2.2 *and* 4.5.4.3.2(a)]

Sl No.	*l* / *b* or *l* / *D*	2	5	10	20	40	50	100	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Circular cylinder, subcritical flow	0.58	0.62	0.68	0.74	0.82	0.87	0.98	1.00
ii)	Circular cylinder, supercritical flow ($D\overline{V_d} \geq 6$ m^2/s)	0.80	0.80	0.82	0.90	0.98	0.99	1.00	1.00
iii)	For plate perpendicular to wind ($b\overline{V_d} \geq 6$ m^2/s)	0.62	0.66	0.69	0.81	0.87	0.90	0.95	1.00

4.5.4.3.5 *Lattice towers*

a) Force coefficient for lattice towers of square or equilateral triangle section with flat- sided members for wind blowing against any face shall be as given in Table 36.

b) For square lattice towers with flat-sided members the maximum load, which occurs when the wind blows into a corner, shall be taken as 1.2 times the load for the wind blowing against a face.

c) For equilateral triangle lattice towers with flat-sided members, the load may be assumed to be constant for any inclination of wind to a face.

d) Force coefficients for lattice towers of square section with circular members, all in the same flow regime, may be as given in Table 37.

e) Force coefficients for lattice towers of equi-lateral-triangle section with circular members all in the same flow regime may be as given in Table 38.

4.5.4.3.6 *Tower appurtenances*

The wind loading on tower appurtenances, such as ladders, conduits, lights, elevators, etc, shall be calculated using appropriate net pressure coefficients for these elements. Allowance may be made for shielding effect from other elements.

4.6 Interference Effects

4.6.1 *General*

Wind interference is caused by modification in the wind characteristics produced by the obstruction caused by an object or a building/structure in the path of the wind. If such wind strikes another structure, the wind pressures usually get enhanced, though there can also be some shielding effect between two very closely spaced buildings/structures. The actual phenomenon is too complex to justify generalization of the wind forces/ pressures produced due to interference which can only be ascertained by detailed wind tunnel/CFD studies. However, some guidance can be provided for the purpose of preliminary design. To account for the effect of interference, a wind interference factor (IF) has been introduced as a multiplying factor to be applied to the design wind pressure/force. Interference effects can be more significant for tall buildings. The interference factor is defined as the ratio between the enhanced pressure/force in the grouped configuration to the corresponding pressure/force in isolated configuration. Since the values of IF can vary considerably based on building geometry and location, the given values of IF are a kind of median values and are meant only for preliminary design estimates. The designer is advised that for assigning values of IF for final design particularly for tall buildings, specialist literature be consulted or a wind tunnel study carried out.

4.6.2 *Roof of Buildings of Height Less than 20 m*

Maximum increase in wind force on the roof due to interference from similar buildings in case of closely spaced buildings of height less than 20 m with flat roofs may be up to 25 percent for centre-to-centre distance (x) between the buildings of 5 times the dimension (b) of the interfering building normal to the direction of wind (*see* Fig. 7). Interference effect beyond 20b may be considered to be negligible. For intermediate spacing linear interpolation may be used.

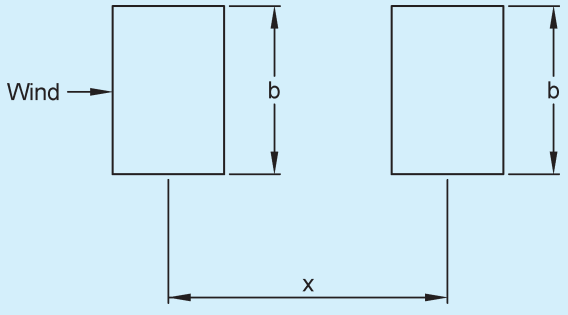


FIG. 7 BUILDINGS IN TANDEM CAUSING INTERFERENCE EFFECT

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Table 32 Force Coefficients, C_f for Individual Structural Members of Infinite Length

[*Clause* 4.5.4.3.2(b)]

θ Degree	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
0	+ 1.9	+ 0.95	+ 1.8	+ 1.8	+ 1.75	+ 0.1	+ 1.6	0	+ 2.05	0
45	+ 1.8	+ 0.8	+ 2.1	+ 1.8	+ 0.85	+ 0.85	+ 1.5	- 0.1	+ 1.85	+ 0.6
90	+ 2.0	+ 1.7	- 1.9	- 1.0	+ 0.1	+ 1.75	- 0.95	+ 0.7	0	+ 0.6
135	- 1.8	- 0.1	- 2.0	+ 0.3	- 0.75	+ 0.75	- 0.5	+ 1.05	- 1.6	+ 0.4
180	- 2.0	+ 0.1	- 1.4	- 1.4	- 1.75	- 0.1	- 1.5	0	- 1.8	0

θ Degree	C_{fn}	C_{ft}	C_{fn}	C_{ft}	C_{fn}	C_{ft}
0	+ 1.4	0	+ 2.05	0	+ 1.6	0	+ 2.0	0	+ 2.0	0
45	+ 1.2	+ 1.6	+ 1.95	+ 0.6	+ 1.5	+ 1.5	+ 1.8	+ 0.1	+ 1.55	+ 1.55
90	0	+ 2.2	+ 0.5	+ 0.9	0	+ 1.9	0	+ 0.1	0	+ 2.0

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Table 33 Force Coefficients, C_f for Wires and Cables (l/D = 100)
[*Clause* 4.5.4.3.2(b)]

Sl No.	Flow Regime	Force Coefficient, C_f for			
		Smooth Surface	Moderately Smooth Wire (Galvanized or Painted)	Fine Stranded Cables	Thick Stranded Cables
(1)	(2)	(3)	(4)	(5)	(6)
i)	$\overline{DV}_d < 6$ m²/s	1.2	1.2	1.2	1.3
ii)	$\overline{DV}_d \geq 6$ m²/s	0.5	0.7	0.9	1.1

Table 34 Force Coefficients for Single Frames
(*Clause* 4.5.4.3.3)

Sl No.	Solidity Ratio, Φ	Force Coefficient, C_f for		
		Flat Sided Members	Circular Sections	
			Subcritical Flow ($\overline{DV}_d < 6$ m²/s)	Super Critical Flow ($\overline{DV}_d \geq 6$ m²/s)
(1)	(2)	(3)	(4)	(5)
i)	0.1	1.9	1.2	0.7
ii)	0.2	1.8	1.2	0.8
iii)	0.3	1.7	1.2	0.8
iv)	0.4	1.7	1.1	0.8
v)	0.5	1.6	1.1	0.8
vi)	0.75	1.6	1.5	1.4
vii)	1.00	2.0	2.0	2.0

NOTE — Linear interpolation between the values is permitted.

Table 35 Shielding Factor, η for Multiple Frames
(*Clause* 4.5.4.3.4)

Sl No.	Effective Solidity Ratio, Φe	Frame Spacing Ratio				
		< 0.5	1.0	2.0	4.0	> 8.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	0	1.0	1.0	1.0	1.0	1.0
ii)	0.1	0.9	1.0	1.0	1.0	1.0
iii)	0.2	0.8	0.9	1.0	1.0	1.0
iv)	0.3	0.7	0.8	1.0	1.0	1.0
v)	0.4	0.6	0.7	1.0	1.0	1.0
vi)	0.5	0.5	0.6	0.9	1.0	1.0
vii)	0.7	0.3	0.6	0.8	0.9	1.0
viii)	1.0	0.3	0.6	0.6	0.8	1.0

NOTE — Linear interpolation between the values is permitted.

Table 36 Overall Force Coefficients for Towers Composed of Flat Sided Members
[*Clause* 4.5.4.3.5(a)]

Sl No.	Solidity Ratio, Φ	Force Coefficient For	
		Square Towers	Equilateral Triangular Towers
(1)	(2)	(3)	(4)
i)	< 0.1	3.8	3.1
ii)	0.2	3.3	2.7
iii)	0.3	2.8	2.3
iv)	0.4	2.3	1.9
v)	0.5	2.1	1.5

Table 37 Overall Force Coefficients for Square Towers Composed of Circular Members
[*Clause* 4.5.4.3.5 (d)]

Sl No.	Solidity Ratio of Front Face Φ	Force Coefficient For			
		Subcritical Flow ($\overline{DV}_d < 6$ m²/s)		Super Critical Flow ($\overline{DV}_d \geq 6$ m²/s)	
		Onto Face	Onto Corner	Onto Face	Onto Corner
(1)	(2)	(3)	(4)	(5)	(6)
i)	< 0.05	2.4	2.5	1.1	1.2
ii)	0.1	2.2	2.3	1.2	1.3
iii)	0.2	1.9	2.1	1.3	1.6
iv)	0.3	1.7	1.9	1.4	1.6
v)	0.4	1.6	1.9	1.4	1.6
vi)	0.5	1.4	1.9	1.4	1.6

4.6.3 *Tall Buildings*

Based on studies on tall rectangular buildings, Fig. 8 gives various zones of interference. The interference factor (IF), which needs to be considered as a multiplication factor for wind loads corresponding to isolated building, may be assumed as follows for preliminary estimate of the wind loads under interference caused by another interfering tall building of same or more height located at different zones Z1 to Z4 as shown in Fig. 8:

Zone	Z1	Z2	Z3	Z4
IF	1.35	1.25	1.15	1.07

The interference effect due to buildings of height less than one-third of the height of the building under consideration may be considered to be negligible while for interference from a building of intermediate height, linear interpolation may be used between one-third and full height.

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Table 38 Overall Force Coefficients for Equilateral Triangular Towers Composed of Circular Members
[*Clause* 4.5.4.3.5(e)]

Sl No.	Solidity Ratio of Front Face Φ	Force Coefficient For	
		Subcritical Flow ($\bar{D}V_d < 6$ m²/s)	Super Critical Flow ($\bar{D}V_d \geq 6$ m²/s)
		All Wind Directions	All Wind Directions
(1)	(2)	(3)	(4)
i)	< 0.05	1.8	0.8
ii)	0.1	1.7	0.8
iii)	0.2	1.6	1.1
iv)	0.3	1.5	1.1
v)	0.4	1.5	1.1
vi)	0.5	1.4	1.2

4.7 Dynamic Effects

4.7.1 *General*

Flexible slender structures and structural elements shall be investigated to ascertain the importance of wind induced oscillations or excitations in along wind and across wind directions.

In general, the following guidelines may be used for examining the problems of wind-induced oscillations:

a) Buildings and closed structures with a height to minimum lateral dimension ratio of more than about 5.0, or

b) Buildings and structures whose natural frequency in the first mode is less than 1.0 Hz.

Any building or structure which satisfies either of the above two criteria shall be examined for dynamic effects of wind.

NOTES

1 The fundamental time period (T), in second, may either be established by experimental observations on similar buildings or calculated by any rational method of analysis. In the absence of such data, T may be determined as follows for multi-storeyed buildings:

a) For moment resistant frames without bracings or shear walls resisting the lateral loads,

$$T = 0.1\,n$$

where

n = number of storeys, including basement storeys.

b) For all others,

$$T = \frac{0.09H}{\sqrt{d}}$$

where

H = total height of the main structures of the building, in m; and

d = maximum base dimension of building in metre in a direction parallel to the applied wind force.

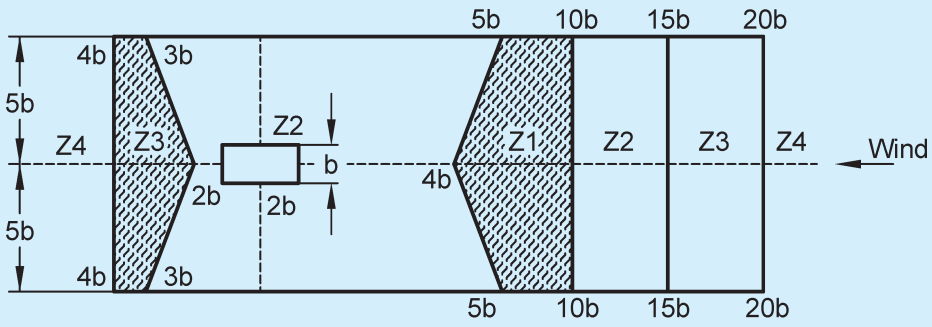
2 If preliminary studies indicate that wind-induced oscillations are likely to be significant, investigations should be pursued with the aid of analytical methods or if necessary, by means of wind tunnel tests on models.

3 Across-wind motions may be due to lateral gustiness of the wind, unsteady wake flow (for example, vortex shedding), negative aerodynamic damping or due to a combination of these effects. These cross-wind motions may become critical in the design of tall buildings/structures.

4 Motions in the direction of wind (also known as buffeting) are caused by fluctuating wind force associated with gust. The excitation depends on gust energy available at the resonant frequency.

5 The eddies shed from an upstream body may intensify motion in the direction of the wind and may also affect cross-wind motion.

6 The designer should also be aware of the following three forms



Z1 - Zone of high interference
Z2 - Zone of moderate interference
Z3 - Zone of low interference
Z4 - Zone of insignificant interference

FIG. 8 INTERFERENCE ZONES FOR TALL RECTANGULAR BUILDINGS OF SAME OR GREATER HEIGHT

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of wind-induced motion which are characterized by increasing amplitude of oscillation with the increase of wind speed:

a) *Galloping* — Galloping is transverse oscillations of some structures due to the development of aerodynamic forces which are in phase with the motion. It is characterized by the progressively increasing amplitude of transverse vibration with increase of wind speed. The cross-sections which are particularly prone to this type of excitation include the following:

1) All structures with non-circular cross-sections, such as triangular, square, polygons, as well as angles, crosses, and T sections.

2) Twisted cables and cables with ice encrustations.

b) *Flutter* — Flutter is unstable oscillatory motion of a structure due to coupling between aerodynamic force and elastic deformation of the structure. Perhaps the most common form is oscillatory motion due to combined bending and torsion. Although oscillatory motion in each degree of freedom may be damped, instability can set in due to energy transfer from one mode of oscillation to another and the structure is seen to execute sustained or divergent oscillations with a type of motion which is a combination of the individual modes of vibration. Such energy transfer takes place when the natural frequencies of modes taken individually are close to each other (ratio being typically less than 2.0). Flutter can set in at wind speeds much less than those required for exciting the individual modes of motion. Long span suspension bridge decks or any member of a structure with large values of d/t (where d is the length of the member and t is its dimension parallel to wind stream) are prone to low speed flutter. Wind tunnel testing is required to determine critical flutter speeds and the likely structural response. Other types of flutter are single degree of freedom stall flutter, torsional flutter, etc.

c) *Ovalling* — Thin walled structures with open ends at one or both ends such as oil storage tanks and natural draught cooling towers in which the ratio of the diameter or minimum lateral dimension to the wall thickness is of the order of 100 or more are prone to ovalling oscillations. These oscillations are characterized by periodic radial deformation of the hollow structure.

7 Buildings and structures that may be subjected to significant wind excited oscillations require careful investigations. It is to be noted that wind induced oscillations may occur at wind speeds lower than the design wind speed.

8 Analytical methods for the evaluation of response of dynamic structures to wind loading can be found in the special publications.

9 In assessing wind loads due to such dynamic phenomenon as galloping, flutter and ovalling, in the absence of the required information either in the special publications or other literature, expert advice should be sought including experiments on models in boundary layer wind tunnels.

4.7.2 *Motion due to Vortex Shedding*

4.7.2.1 *Slender structures*

For a structure, the vortex shedding frequency, f_s, shall be determined by the following formula:

$$f_s = \frac{S_t \overline{V}_{z,H}}{b}$$

where

S_t = Strouhal number,

$\overline{V}_{z,H}$ = hourly mean wind speed at height z, and

b = breadth of a structure or structural member normal to the wind direction in the horizontal plane.

a) *Circular structures* — For structures of circular cross-section:

S_t = 0.20 for $D\overline{V}_{z,H}$ less than 6 m²/s, and

= 0.25 for $D\overline{V}_{z,H}$ more than or equal to 6 m²/s.

b) *Rectangular structures* — For structures of rectangular cross-section:

$S_t = 0.10$

NOTES

1 Significant cross wind motions may be produced by vortex shedding, if the natural frequency of the structure or structural element is equal to the frequency of the vortex shedding within the range of expected wind speeds. In such cases, further analysis should be carried out on the basis of special publications.

2 Unlined welded steel cylindrical structures are prone to excitations by vortex shedding.

3 Intensification of the effects of periodic vortex shedding has been reported in cases where two or more similar structures are located in close proximity, for example at less than 20b apart, where b is the dimension of the structure normal to the wind.

4 The formulae given in **4.7.2.1**(a) is valid for infinitely long cylindrical structures. The value of S_t decreases slowly as the ratio of length to maximum transverse width decreases, the reduction being up to about half the value, if the structure is only three times higher than its width. Vortex shedding need not be considered, if the ratio of length to maximum transverse dimension is less than 2.0.

4.8 Dynamic Wind Response

4.8.1 *General*

Tall buildings/structures which are 'wind sensitive' shall be designed for dynamic wind loads. Hourly mean wind speed is used as a reference wind speed to be used in dynamic wind analysis. For calculation of along wind loads and response (bending moments, shear forces, or tip deflections) the Gust Factor (GF) method is used as specified in **4.8.2**. The across wind design peak base overturning moment and tip deflection shall be calculated using **4.8.3**.

4.8.2 *Along Wind Response*

For calculation of along-wind load effects at a level s on a building/structure, the design hourly mean wind pressure at height z shall be multiplied by the Gust Factor (G). This factor is dependent on both the overall height h and the level s under consideration (*see* Fig. 9). For calculation of base bending moment and deflection

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at the top of the building/structure, '*s*' should be taken as zero.

Note that $0 < s <$ h, and $s < z < h$.

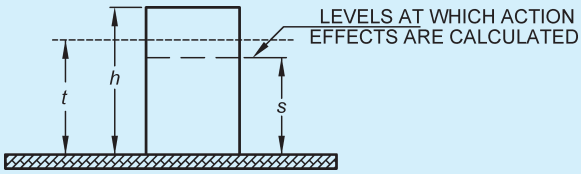


FIG. 9 NOTATIONS FOR HEIGHTS

The design peak along wind base bending moment (M_a) shall be obtained by summing the moments resulting from design peak along wind loads acting at different heights, z, along the height of the building/structure and can be obtained from,

$$M_a = \sum F_z z$$

$$F_z = C_{f,z} A_z \bar{p}_d G$$

where

F_z = design peak along wind load on the building/structure at any height *z;*

A_z = effective frontal area of the building/structure at any height *z*, in m^2;

$\bar{p}_d$ = design hourly mean wind pressure corresponding to $\bar{V}_{z,d}$ and obtained as $0.6\bar{V}_{z,d}$ (N/m^2);

$\bar{V}_{z,d}$ = design hourly mean wind speed at height *z*, in m/s (*see* **4.4.4**);

$C_{f,z}$ = drag force coefficient of the building/structure corresponding to the area A_z;

G = Gust Factor and is given by:

$$= 1 + r\sqrt{\left[g_v^2 B_s (1+\phi)^2 + \frac{H_s g_R^2 SE}{\beta}\right]}$$

where

r = roughness factor which is twice the longitudinal turbulence intensity, $I_{h,i}$ (*see* **4.4.5**);

g_v = peak factor for upwind velocity fluctuation

= 3.0 for category 1 and 2 terrains; and

= 4.0 for category 3 and 4 terrains;

B_s = background factor indicating the measure of slowly varying component of fluctuating wind load caused by the lower frequency wind speed variations

$$= \frac{1}{\left[1 + \frac{\sqrt{0.26(h-s)^2 + 0.46 b_{sh}^2}}{L_h}\right]}$$

where

b_{sh} = average breadth of the building/structure between heights *s* and *h*;

L_h = measure of effective turbulence length scale at the height, *h*, in m;

$$= 85\left(\frac{h}{10}\right)^{0.25}$$ for terrain category 1 to 3, and

$$= 70\left(\frac{h}{10}\right)^{0.25}$$ for terrain category 4

ϕ = factor to account for the second order turbulence intensity;

$$= \frac{g_v I_{h,i} \sqrt{B_s}}{2}$$

$I_{h,i}$ = turbulence intensity at height *h* in terrain category *i*;

H_s = height factor for resonance response;

$$= 1 + \left(\frac{s}{h}\right)^2$$

S = size reduction factor given by:

$$= \frac{1}{\left[1 + \frac{3.5 f_a h}{\bar{V}_{h,d}}\right]\left[1 + \frac{4 f_a b_{0h}}{\bar{V}_{h,d}}\right]}$$

where

b_{0h} = average breadth of the building/structure between 0 and *h*;

E = spectrum of turbulence in the approaching wind stream

$$= \frac{\pi N}{\left(1 + 70.8N^2\right)^{5/6}}$$

where

N = effective reduced frequency

$$= \frac{f_a L_h}{\bar{V}_{h,d}}$$

f_a = first mode natural frequency of the building/structure in along wind direction, in Hz;

$\bar{V}_{h,d}$ = design hourly mean wind speed at height, *h*, in m/s (*see* **4.4.4**);

β = damping coefficient of the building/structure (*see* Table 39); and

g_R = peak factor for resonant response.

$$= \sqrt{[2\ln(3\,600 f_a)]}$$

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Table 39 Suggested Values of Structural Damping Coefficients
(*Clause* 4.8.2)

Sl No.	Kind of Structure	Damping Coefficient β
(1)	(2)	(3)
i)	Welded steel structures	0.010
ii)	Bolted steel structures/RCC structures	0.020
iii)	Prestressed concrete structures	0.016

4.8.2.1 *Peak acceleration in along wind direction*

The peak acceleration at the top of the building structure in along wind direction ($\hat{\ddot{x}}$ in m/s^2) is given by the following equation:

$$\hat{\ddot{x}} = (2\pi f_a)^2 \bar{x}\, g_R\, r \sqrt{\frac{SE}{\beta}}$$

where

$\bar{x}$ = mean deflection at the position where the acceleration is required. Other notations are same as given in **9.2**.

For computing the peak acceleration in the along wind direction, a mean wind speed at the height of the building /structure, $\overline{V_h}$ corresponding to a 5 year mean return period shall be used. A reduced value of 0.011 is also suggested for the structural damping, β for reinforced concrete structures.

4.8.3 *Across Wind Response*

This section gives method for determining equivalent static wind load and base overturning moment in the across wind direction for tall enclosed buildings and towers of rectangular cross-section. Calculation of across wind response is not required for lattice towers.

The across wind design peak base bending moment M_c for enclosed buildings and towers shall be determined as follows:

$$M_c = 0.5 g_h \bar{p}_h b h^2 (1.06 - 0.06k) \sqrt{\frac{\pi C_{fs}}{\beta}}$$

where

g_h = peak factor;
= $\sqrt{[2\ln(3\,600 f_c)]}$ in cross wind direction;

$\bar{p}_h$ = hourly mean wind pressure at height h, in Pa;

b = breadth of the structure normal to the wind, in m;

h = height of the structure, in m;

k = mode shape power exponent for representation of the fundamental mode shape as represented by:

$$\psi(z) = \left(\frac{z}{h}\right)^k \text{; and}$$

f_c = first mode natural frequency of the building/ structure in across wind direction, in Hz.

The across wind load distribution on the building/ structure can be obtained from M_c using linear distribution of loads as given below:

$$F_{z,c} = \left(\frac{3M_c}{h^2}\right)\left(\frac{z}{h}\right)$$

where $F_{z,c}$ = across wind load per unit height at height z.

4.8.3.1 *Peak acceleration in across wind direction*

The peak acceleration at the top of the building structure in across-wind direction ($\hat{\ddot{y}}$ in m/s^2) with approximately constant mass per unit height shall be determined as follows:

$$\hat{\ddot{y}} = 1.5 \frac{g_h \bar{p}_h b}{m_0} (0.76 + 0.24k) \sqrt{\left(\frac{\pi C_{fs}}{\beta}\right)}$$

Typical values of the mode shape power exponent, k are as follows:

a) uniform cantilever, $k = 1.5$
b) slender framed structure (moment resisting), $k = 0.5$
c) building with a central core and moment resisting façade, $k = 1.0$
d) lattice tower decreasing in stiffness with height, or a tower with a large mass at the top, $k = 2.3$

C_{fs} = across wind force spectrum coefficient generalized for a linear mode (*see* Fig. 10);

β = damping coefficient of the building/structure (*see* Table 39); and

m_0 = average mass per unit height of the structure, in kg/m.

4.8.4 *Combination of Along Wind and Across Wind Load Effects*

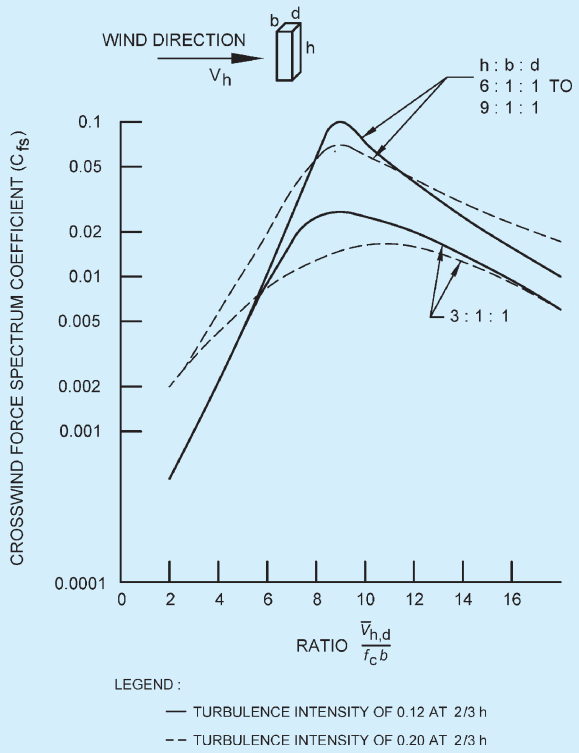
The along wind and across wind loads have to be applied simultaneously on the building/structure during design.

5 SEISMIC FORCE

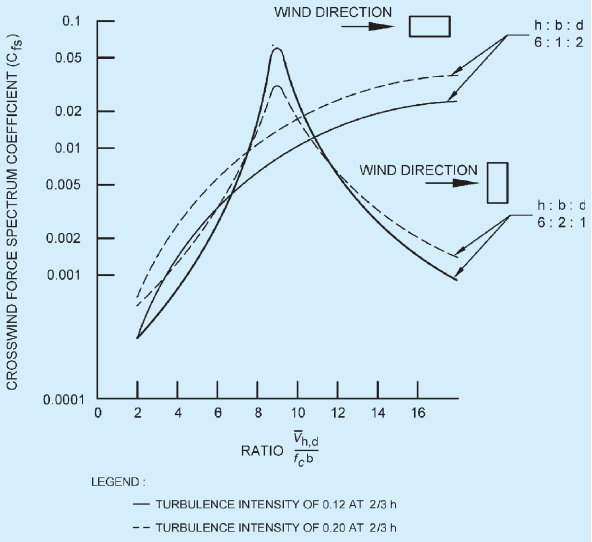
This clause primarily deals with earthquake hazard assessment and earthquake-resistant design of buildings.

All structures, like parking structures, security cabins and ancillary structures need to be designed for

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10A VALUES OF THE CROSS WIND FORCE SPECTRUM COEFFICIENT FOR SQUARE SECTION BUILDINGS



10B VALUES OF THE CROSS WIND FORCE SPECTRUM COEFFICIENT FOR 2:1 AND 1:2 RECTANGULAR SECTION BUILDINGS

FIG. 10 WIND FORCE SPECTRUM COEFFICIENT

appropriate earthquake effects as per this clause. Also, temporary elements, such as scaffolding and temporary excavations, need to be designed as per this clause. This clause does not deal with construction features relating to earthquake-resistant buildings and other structures. For guidance on earthquake-resistant construction of buildings, reference may be made to the latest revisions of the following good practice [6 1(6)].

The provisions of this clause are applicable even to critical and special structures, like nuclear power plants and petroleum refinery plants. For such structures, additional requirements may be imposed based on special studies, such as site-specific hazard assessment. In such cases, the earthquake effects specified by this clause shall be taken as at least the minimum.

For the purpose of this clause the symbols given at Annex G are applicable.

5.1 Terminology

For the purpose of this clause, definitions given below shall apply to all structures, in general. For definition of terms pertaining to soil mechanics and soil dynamics, reference may be made to Part 6 'Structural Design, Section 2 Soils and Foundations' of the Code; and for definition of terms pertaining to 'Loads', **3.2** and **4.3** may be referred.

5.1.1 *Closely-Spaced Modes* — Closely-spaced modes of a structure are those of the natural modes of oscillation of a structure, whose natural frequencies differ from each other by 10 percent or less of the lower frequency.

5.1.2 *Critical Damping* — The damping beyond which the free vibration motion will not be oscillatory.

5.1.3 *Damping* — The effect of internal friction, inelasticity of materials, slipping, sliding, etc, in reducing the amplitude of oscillation; it is expressed as a fraction of critical damping (*see* **5.1.2**).

5.1.4 *Design Acceleration Spectrum* — Design acceleration spectrum refers to an average smoothened graph of maximum acceleration as a function of natural frequency or natural period of oscillation for a specified damping ratio for the expected earthquake excitations at the base of a single degree of freedom system.

5.1.5 *Design Horizontal Acceleration Coefficient* (A_h) — It is a horizontal acceleration coefficient that shall be used for design of structures.

5.1.6 *Design Horizontal Force* — It is the horizontal seismic force prescribed by this Section that shall be used to design a structure.

5.1.7 *Ductility* — It is the capacity of a structure (or its members) to undergo large inelastic deformations without significant loss of strength or stiffness.

5.1.8 *Epicentre* — It is the geographical point on the

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surface of earth vertically above the point of origin of the earthquake.

5.1.9 *Floor Response Spectrum* — It is the response spectrum (for a chosen material damping value) of the time history of the shaking generated at a floor of a structure, when the structure is subjected to a given earthquake ground motion at its base.

5.1.10 *Importance Factor* (I) — It is a factor used to estimate design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.

5.1.11 *Intensity of Earthquake* — It is the measure of the strength of ground shaking manifested at a place during the earthquake, and is indicated by a roman capital numeral on the MSK scale of seismic intensity (*see* Annex H).

5.1.12 *Liquefaction* — It is a state primarily in saturated cohesionless soils wherein the effective shear strength is reduced to negligible value for all engineering purposes, when the pore pressure approaches the total confining pressure during earthquake shaking. In this condition, the soil tends to behave like a fluid mass (*see* Annex J).

5.1.13 *Lithological Features* — Features that reflect the nature of the geological formation of the earth's crust above bed rock characterized on the basis of structure, mineralogical composition and grain size.

5.1.14 *Modal Mass* (M_k) *in Mode* (k) *of a Structure* — It is a part of the total seismic mass of the structure that is effective in natural mode k of oscillation during horizontal or vertical ground motion.

5.1.15 *Modal Participation Factor* (P_k) *in Mode* (k) *of a Structure* — The amount by which natural mode k contributes to overall oscillation of the structure during horizontal or vertical earthquake ground motion. Since the amplitudes of mode shapes can be scaled arbitrarily, the value of this factor depends on the scaling used for defining mode shapes.

5.1.16 *Modes of Oscillation* — *See* **5.1.19**.

5.1.17 *Mode Shape Coefficient* (ϕ_{ik}) — It is the spatial deformation pattern of oscillation along degree of freedom i, when the structure is oscillating in its natural mode k. A structure with N degrees of freedom possesses N natural periods and N associated natural mode shapes. These natural mode shapes are together presented in the form of a mode shape matrix [ϕ], in which each column represents one natural mode shape. The element ϕ_{ik} is called the mode shape coefficient associated with degree of freedom i, when the structure is oscillating in mode k.

5.1.18 *Natural Period* (T_k) *in Mode* (k) *of Oscillation* — The time taken (in second) by the structure to complete one cycle of oscillation in its natural mode k of oscillation.

5.1.18.1 *Fundamental lateral translational natural period* (T_1) — It is the longest time taken (in second) by the structure to complete one cycle of oscillation in its lateral translational mode of oscillation in the considered direction of earthquake shaking. This mode of oscillation is called the fundamental lateral translational natural mode of oscillation. A three-dimensional model of a structure will have one such fundamental lateral translational mode of oscillation along each of the two orthogonal plan directions.

5.1.19 *Normal Mode of Oscillation* — The mode of oscillation in which there are special undamped free oscillations in which all points on the structure oscillate harmonically at the same frequency (or period), such that all these points reach their individual maximum responses simultaneously.

5.1.20 *Peak Ground Acceleration* — It is the maximum acceleration of the ground in a given direction of ground shaking. Here, the acceleration refers to that of the horizontal motion, unless specified otherwise.

5.1.21 *Response Reduction Factor* (R) — It is the factor by which the base shear induced in a structure, if it were to remain elastic, is reduced to obtain the design base shear. It depends on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations, redundancy in the structure, or overstrength inherent in the design process.

5.1.22 *Response Spectrum* — It is the representation of maximum responses of a spectrum of idealized single degree freedom systems of different natural periods but having the same damping, under the action of the same earthquake ground motion at their bases. The response referred to here can be maximum absolute acceleration, maximum relative velocity, or maximum relative displacement.

5.1.23 *Response Acceleration Coefficient of a Structure* (S_a/g) — It is a factor denoting the normalized design acceleration spectrum value to be considered for the design of structures subjected to earthquake ground shaking; this value depends on the natural period of oscillation of the structure and damping to be considered in the design of the structure.

5.1.24 *Seismic Mass of a Floor* — It is the seismic

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weight of the floor divided by acceleration due to gravity.

5.1.25 *Seismic Mass of a Structure* — It is the seismic weight of a structure divided by acceleration due to gravity.

5.1.26 *Seismic Weight of a Floor* (*W*) — It is the sum of dead load of the floor, appropriate contributions of weights of columns, walls and any other permanent elements from the storeys above and below, finishes and services, and appropriate amounts of specified imposed load on the floor.

5.1.27 *Seismic Weight of a Structure* (*W*) — It is the sum of seismic weights of all floors.

5.1.28 *Seismic Zone Factor* (*Z*) — It is the value of peak ground acceleration considered by this Section for the design of structures located in each seismic zone.

5.1.29 *Time History Analysis* — It is an analysis of the dynamic response of the structure at each instant of time, when its base is subjected to a specific ground motion time history.

5.2 Special Terminology for Buildings

5.2.1 The definitions given below shall apply for the purpose of earthquake resistant design of buildings, as enumerated in this Section.

5.2.2 *Base* — It is the level at which inertia forces generated in the building are considered to be transferred to the ground through the foundation. For buildings with basements, it is considered at the bottommost basement level. For buildings resting on,

a) pile foundations, it is considered to be at the top of pile cap;
b) raft, it is considered to be at the top of raft; and
c) footings, it is considered to be at the top of the footing.

For buildings with combined types of foundation, the base is considered as the bottom-most level of the bases of the constituent individual foundations as per definitions above.

5.2.3 *Base Dimension* (*d*) — It is the dimension (in metre) of the base of the building along a direction of shaking.

5.2.4 *Centre of Mass* (*CM*) — The point in the floor of a building through which the resultant of the inertia force of the floor is considered to act during earthquake shaking. Unless otherwise stated, the inertia force considered is that associated with the horizontal shaking of the building.

5.2.5 *Centre of Resistance* (*CR*)

5.2.5.1 *For single storey buildings* — It is the point on the roof of a building through which when the resultant internal resistance acts, the building undergoes,

a) pure translation in the horizontal direction; and
b) no twist about vertical axis passing through the *CR*.

5.2.5.2 *For multi-storey buildings* — It is the set of points on the horizontal floors of a multi-storey building through which, when the resultant incremental internal resistances across those floors act, all floors of the building undergo,

a) pure translation in the horizontal direction; and
b) no twist about vertical axis passing through the *CR*.

5.2.6 *Eccentricity*

5.2.6.1 *Design eccentricity* (e_{di}) — It is the value of eccentricity to be used for floor *i* in calculations of design torsion effects.

5.2.6.2 *Static eccentricity* (e_{si}) — It is the distance between centre of mass (*CM*) and centre of resistance (*CR*) of floor *i*.

5.2.7 *Design Seismic Base Shear* (V_B) — It is the horizontal lateral force in the considered direction of earthquake shaking that the structure shall be designed for.

5.2.8 *Diaphragm* — It is a horizontal or nearly horizontal structural system (for example, reinforced concrete floors and horizontal bracing systems), which transmits lateral forces to vertical elements connected to it.

5.2.9 *Height of Floor* (h_i) — It is the difference in vertical elevations (in metre) of the base of the building and top of floor *i* of the building.

5.2.10 *Height of Building* (*h*) — It is the height of building (in metre) from its base to top of roof level,

a) excluding the height of basement storeys, if basement walls are connected with the ground floor slab or basement walls are fitted between the building columns, but

b) including the height of basement storeys, if basement walls are not connected with the ground floor slab and basement walls are not fitted between the building columns.

In step-back buildings, it shall be taken as the average of heights of all steps from the base, weighted with their corresponding floor areas. And, in buildings founded on hill slopes, it shall be taken as the height of the roof from the top of the highest footing level or pile cap level.

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5.2.11 *Horizontal Bracing System* — It is a horizontal truss system that serves the same function as a diaphragm.

5.2.12 *Joints* — These are portions of columns that are common to beams/braces and columns, which frame into columns.

5.2.13 *Lateral Force Resisting System* — It is part of the structural system, and consists of all structural members that resist lateral inertia forces induced in the building during earthquake shaking.

5.2.14 *Moment-Resisting Frame* — It is an assembly of beams and columns that resist induced and externally applied forces primarily by flexure.

5.2.14.1 *Ordinary moment-resisting frame (OMRF)* — It is a moment-resisting frame designed and detailed as per relevant good practices [6-1(7)], but not meeting special detailing requirements for ductile behaviour as per good practices [6-1(8)] or [6-1(9)], as applicable.

5.2.14.2 *Special moment-resisting frame (SMRF)* — It is a moment-resisting frame designed and detailed as per relevant good practices [6-1(7)], and meeting special detailing requirements for ductile behaviour as per good practices [6-1(8)] or [6-1(9)], as applicable.

5.2.15 *Number of Storeys* (*n*) — It is the number of levels of a building above the base at which mass is present in substantive amounts. This,

a) excludes the basement storeys, where basement walls are connected with the ground floor deck or fitted between the building columns; and
b) includes the basement storeys, when they are not so connected.

5.2.16 *Core Structural Walls, Perimeter Columns, Outriggers and Belt Truss System* — It is a structural system comprising a core of structural walls and perimeter columns, resisting the vertical and lateral loads, with

a) the core structural walls connected to select perimeter column element(s) (often termed outrigged columns) by deep beam elements, known as outriggers, at discrete locations along the height of the building; and
b) the outrigged columns connected by deep beam elements (often known as belt truss), typically at the same level as the outrigger elements.

A structure with this structural system has enhanced lateral stiffness, wherein core structural walls and perimeter columns are mobilized to act with each other through the outriggers, and the perimeter columns themselves through the belt truss. The global lateral stiffness is sensitive to: flexural stiffness of the core element, the flexural stiffness of the outrigger element(s), the axial stiffness of the outrigged column(s), and the flexural stiffness of the outrigger elements connecting the core structural walls to the perimeter columns.

5.2.17 *Principal Plan Axes* — These are two mutually perpendicular horizontal directions in plan of a building along which the geometry of the building is oriented.

5.2.18 *P-Δ Effect* — It is the secondary effect on shear forces and bending moments of lateral force resisting elements generated under the action of the vertical loads, interacting with the lateral displacement of building resulting from seismic effects.

5.2.19 *RC Structural Wall* — It is a wall designed to resist lateral forces acting in its own plane.

5.2.19.1 *Ordinary RC structural wall* — It is a reinforced concrete (RC) structural wall designed and detailed as per good practice [6-1(10)], but not meeting special detailing requirements for ductile behaviour as per good practice [6-1(8)].

5.2.19.2 *Special RC structural wall* — It is a RC structural wall designed and detailed in accordance with and meeting special detailing requirements for ductile behaviour, as per good practice [6-1(8)].

5.2.20 *Storey* — It is the space between two adjacent floors.

5.2.20.1 *Soft storey* — It is one in which the lateral stiffness is less than that in the storey above. The storey lateral stiffness is the total stiffness of all seismic force resisting elements resisting lateral earthquake shaking effects in the considered direction.

5.2.20.2 *Weak storey* — It is one in which the storey lateral strength [cumulative design shear strength of all structural members other than that of unreinforced masonry (URM) infills] is less than that in the storey above. The storey lateral strength is the total strength of all seismic force resisting elements sharing the lateral storey shear in the considered direction.

5.2.21 *Storey Drift* — It is the relative displacement between the floors above and/or below the storey under consideration.

5.2.22 *Storey Shear* (V_i) — It is the sum of design lateral forces at all levels above the storey *i* under consideration.

5.2.23 *Storey Lateral Shear Strength* (S_i) — It is the total lateral strength of all lateral force resisting

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elements in the storey considered in a principal plan direction of the building.

5.2.24 *Storey Lateral Translational Stiffness* (K_i) — It is the total lateral translational stiffness of all lateral force resisting elements in the storey considered in a principal plan direction of the building.

5.2.25 *RC Structural Wall Plan Density* (ρ_{sw}) — It is the ratio of the cross-sectional area at the plinth level of RC structural walls resisting the lateral load and the plinth of the building, expressed as a percentage.

5.3 General Principles and Design Criteria

5.3.1 *General Principles*

5.3.1.1 *Ground motion*

The characteristics (intensity, duration, frequency content, etc) of seismic ground vibrations expected at any site depend on magnitude of earthquake, its focal depth, epicentral distance, characteristics of the path through which the seismic waves travel, and soil strata on which the structure is founded. The random earthquake ground motions, which cause the structure to oscillate, can be resolved in any three mutually perpendicular directions. The predominant direction of ground vibration is usually horizontal.

Effects of earthquake-induced vertical shaking can be significant for overall stability analysis of structures, especially in structures (a) with large spans, and (b) those in which stability is a criterion for design. Reduction in gravity force due to vertical ground motions can be detrimental particularly in prestressed horizontal members, cantilevered members and gravity structures. Hence, special attention shall be paid to effects of vertical ground motion on prestressed or cantilevered beams, girders and slabs.

5.3.1.2 The response of a structure to ground vibrations depends on (a) type of foundation; (b) materials, form, size and mode of construction of structures; and (c) duration and characteristics of ground motion. This Section specifies design forces for structures founded on rocks or soils, which do not settle, liquefy or slide due to loss of strength during earthquake ground vibrations.

5.3.1.3 Actual forces that appear on structures during earthquakes are much higher than the design forces specified in the Section. Ductility arising from inelastic material behaviour with appropriate design and detailing, and overstrength resulting from the additional reserve strength in structures over and above the design strength are relied upon for the deficit in actual and design lateral loads. In other words, earthquake resistant design as per this Section relies on inelastic behaviour of structures. But, the maximum ductility that can be realized in structures is limited. Therefore, structures shall be designed for at least the minimum design lateral force specified in this Section.

5.3.1.4 Members and connections of reinforced and prestressed concrete structures shall be designed (as per good practices [6-1(11)] such that premature failure does not occur due to shear or bond. Some provisions for appropriate ductile detailing of RC members are given in good practice [6-1(8)]. Members and their connections of steel structures should be so proportioned that high ductility is obtained in the structure, avoiding premature failure due to elastic or inelastic buckling of any type. Some provisions for appropriate ductile detailing of steel members are given in good practice [6-1(9)].

5.3.1.5 The soil-structure interaction refers to effects of the flexibility of supporting soil-foundation system on the response of structure. Soil-structure interaction may not be considered in the seismic analysis of structures supported on rock or rock-like material at shallow depth.

5.3.1.6 Equipment and other systems, which are supported at various floor levels of a structure, will be subjected to different motions at their support points. In such cases, it may be necessary to obtain floor response spectra for design of equipment and its supports. For details, reference may be made to good practice [6-1(12)].

5.3.1.7 *Additions to existing structures*

Additions shall be made to existing structures only as follows:

a) An addition that is structurally independent from an existing structure shall be designed and constructed in accordance with the seismic requirements for new structures.
b) An addition that is structurally connected to an existing structure shall be designed and constructed such that the entire structure conforms to the seismic force resistance requirements for new structures, unless the following three conditions are complied with:
    1) Addition shall comply with the requirements for new structures,
    2) Addition shall not increase the seismic forces in any structural element of the existing structures by more than 5 percent, unless the capacity of the element subject to the increased force is

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still in compliance with this Section, and

3) Addition shall not decrease the seismic resistance of any structural element of the existing structure unless reduced resistance is equal to or greater than that required for new structures.

5.3.1.8 *Change in occupancy*

When a change of occupancy results in a structure being reclassified to a higher importance factor (I), the structure shall conform to seismic requirements laid down for new structures with the higher importance factor.

5.3.2 *Assumptions*

The following assumptions shall be made in the earthquake-resistant design of structures:

a) Earthquake ground motions are complex and irregular, consisting of several frequencies and of varying amplitudes each lasting for a small duration. Therefore, usually, resonance of the type as visualized under steady-state sinusoidal excitations will not occur, as it would need time to build up such amplitudes. But, there are exceptions where resonance-like conditions have been seen to occur between long distance waves and tall structures founded on deep soft soils.

b) Earthquake is not likely to occur simultaneously with high wind, maximum flood or maximum sea waves.

c) The values of elastic modulus of materials, wherever required, will be taken as for static analysis, unless more definite values are available for use in dynamic conditions {*see* good practice [6-1(13)]}.

5.3.3 *Load Combinations and Increase in Permissible Stresses*

5.3.3.1 *Load combinations*

The load combinations shall be considered as specified in respective standards due to all load effects mentioned therein. In addition, those specified in this standard shall be applicable, which include earthquake effects.

5.3.3.1.1 Even when load combinations that do not contain earthquake effects, indicate larger demands than combinations including them, the provisions shall be adopted related to design, ductile detailing and construction relevant for earthquake conditions, which are given in this Section, good practice [6-1(8)] and good practice [6-1(9)].

5.3.3.2 *Design horizontal earthquake load*

5.3.3.2.1 When lateral load resisting elements are oriented along two mutually orthogonal horizontal directions, structure shall be designed for effects due to full design earthquake load in one horizontal direction at a time, and not in both directions simultaneously.

5.3.3.2.2 When lateral load resisting elements are not oriented along mutually orthogonal horizontal directions [as per **5.4.1** and Sl No. (v) of Table 44], structure shall be designed for the simultaneous effects due to full design earthquake load in one horizontal direction plus 30 percent of design earthquake load along the other horizontal direction. Thus, structure should be designed for the following sets of combinations of earthquake effects:

a) $\pm EL_X \pm 0.3\ EL_Y$, and

b) $\pm 0.3\ EL_X \pm EL_Y$,

where X and Y are two orthogonal horizontal plan directions. Thus, EL in the load combinations shall be replaced by ($EL_X \pm 0.3\ EL_Y$) or ($EL_Y \pm 0.3\ EL_X$). Hence, the sets of load combinations to be considered shall be as given below:

1) $1.2\ [DL + IL \pm (EL_X \pm 0.3\ EL_Y)]$ and
   $1.2\ [DL + IL \pm (EL_Y \pm 0.3\ EL_X)]$;
2) $1.5\ [DL \pm (EL_X \pm 0.3\ EL_Y)]$ and
   $1.5\ [DL \pm (EL_Y \pm 0.3\ EL_X)]$; and
3) $0.9\ DL \pm 1.5\ (EL_X \pm 0.3\ EL_Y)$ and
   $0.9\ DL \pm 1.5\ (EL_Y \pm 0.3\ EL_X)$.

5.3.3.3 *Design vertical earthquake effects*

5.3.3.3.1 Effects due to vertical earthquake shaking shall be considered when any of the following conditions apply:

a) Structure is located in Seismic Zone IV or V;

b) Structure has vertical or plan irregularities;

c) Structure is rested on soft soil;

d) Bridges;

e) Structure has long spans; or

f) Structure has large horizontal overhangs of structural members or sub-systems.

5.3.3.3.2 When effects due to vertical earthquake shaking are to be considered, the design vertical force shall be calculated for vertical ground motion as detailed in **5.3.4.6**.

5.3.3.3.3 Where both horizontal and vertical seismic

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forces are taken into account, load combination specified in **5.3.3.4** shall be considered.

5.3.3.4 *Combinations to account for three directional earthquake ground shaking*

5.3.3.4.1 When responses from the three earthquake components are to be considered, the responses due to each component may be combined using the assumption that when the maximum response from one component occurs, the responses from the other two components are 30 percent each of their maximum. All possible combinations of three components (EL_X, EL_Y and EL_Z) including variations in sign (plus or minus) shall be considered. Thus, the structure should be designed for the following sets of combinations of earthquake load effects:

a) $\pm EL_X \pm 0.3\ EL_Y \pm 0.3\ EL_Z$,
b) $\pm EL_Y \pm 0.3\ EL_Z \pm 0.3\ EL_X$, and
c) $\pm EL_Z \pm 0.3\ EL_X \pm 0.3\ EL_Y$,

where *X* and *Y* are orthogonal plan directions and *Z* vertical direction. Thus, *EL* in the above referred load combinations shall be replaced by ($EL_X \pm 0.3\ EL_Y \pm 0.3\ EL_Z$), ($EL_Y \pm 0.3\ EL_Z \pm 0.3\ EL_X$) or ($EL_Z \pm 0.3\ EL_X \pm 0.3\ EL_Y$,). This implies that the sets of load combinations involving earthquake effects to be considered shall be as given below:

1) 1.2 [DL + IL ± ($EL_X \pm 0.3\ EL_Y \pm 0.3\ EL_Z$)] and
   1.2 [DL + IL ± ($EL_Y \pm 0.3\ EL_X \pm 0.3\ EL_Z$)];
2) 1.5 [DL ± ($EL_X \pm 0.3\ EL_Y \pm 0.3\ EL_Z$)] and
   1.5 [DL ± ($EL_Y \pm 0.3\ EL_X \pm 0.3\ EL_Z$)]; and
3) 0.9 DL ± 1.5 ($EL_X \pm 0.3\ EL_Y \pm 0.3\ EL_Z$) and
   0.9 DL ± 1.5 ($EL_Y \pm 0.3\ EL_X \pm 0.3\ EL_Z$).

5.3.3.4.2 As an alternative to the procedure in **5.3.3.4.1**, the net response (*EL*) due to the combined effect of the three components can be obtained by:

$$EL = \sqrt{(EL_X)^2 + (EL_Y)^2 + (EL_Z)^2}$$

Caution may be exercised on loss of sign especially of the axial force, shear force and bending moment quantities, when this procedure is used; it can lead to grossly uneconomical design of structures.

5.3.3.4.3 Procedure for combining shaking effects given by **5.3.3.4.1** and **5.3.3.4.2** apply to the same response quantity (say, bending moment in a column about its major axis, or storey shear force in a frame) due to different components of the ground motion.

5.3.3.4.4 When components corresponding to only two ground motion components (say one horizontal and one vertical, or only two horizontal) are combined, the equations in **5.3.3.4.1** and **5.3.3.4.2** should be modified by deleting the term representing the response due to the component of motion not being considered.

5.3.3.5 *Increase in net pressure on soils in design of foundations*

5.3.3.5.1 In the design of foundations, unfactored loads shall be combined in line with good practices [6-1(14)], while assessing the bearing pressure in soils.

5.3.3.5.2 When earthquake forces are included, net bearing pressure in soils can be increased as per Table 40, depending on type of foundation and type of soil. For determining the type of soil for this purpose, soils shall be classified in four types as given in Table 41. In soft soils, no increase shall be applied in bearing pressure, because settlements cannot be restricted by increasing bearing pressure.

5.3.3.5.3 In soil deposits consisting of submerged loose sands and soils falling under classification SP with corrected standard penetration test values *N*, less than 15 in Seismic Zones III, IV and V, and less than 10 in Seismic Zone II, the shaking caused by earthquake ground motion may cause liquefaction or excessive total and differential settlements. Such sites should be avoided preferably for locating new structures, and should be avoided for locating structures of important projects. Otherwise, settlements need to be investigated, and appropriate methods adopted of compaction or stabilization to achieve *N* values indicated in Note 4 of Table 40. Alternatively, deep pile foundations may be adopted and anchored at depths well below the underlying soil layers, which are likely to liquefy or undergo excessive settlements.

Also, marine clay layers and other sensitive clay layers are known to liquefy, undergo excessive settlements or even collapse, owing to low shear strength of the said soil; such soils will need special treatment according to site condition (*see* Table 41).

A simplified method is given in Annex J, for evaluation of liquefaction potential.

5.3.4 *Design Acceleration Spectrum*

5.3.4.1 For the purpose of determining design seismic force, the country is classified into four seismic zones as shown in Fig. 11.

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Table 40 Percentage Increase in Net Bearing Pressure and Skin Friction of Soils
(*Clause* 5.3.3.5.2)

Sl No.	Soil Type	Percentage Increase Allowable
(1)	(2)	(3)
i)	*Type A:* Rock or hard soils	50
ii)	*Type B:* Medium or stiff soils	25
iii)	*Type C:* Soft soils	0

NOTES

1 The net bearing pressure shall be determined in accordance with good practice [6-1(15)] or accepted standards [6-1(16)]

2 Only corrected values of *N* shall be used.

3 If any increase in net bearing pressure has already been permitted for forces other than seismic forces, the total increase in allowable bearing pressure, when seismic force is also included, shall not exceed the limits specified above.

4 The desirable minimum corrected field values of *N* shall be as specified below:

Seismic Zone	*Depth* (m) *below Ground Level*	*N Values*	*Remarks*
III, IV and V	≤ 5 ≥ 10	15 25	For values of depths between 5 m and 10 m, linear interpolation is recommended
II	≤ 5 ≥ 10	10 20	

If soils of lower *N* values are encountered than those specified in the table above, then suitable ground improvement techniques shall be adopted to achieve these values. Alternately, deep pile foundations should be used, which are anchored in stronger strata, underlying the soil layers that do not meet the requirement.

5 Piles should be designed for lateral loads neglecting lateral resistance of those soil layers (if any), which are liable to liquefy.

6 Accepted standard [6-1(17)] may be referred for soil notation, and corrected *N* values shall be determined by applying correction factor C_N for effective overburden pressure σ'_{vo} using relation $N=C_N N_1$, where $C_N = \sqrt{P_a / \sigma'_{vo}} \leq 1.7$, P_a is the atmospheric pressure, and N_1 is the uncorrected SPT value for soil.

7 While using this table, the value of *N* to be considered shall be determined as below:

a) *Isolated footings* — Weighted average of *N* of soil layers from depth of founding, to depth of founding plus twice the breadth of footing;

b) *Raft foundations* — Weighted average of *N* of soil layers from depth of founding, to depth of founding plus twice the breadth of raft;

c) *Pile foundation* — Weighted average of *N* of soil layers from depth of bottom tip of pile, to depth of bottom tip of pile plus twice the diameter of pile;

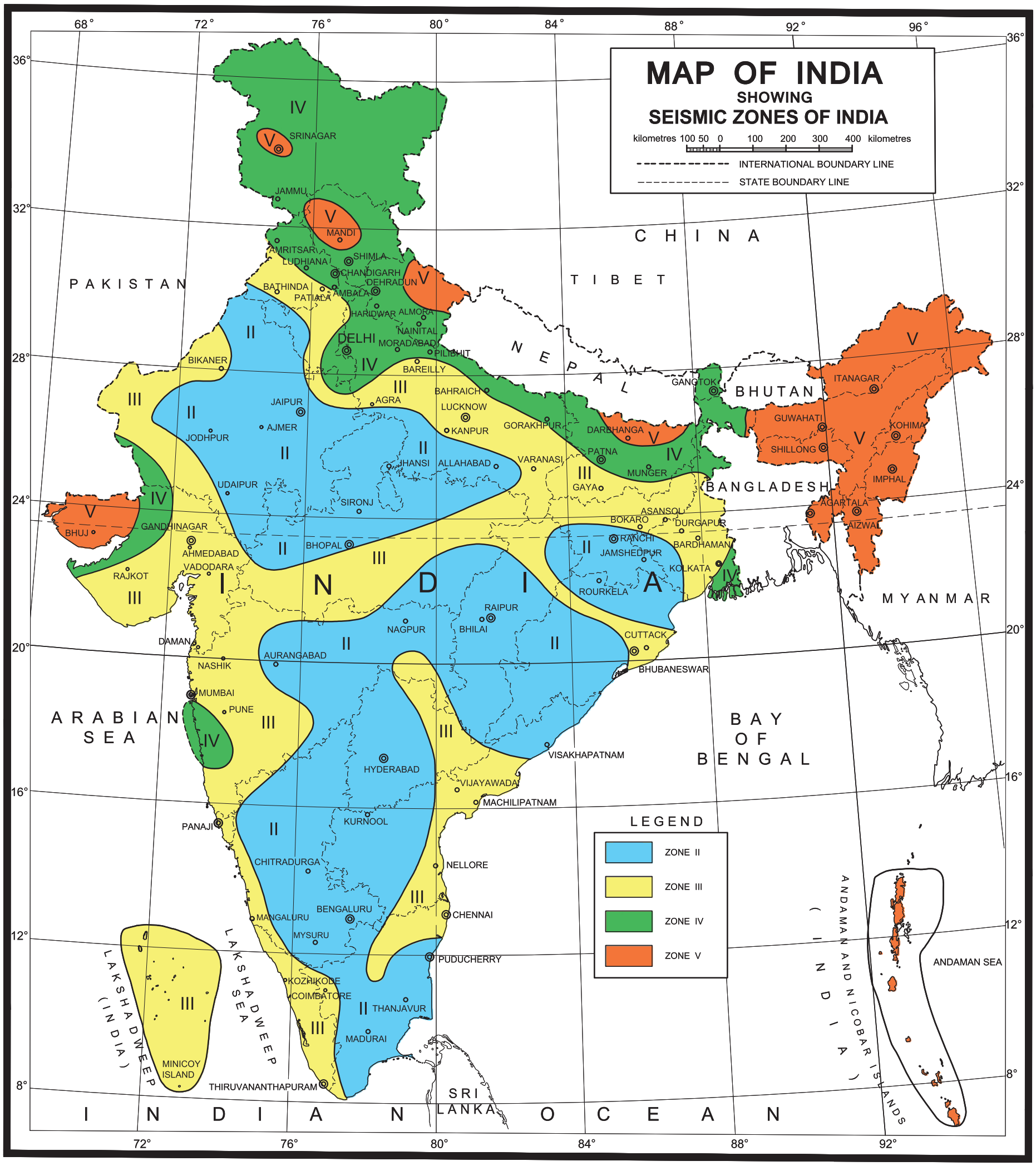
d) *Group pile foundation* — Weighted average of *N* of soil layers from depth of bottom tip of pile group, to depth of bottom tip of pile group plus twice the width of pile group; and

e) *Well foundation* — Weighted average of *N* of soil layers from depth of bottom tip of well, to depth of bottom tip of well plus twice the width of well.

Table 41 Classification of Types of Soils for Determining Percentage Increase in Net Bearing Pressure and Skin Friction
(*Clause* 5.3.3.5.2)

Sl No.	Soil Type	Remarks
(1)	(2)	(3)
i)	**Type A** Rock or hard soils	Well graded gravel (GW) or well graded sand (SW) both with less than 5 percent passing 75 µm sieve (Fines) Well graded gravel – sand mixtures with or without fines (GW-SW) Poorly-graded sand (SP) or Clayey sand (SC), all having *N* above 30 stiff to hard clays having *N* above 30, where *N* is corrected standard penetration test value
ii)	**Type B** Medium or stiff soils	Poorly graded sands or poorly graded sands with gravel (SP) with little or no fines having *N* between 10 and 30 Stiff to medium stiff fine-grained soils, like silts of low compressibility (ML) or clays of low compressibility (CL) having *N* between 10 and 30
iii)	**Type C** Soft soils	All soft soils other than SP with *N*<10. The various possible soils are: a) Silts of intermediate compressibility (MI); b) Silts of high compressibility (MH); c) Clays of intermediate compressibility (CI); d) Clays of high compressibility (CH); e) Silts and clays of intermediate to high compressibility (MI-MH or CI-CH); f) Silt with clay of intermediate compressibility (MI-CI); and g) Silt with clay of high compressibility (MH-CH).
iv)	**Type D** Unstable, collapsible, liquefiable soils	Requires site-specific study and special treatment according to site condition (*see* **5.3.3.5.3**)

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The state boundaries between Uttarakhand & Uttar Pradesh, Bihar & Jharkhand, and Chhattisgarh & Madhya Pradesh have not been verified by the Governments concerned.

The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

The responsibility for the correctness of internal details rests with the publisher.

NOTE – Towns falling at the boundary of zones demarcation line between two zones shall be considered in higher zone.

FIG. 11 SEISMIC ZONES OF INDIA

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5.3.4.2 The design horizontal seismic coefficient A_h for a structure shall be determined by:

$$A_h = \frac{\left(\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

where

Z = seismic zone factor given in Table 42. Zone factor for some important towns are given at Annex K;

I = importance factor given in good practice [6-1(18)] for the corresponding structures; when not specified, the minimum values of I shall be,
a) 1.5 for critical and lifeline structures;
b) 1.2 for business continuity structures; and
c) 1.0 for the rest.

R = response reduction factor given in good practice [6-1(18)] for the corresponding structures; and

$\left(\frac{S_a}{g}\right)$ = design acceleration coefficient for different soil types, normalized with peak ground acceleration, corresponding to natural period T of structure (considering soil-structure interaction, if required). It shall be as given in good practice [6-1(18)] for the corresponding structures; when not specified, it shall be taken as that corresponding to 5 percent damping, given by expressions below:

a) *For use in equivalent static method* (*see* Fig. 12A):

$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} & \begin{cases} 2.5 & 0 < T < 0.40 \text{ s} \\ \frac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 0.400 \text{ s} \end{cases} \\ \text{For medium stiff soil sites} & \begin{cases} 2.5 & 0 < T < 0.55 \text{ s} \\ \frac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 0.400 \text{ s} \end{cases} \\ \text{For soft soil sites} & \begin{cases} 2.5 & 0 < T < 0.67 \text{ s} \\ \frac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.42 & T > 0.400 \text{ s} \end{cases} \end{cases}$$

b) *For use in response spectrum method* (*see* Fig. 12B)*:*

$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} & \begin{cases} 1+15T & T < 0.10 \text{s} \\ 2.5 & 0.10 \text{ s} < T < 0.40 \text{ s} \\ \frac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 4.00 \text{S} \end{cases} \\ \text{For medium stiff soil sites} & \begin{cases} 1+15T & T < 0.10 \text{ s} \\ 2.5 & 0.10 \text{ s} < T < 0.55 \text{ s} \\ \frac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 4.00 \text{s} \end{cases} \\ \text{For soft soil sites} & \begin{cases} 2.5 & 0.10 \text{ s} < T < 0.67 \text{ s} \\ \frac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 0.400 \text{ s} \end{cases} \end{cases}$$

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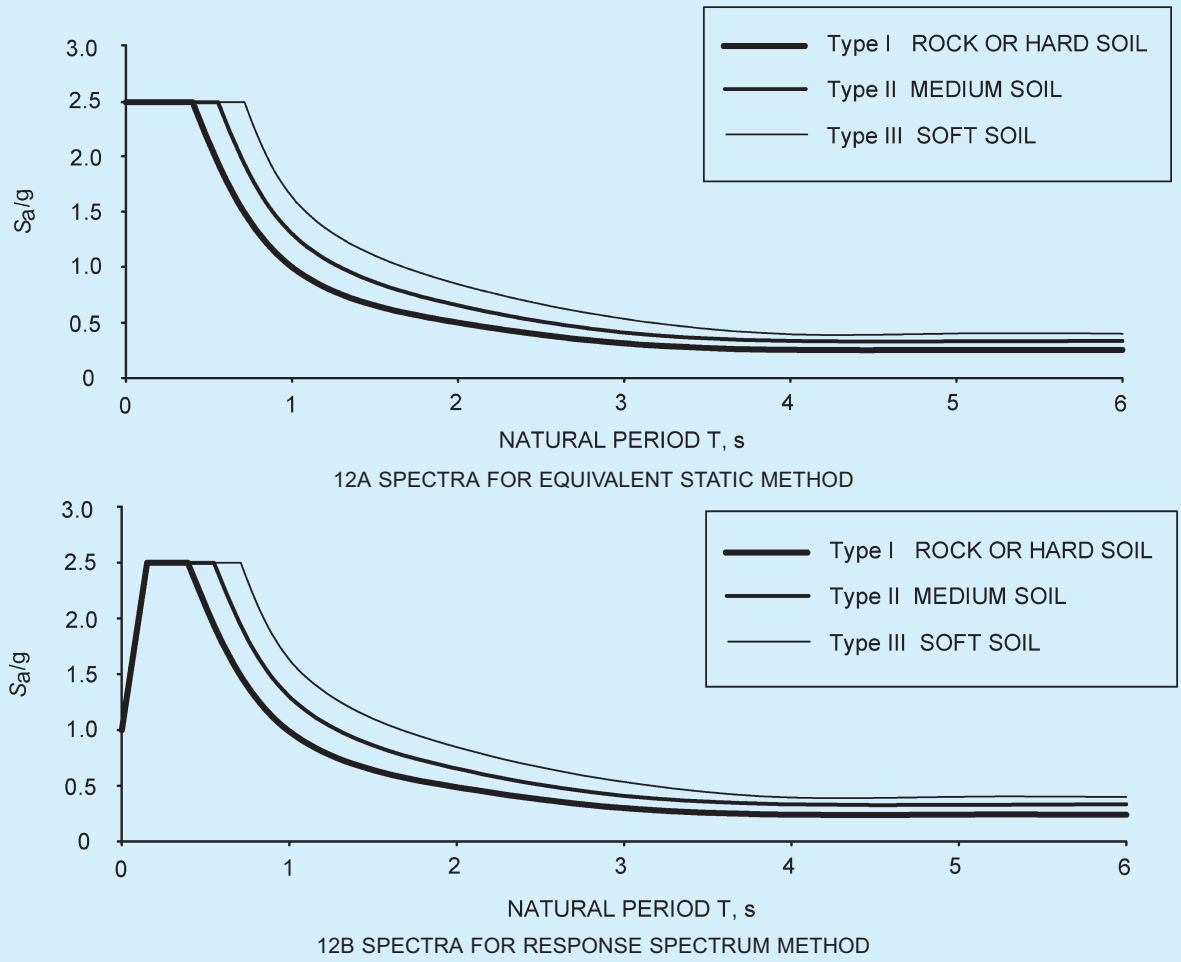


FIG. 12 DESIGN ACCELERATION COEFFICIENT (S_a/g) (CORRESPONDING TO 5 PERCENT DAMPING)

Table 42 Seismic Zone Factor *Z*
(*Clause* 5.3.4.2)

Seismic Zone Factor	II	III	IV	V
(1)	(2)	(3)	(4)	(5)
Z	0.10	0.16	0.24	0.36

5.3.4.2.1 For determining the correct spectrum to be used in the estimate of S_a/g, the type of soil on which the structure is placed shall be identified by the classification given in Table 43, as:

a) *Soil type* I — Rock or hard soils;
b) *Soil type* II — Medium or stiff soils; and
c) *Soil type* III — Soft soils.

In Table 43, the value of *N* to be used shall be the weighted average of *N* of soil layers from the existing ground level, to 30 m below the existing ground level; here, the *N* values of individual layers shall be the corrected values.

5.3.4.3 Effects of design earthquake loads applied on structures can be considered in two ways, namely:

a) Equivalent static method, and
b) Dynamic analysis method.

In turn, dynamic analysis can be performed in three ways, namely:

1) Response spectrum method,
2) Modal time history method, and
3) Time history method.

In this Section, equivalent static method, response spectrum method and time history method are adopted. Equivalent static method may be used for analysis of regular structures with approximate natural period T_a less than 0.4 s.

5.3.4.3.1 For structural analysis, the moment of inertia shall be taken as:

a) In RC and masonry structures: 70 percent of I_{gross} of columns, and 35 percent of I_{gross} of beams; and
b) In steel structures: I_{gross} of both beams and columns.

5.3.4.4 Where a number of modes are to be considered in response spectrum method, A_h as defined in **5.3.4.2** for each mode *k* shall be determined using natural period T_k of oscillation of that mode.

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Table 43 Classification of Types of Soils for Determining the Spectrum to be Used to Estimate Design Earthquake Force
(*Clause* 5.3.4.2.1)

Sl No.	Soil Type	Remarks
(1)	(2)	(3)
i)	**I** Rock or Hard soils	a) Well graded gravel (GW) or well graded sand (SW) both with less than 5 percent passing 75 μm sieve (Fines) b) Well graded gravel-sand mixtures with or without fines (GW-SW) c) Poorly graded sand (SP) or clayey sand (SC), all having *N* above 30 d) Stiff to hard clays having *N* above 30, where *N* is standard penetration test value
ii)	**II** Medium or Stiff soils	a) Poorly graded sands or poorly graded sands with gravel (SP) with little or no fines having *N* between 10 and 30 b) Stiff to medium stiff fine-grained soils, like silts of low compressibility (ML) or clays of low compressibility (CL) having *N* between 10 and 30
iii)	**III** Soft soils	All soft soils other than SP with *N*<10. The various possible soils are: a) Silts of intermediate compressibility (Ml) b) Silts of high compressibility (MH); c) Clays of intermediate compressibility (CI) d) Clays of high compressibility (CH); e) Silts and clays of intermediate to high compressibility (MI-MH or CI-CH) d) Silt with clay of intermediate compressibility (MI-CI) g) Silt with clay of high compressibility (MH-CH).

5.3.4.5 For underground structures and buildings whose base is located at depths of 30 m or more, A_h at the base shall be taken as half the value obtained from **5.3.4.2**. This reduced value shall be used only for estimating inertia effects due to masses at the corresponding levels below the ground; the inertia effects for the above ground portion of the building shall be estimated based on the unreduced value of A_h. For estimating inertia effects due to masses of structures and foundations placed between the ground level and 30 m depth, the design horizontal acceleration spectrum value shall be linearly interpolated between A_h and 0.5 A_h where A_h is as specified in **5.3.4.2**.

5.3.4.6 The design seismic acceleration spectral value A_v for vertical motions shall be taken as:

$$A_v = \begin{cases} \dfrac{\left(\frac{2}{3}\times\frac{Z}{2}\right)(2.5)}{\left(\frac{R}{I}\right)} & \text{For buildings governed by IS 1893 (Part 1)} \\ \dfrac{\left(\frac{2}{3}\times\frac{Z}{2}\right)(2.5)}{\left(\frac{R}{I}\right)} & \text{For liquid retaining tanks governed by IS 1893 (Part 2)} \\ \dfrac{\left(\frac{2}{3}\times\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)} & \text{For bridges governed by IS 1893 (Part 3)} \\ \dfrac{\left(\frac{2}{3}\times\frac{Z}{2}\right)\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)} & \text{For industrial structures governed by IS 1893 (Part 4)} \end{cases}$$

The value of S_a/g shall be based on natural period T corresponding to the first vertical mode of oscillation, using **5.3.4.2**.

5.3.4.7 When design acceleration spectrum is developed specific to a project site, the same may be used for design of structures of the project. In such cases, effects of the site-specific spectrum shall not be less than those arising out of the design spectrum specified in this Section.

5.4 Buildings

The four main desirable attributes of an earthquake resistant building are:

a) Robust structural configuration,
b) At least a minimum elastic lateral stiffness,
c) At least a minimum lateral strength, and
d) Adequate ductility.

5.4.1 *Regular and Irregular Configurations*

Buildings with simple regular geometry and uniformly distributed mass and stiffness in plan and in elevation, suffer much less damage, than buildings with irregular configurations. All efforts shall be made to eliminate irregularities by modifying architectural planning and structural configurations. A building shall be considered to be irregular for the purpose of this Section, even if any one of the conditions given in Tables 44 and 45 is applicable. Limits on irregularities for Seismic Zones III, IV and V and special requirements are laid out in Tables 44 and 45.

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Table 44 Definitions of Irregular Buildings — Plan Irregularities (*see* Fig. 13)
(*Clause* 5.4.1)

Sl No.	Type of Plan Irregularity
(1)	(2)
i)	**Torsional Irregularity** Usually, a well-proportioned building does not twist about its vertical axis, when a) the stiffness distribution of the vertical elements resisting lateral loads is balanced in plan according to the distribution of mass in plan (at each storey level); and b) the floor slabs are stiff in their own plane (this happens when its plan aspect ratio is less than 3) A building is said to be torsionally irregular, when, 1) the maximum horizontal displacement of any floor in the direction of the lateral force at one end of the floor is more than 1.5 times its minimum horizontal displacement at the far end of the same floor in that direction; and 2) the natural period corresponding to the fundamental torsional mode of oscillation is more than those of the first two translational modes of oscillation along each principal plan directions *In torsionally irregular buildings, when the ratio of maximum horizontal displacement at one end and the minimum horizontal displacement at the other end is,* i) *in the range 1.5 – 2.0, (a) the building configuration shall be revised to ensure that the natural period of the fundamental torsional mode of oscillation shall be smaller than those of the first two translational modes along each of the principal plan directions, and then (b) three dimensional dynamic analysis method shall be adopted; and* ii) *more than 2.0, the building configuration shall be revised*
ii)	**Re-entrant Corners** A building is said to have a re-entrant corner in any plan direction, when its structural configuration in plan has a projection of size greater than 15 percent of its overall plan dimension in that direction *In buildings with re-entrant corners, three-dimensional dynamic analysis method shall be adopted*
iii)	**Floor Slabs having Excessive Cut-Outs or Openings** Openings in slabs result in flexible diaphragm behaviour, and hence the lateral shear force is not shared by the frames and/or vertical members in proportion to their lateral translational stiffness. The problem is particularly accentuated when the opening is close to the edge of the slab. A building is said to have discontinuity in their in-plane stiffness, when floor slabs have cut-outs or openings of area more than 50 percent of the full area of the floor slab *In buildings with discontinuity in their in-plane stiffness, if the area of the geometric cut-out is,* a) *less than or equal to 50 percent, the floor slab shall be taken as rigid or flexible depending on the location of and size of openings; and* b) *more than 50 percent, the floor slab shall be taken as flexible*
iv)	**Out-of-Plane Offsets in Vertical Elements** Out-of-plane offsets in vertical elements resisting lateral loads cause discontinuities and detours in the load path, which is known to be detrimental to the earthquake safety of the building. A building is said to have out-of-plane offset in vertical elements, when structural walls or frames are moved out of plane in any storey along the height of the building *In a building with out-of-plane offsets in vertical elements,* *a) specialist literature shall be referred for design of such a building, if the building is located in Seismic Zone II; and* *b) the following two conditions shall be satisfied, if the building is located in Seismic Zones III, IV and V:* 1) *Lateral drift shall be less than 0.2 percent in the storey having the offset and in the storeys below; and* 2) *Specialist literature shall be referred for removing the irregularity arising due to out-of-plane offsets in vertical elements.*
v)	**Non-Parallel Lateral Force System** Buildings undergo complex earthquake behaviour and hence damage, when they do not have lateral force resisting systems oriented along two plan directions that are orthogonal to each other. A building is said to have non-parallel system when the vertically oriented structural systems resisting lateral forces are not oriented along the two principal orthogonal axes in plan *Buildings with non-parallel lateral force resisting system shall be analysed for load combinations mentioned in* **5.3.3.2.2** or **5.3.3.4.1**.

Table 45 Definition of Irregular Buildings — Vertical Irregularities (*see* Fig. 14)
(*Clause* 5.4.1)

Sl No.	Type of Plan Irregularity
(1)	(2)
i)	**Stiffness Irregularity (Soft Storey)** A soft storey is a storey whose lateral stiffness is less than that of the storey above. *The structural plan density (SPD) shall be estimated when unreinforced masonry infills are used. When SPD of masonry infills exceeds 20 percent, the effect of URM infills shall be considered by explicitly modelling the same in structural analysis (as per* **5.4.9***). The design forces for RC members shall be larger of that obtained from analysis of:* *a) Bare frame, and* *b) Frames with URM infills,* using 3D modelling of the structure. In buildings designed considering URM infills, the inter-storey drift shall be limited to 0.2 percent in the storey with stiffening and also in all storeys below.
ii)	**Mass Irregularity** Mass irregularity shall be considered to exist, when the seismic weight *(as per* **5.4.7***)* of any floor is more than 150 percent of that of the floors below. *In buildings with mass irregularity and located in Seismic Zones III, IV and V, the earthquake effects shall be estimated by Dynamic Analysis Method (as per* **5.4.7***).*
iii)	**Vertical Geometric Irregularity** Vertical geometric irregularity shall be considered to exist, when the horizontal dimension of the lateral force resisting

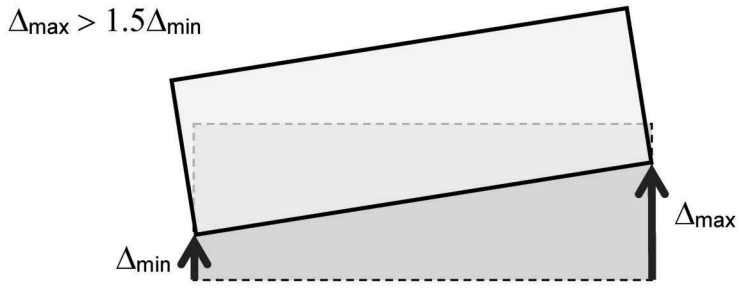
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Table 45 — (*Contined*)

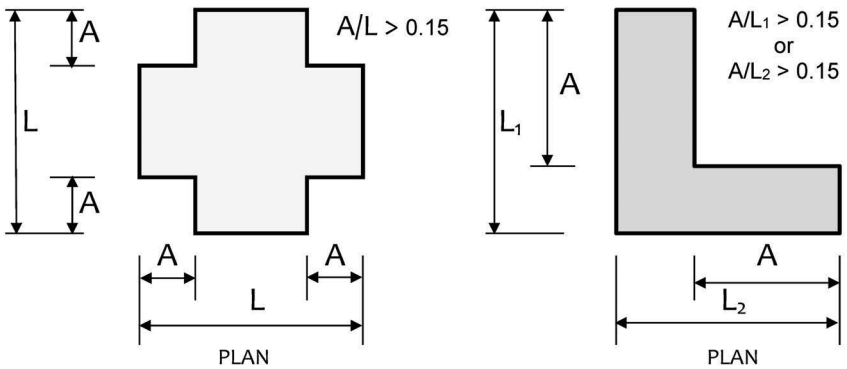
(1)	(2)
	system in any storey is more than 125 percent of the storey below. *In buildings with vertical geometric irregularity and located in Seismic Zones III, IV and V, the earthquake effects shall be estimated by Dynamic Analysis Method (as per* **5.4.7***).*
iv)	**In-Plane Discontinuity in Vertical Elements Resisting Lateral Force** In-plane discontinuity in vertical elements which are resisting lateral force shall be considered to exist, when in-plane offset of the lateral force resisting elements is greater than 20 percent of the plan length of those elements. In buildings with in-plane discontinuity and located in Seismic Zones II, the lateral drift of the building under the design lateral force shall be limited to 0.2 percent of the building height; in Seismic Zones III, IV and V, buildings with in-plane discontinuity shall not be permitted.
v)	**Strength Irregularity (Weak Storey)** A weak storey is a storey whose lateral strength is less than that of the storey above. *In such a case, buildings in Seismic Zones III, IV and V shall be designed such that safety of the building is not jeopardized; also, provisions of* ***5.4.10*** *shall be followed.*
vi)	**Floating or Stub Columns** Such columns are likely to cause concentrated damage in the structure.

Table 45 — (*Concluded*)

(1)	(2)
	This feature is undesirable, and hence should be prohibited, if it is part of or supporting the primary lateral load resisting system.
vii)	**Irregular Modes of Oscillation in Two Principal Plan Directions** Stiffnesses of beams, columns, braces and structural walls determine the lateral stiffness of a building in each principal plan direction. A building is said to have lateral storey irregularity in a principal plan direction, if a) the first three modes contribute less than 65 percent mass participation factor in each principal plan direction, and b) the fundamental lateral natural periods of the building in the two principal plan directions are closer to each other by 10 percent of the larger value. *In buildings located in Seismic Zones II and III, it shall be ensured that the first three modes together contribute at least 65 percent mass participation factor in each principal plan direction. And, in buildings located in Seismic Zones IV and V, it shall be ensured that,* 1) the first three modes together contribute at least 65 percent mass participation factor in each principal plan direction, and 2) the fundamental lateral natural periods of the building in the two principal plan directions are away from each other by at least 10 percent of the larger value.

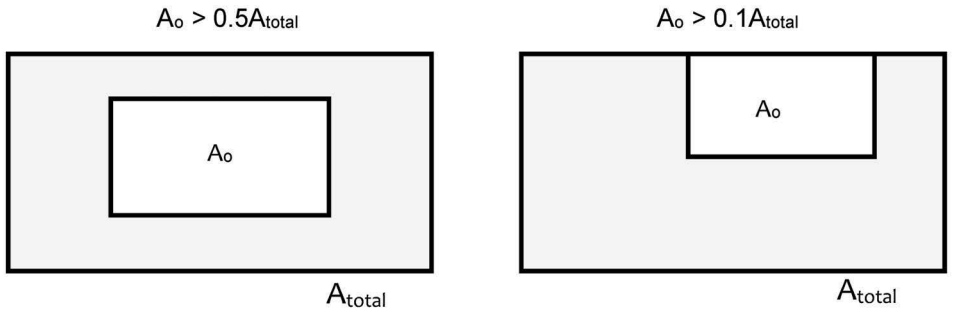


13A TORSIONAL IRREGULARITY



13B RE-ENTRANT CORNERS

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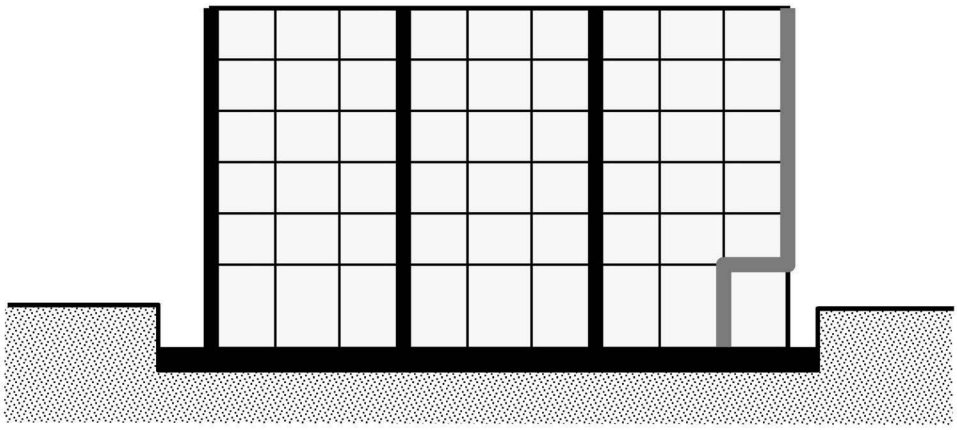
OPENING LOCATED ANYWHERE IN THE SLAB

PLAN

OPENING LOCATED ALONG ANY EDGE OF THE SLAB

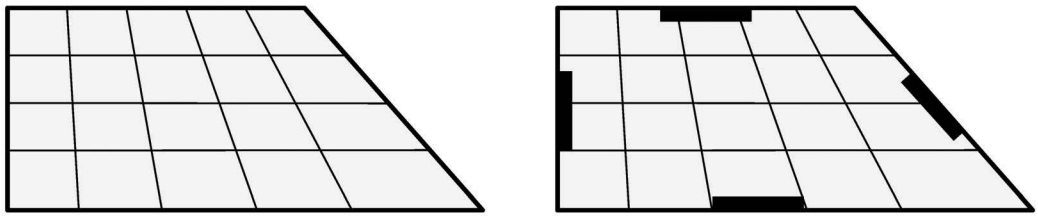
PLAN

13C FLOOR SLABS HAVING EXCESSIVE CUT-OUT AND OPENINGS



ELEVATION

13D OUT-OF-PLANE OFFSETS IN VERTICAL ELEMENTS



PLAN

(i)

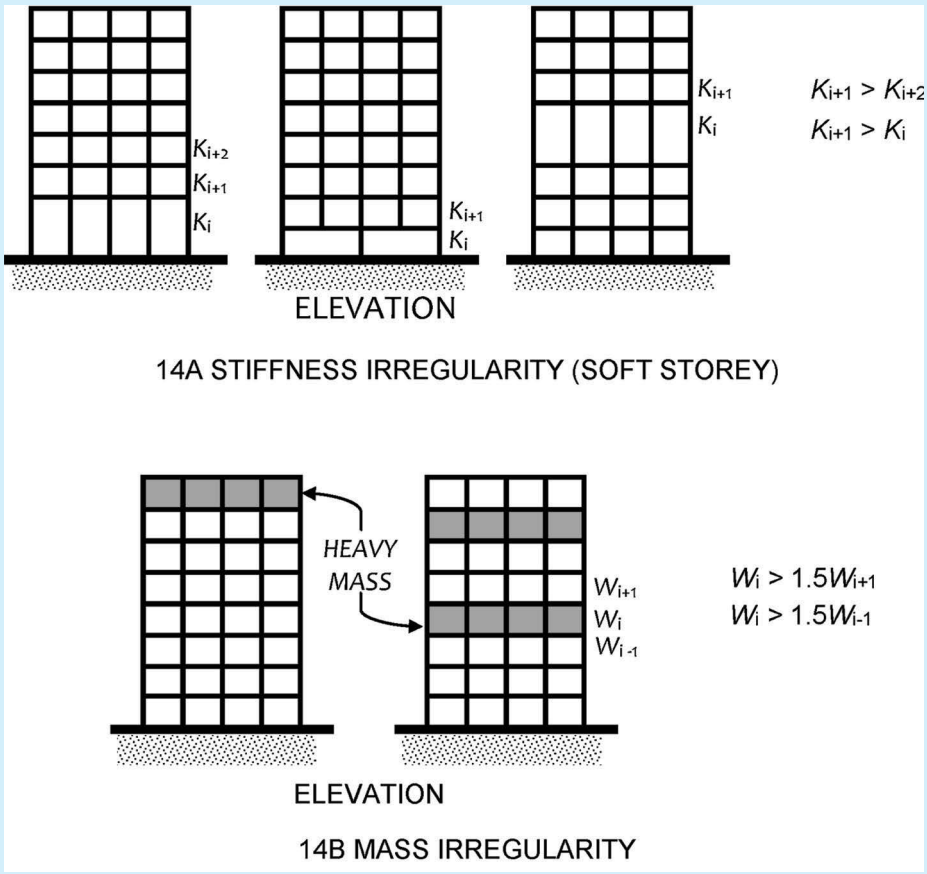
PLAN

(ii)

13E NON-PARALLEL LATERAL FORCE SYSTEM:
(i) MOMENT FRAME BUILDING, and
(ii) MOMENT FRAME BUILDING WITH STRUCTURAL WALLS

FIG. 13 DEFINITIONS OF IRREGULAR BUILDINGS — PLAN IRREGULARITIES

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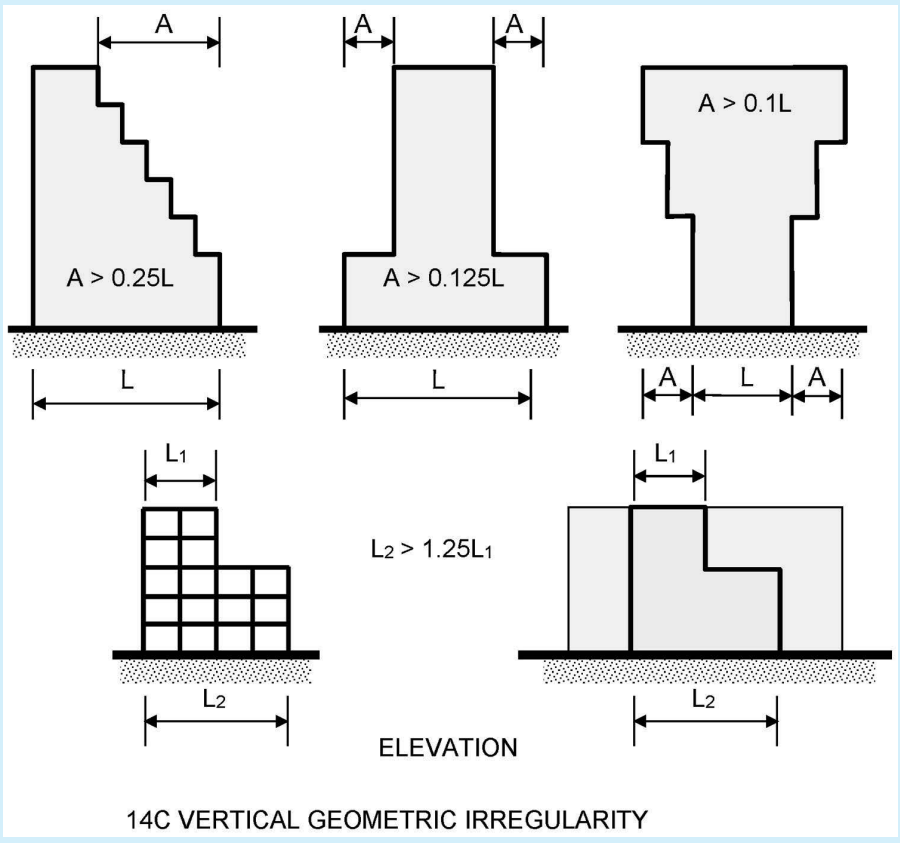
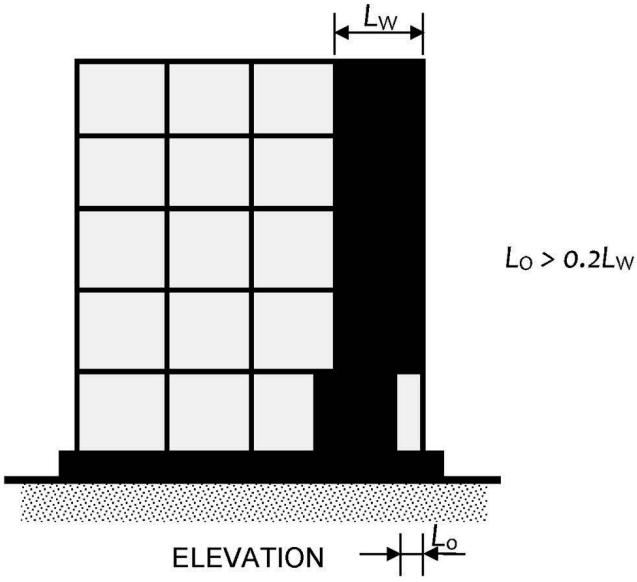
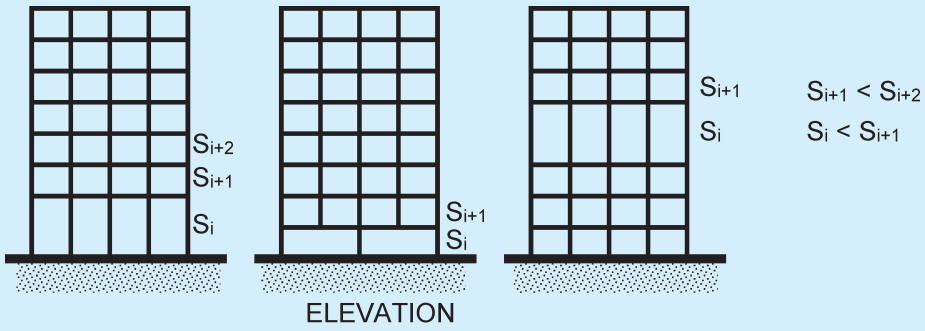


FIG. 14 — (*Continued*)

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14D IN-PLANE DISCONTINUITY IN VERTICAL ELEMENTS RESISTING LATERAL FORCE



14E STRENGTH IRREGULARITY (WEAK STOREY)

FIG. 14 DEFINITIONS OF IRREGULAR BUILDINGS — VERTICAL IRREGULARITIES

5.4.2 *Lateral Force*

5.4.2.1 *Design lateral force*

Buildings shall be designed for the design lateral force V_B given by:

$$V_B = A_h W$$

where A_h shall be estimated as per **5.3.4.2**, and W as per **5.4.4**.

5.4.2.2 *Minimum design lateral force*

Buildings and portions there of shall be designed and constructed to resist at least the effects of design lateral force specified in **5.4.2.1**. But, regardless of design earthquake forces arrived at as per **5.4.3.1**, buildings shall have lateral load resisting systems capable of resisting a horizontal force not less than $(V_B)_{min}$ as given in Table 46.

Table 46 Minimum Design Earthquake Horizontal Lateral Force for Buildings
(*Clause* 5.4.2.2)

Sl No.	Seismic Zone	ρ percent
(1)	(2)	(3)
i)	II	0.7
ii)	III	1.1
iii)	IV	1.6
iv)	V	2.4

5.4.2.3 *Importance factor (I)*

In estimating design lateral force V_B of buildings as per **5.4.2.1**, the importance factor I of buildings shall be taken as per Table 47.

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Table 47 Importance Factor (*I*)
(*Clause* 5.4.2.3)

Sl No.	Structure	I
(1)	(2)	(3)
i)	Important service and community buildings or structures (for example critical governance buildings, schools), signature buildings, monument buildings, lifeline and emergency buildings (for example hospital buildings, telephone exchange buildings, television station buildings, radio station buildings, bus station buildings, metro rail buildings and metro rail station buildings), railway stations, airports, food storage buildings (such as warehouses), fuel station buildings, electric power station buildings, and fire station buildings), and large community hall buildings (for example cinema halls, shopping malls, assembly halls and subway stations) and power station buildings	1.5
ii)	Residential or commercial buildings [other than those listed in Sl No. (i)] with occupancy more than 200 persons	1.2
iii)	All other buildings	1.0

NOTES

1 Owners and design engineers of buildings or structures may choose values of importance factor *I* more than those mentioned above.

2 Buildings or structures covered under Sl No. (iii) may be designed for higher value of importance factor *I*, depending on economy and strategy.

3 In Sl No. (ii), when a building is composed of more than one structurally independent unit, the occupancy size shall be for each of the structurally independent unit of the building.

4 In buildings with mixed occupancies, wherein different *I* factors applicable for the respective occupancies, larger of the importance factor *I* values shall be used for estimating the design earthquake force of the building.

5.4.2.4 *Damping ratio*

The value of damping shall be taken as 5 percent of critical damping for the purposes of estimating A_h in the design lateral force V_B of a building as per **5.4.2.1**, irrespective of the material of construction (namely steel, reinforced concrete, masonry, or a combination thereof of these three basic materials) of its lateral load resisting system, considering that buildings experience inelastic deformations under design level earthquake effects, resulting in much higher energy dissipation than that due to initial structural damping in buildings. This value of damping shall be used, irrespective of the method of the structural analysis employed, namely Equivalent Static Method (as per **5.4.6**) or Dynamic Analysis Method (as per **5.4.7**).

5.4.2.5 *Design acceleration spectrum*

Design acceleration coefficient S_a/g corresponding to 5 percent damping for different soil types, normalized to peak ground acceleration, corresponding to natural period *T* of structure considering soil-structure interaction, irrespective of the material of construction of the structure. S_a/g shall be as given by expressions in **5.3.4.2**.

5.4.2.6 *Response reduction factor (R)*

Response reduction factor, along with damping during extreme shaking and redundancy: (a) influences the nonlinear behaviour of buildings during strong earthquake shaking, and (b) accounts for inherent system ductility, redundancy and overstrength normally available in buildings, if designed and detailed as per this Section and the associated Indian Standards.

For the purpose of design as per this Section, response reduction factor *R* for different building systems shall be as given in Table 48. The values of *R* shall be used for design of buildings with lateral load resisting elements, and NOT for just the lateral load resisting elements, which are built in isolation.

5.4.2.7 *Dual system*

Buildings with dual system consist of moment resisting frames and structural walls (or of moment resisting frames and bracings) such that both of the following conditions are valid:

a) Two systems are designed to resist total design lateral force in proportion to their lateral stiffness, considering interaction of two systems at all floor levels; and

b) Moment resisting frames are designed to resist independently at least 25 percent of the design base shear.

5.4.3 *Design Imposed Loads for Earthquake Force Calculation*

5.4.3.1 For various loading classes specified in **3**, design seismic force shall be estimated using full dead load plus percentage of imposed load as given in Table 49. The same shall be used in the three-dimensional dynamic analysis of buildings also.

5.4.3.2 For calculation of design seismic forces of buildings, imposed load on roof need not be considered. But, weights of equipment and other permanently fixed facilities should be considered; in such a case, the reductions of imposed loads mentioned in Table 49 are not applicable to that part of the load.

5.4.3.3 Imposed load values indicated in Table 49 for calculating design earthquake lateral forces are applicable to normal conditions. When loads during earthquakes are more accurately assessed, designers may alter imposed load values indicated or even replace the entire imposed load given in Table 49 with actual assessed load values, subject to the values given in Table 46 as the minimum values. Where imposed load is not assessed as per **5.4.3.1** and **5.4.3.2**,

a) only that part of imposed load, which possesses mass, shall be considered; and

b) lateral earthquake design force shall not be calculated on contribution of impact effects from imposed loads.

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Table 48 Response Reduction Factor *R* for Building Systems
(*Clause* 5.4.2.6)

Sl No. (1)	Lateral Load Resisting System (2)	R (3)
i)	**Moment Frame Systems**	
	a) RC buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	b) RC buildings with special moment resisting frame (SMRF)	5.0
	c) Steel buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	d) Steel buildings with special moment resisting frame (SMRF)	5.0
ii)	**Braced Frame Systems** (*see* Note 2)	
	a) Buildings with ordinary braced frame (OBF) having concentric braces	4.0
	b) Buildings with special braced frame (SBF) having concentric braces	4.5
	c) Buildings with special braced frame (SBF) having eccentric braces	5.0
iii)	**Structural Wall Systems** (*see* Note 3)	
	a) Load bearing masonry buildings	
	1) Unreinforced masonry {designed as per good practice [6-1(19)]} without horizontal RC seismic bands (*see* Note 1)	1.5
	2) Unreinforced masonry {designed as per good practice [6-1(19)]} with horizontal RC seismic bands	2.0
	3) Unreinforced masonry {designed as per good practice [6-1(19)]} with horizontal RC seismic bands and vertical reinforcing bars at corners of rooms and jambs of openings {with reinforcement as per good practice [6-1(20)]}	2.5
	4) Reinforced masonry [*see* Part 6 'Structural Design, Section 4 Masonry' of the Code]	3.0
	5) Confined masonry	3.0
	b) Buildings with ordinary RC structural walls (*see* Note 1)	3.0
	c) Buildings with ductile RC structural walls	4.0
iv)	**Dual Systems** (*see* Note 3)	
	a) Buildings with ordinary RC structural walls and RC OMRFs (*see* Note 1)	3.0
	b) Buildings with ordinary RC structural walls and RC SMRFs (*see* Note 1)	4.0
	c) Buildings with ductile RC structural walls with RC OMRFs (*see* Note 1)	4.0
	d) Buildings with ductile RC structural walls with RC SMRFs	5.0
v)	**Flat Slab – Structural Wall Systems** (*see* Note 4)	
	RC building with the three features given below:	3.0
	a) Ductile RC structural walls (which are designed to resist 100 percent of the design lateral force),	
	b) Perimeter RC SMRFs (which are designed to independently resist 25 percent of the design lateral force), and preferably	
	c) An outrigger and belt truss system connecting the core ductile RC structural walls and the perimeter RC SMRFs (*see* Note 1).	

NOTES

1 RC and steel structures in Seismic Zones III, IV and V shall be designed to be ductile. Hence, this system is not allowed in these seismic zones.

2 Eccentric braces shall be used only with SBFs.

3 Buildings with structural walls also include buildings having structural walls and moment frames, but where,

a) frames are not designed to carry design lateral loads, or

b) frames are designed to carry design lateral loads, but do not fulfill the requirements of 'dual systems'.

4 In these buildings, (a) punching shear failure shall be avoided, and (b) lateral drift at the roof under design lateral force shall not exceed 0.1 percent.

Table 49 Percentage of Imposed Load to be Considered in Calculation of Seismic Weight
(*Clauses* 5.4.3.1)

Sl No.	Imposed Uniformity Distributed Floor Loads kN/m^2	Percentage of Imposed Load
(1)	(2)	(3)
i)	Up to and including 3.0	25
ii)	Above 3.0	50

5.4.3.4 Loads other than those given above (for example snow and permanent equipment) shall be considered appropriately.

5.4.3.5 In regions of severe snow loads and sand storms exceeding intensity of 1.5 kN/m^2, 20 percent of uniform design snow load or sand load respectively, shall be included in the estimation of seismic weight. In case the minimum values of seismic weights corresponding to these load effects given in **2**, **3**, **4**, **6** and **7** are higher, the higher values shall be used.

5.4.3.6 In buildings that have interior partitions, the weight of these partitions on floors shall be included in the estimation of seismic weight; this value shall not

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be less than 0.5 kN/m^2. In case the minimum values of seismic weights corresponding to partitions given in **2**, **3**, **4**, **6** and **7** are higher, the higher values shall be used. It shall be ensured that the weights of these partitions shall be considered only in estimating inertial effects of the building.

5.4.4 *Seismic Weight*

5.4.4.1 *Seismic weight of floors*

Seismic weight of each floor is its full dead load plus appropriate amount of imposed load, as specified in **5.4.3**. While computing the seismic weight of each floor, the weight of columns and walls in any storey shall be appropriately apportioned to the floors above and below the storey.

5.4.4.2 Any weight supported in between storeys shall be distributed to floors above and below in inverse proportion to its distance from the floors.

5.4.6 *Equivalent Static Method*

As per this method, first, the design base shear V_B shall be computed for the building as a whole. Then, this V_B shall be distributed to the various floor levels at the corresponding centre of mass. And, finally, this design seismic force at each floor level shall be distributed to individual lateral load resisting elements through structural analysis considering the floor diaphragm action. This method shall be applicable for regular buildings with height less than 15 m in Seismic Zone II.

5.4.6.1 The design base shear V_B along any principal direction of a building shall be determined by:

$$V_B = A_h W$$

where

A_h = design horizontal acceleration coefficient value as per **5.3.4.2**, using approximate fundamental natural period T_a as per **5.4.6.2** along the considered direction of shaking; and

W = seismic weight of the building as per **5.4.4.2**.

5.4.6.2 The approximate fundamental translational natural period T_a of oscillation, in second, shall be estimated by the following expressions:

a) Bare MRF buildings (without any masonry infills):

$$T_a = \begin{cases} 0.075h^{0.75} & \text{(for RC MRF building)} \\ 0.080h^{0.75} & \text{(for RC-Steel Composite MRF building)} \\ 0.085h^{0.75} & \text{(for steel MRF building)} \end{cases}$$

where

h = height (in m) of building (*see* Fig. 15). This excludes the basement storeys, where basement storey, walls are connected with the ground floor deck or fitted between the building columns, but includes the basement storeys, when they are not so connected.

b) Buildings with RC structural walls:

$$T_a = \frac{0.075h^{0.75}}{\sqrt{A_w}} \geq \frac{0.09h}{\sqrt{d}}$$

where A_w is total effective area (m^2) of walls in the first storey of the building given by:

$$A_w = \sum_{i=1}^{N_w} \left[A_{wi} \left\{ 0.2 + \left(\frac{L_{wi}}{h} \right)^2 \right\} \right]$$

where

h = height of building as defined in **5.4.6.2**(a), in m;

A_{wi} = effective cross-sectional area of wall i in first storey of building, in m^2;

L_{wi} = length of structural wall i in first storey in the considered direction of lateral forces, in m;

d = base dimension of the building at the plinth level along the considered direction of earthquake shaking, in m; and

N_w = number of walls in the considered direction of earthquake shaking.

The value of L_{wi}/h to be used in this equation shall not exceed 0.9.

c) All other buildings:

$$T_a = \frac{0.09h}{\sqrt{d}}$$

where

h = height of building, as defined in **5.4.6.2**(a), in m; and

d = base dimension of the building at the plinth level along the considered direction of earthquake shaking, in m.

5.4.6.3 The design base shear (V_B) computed in **5.4.6.1** shall be distributed along the height of the building and in plan at each floor level as below:

a) *Vertical distribution of base shear to different floor levels* — The design base shear V_B computed in **5.4.6.1** shall be distributed along the height of the building as per the following expression:

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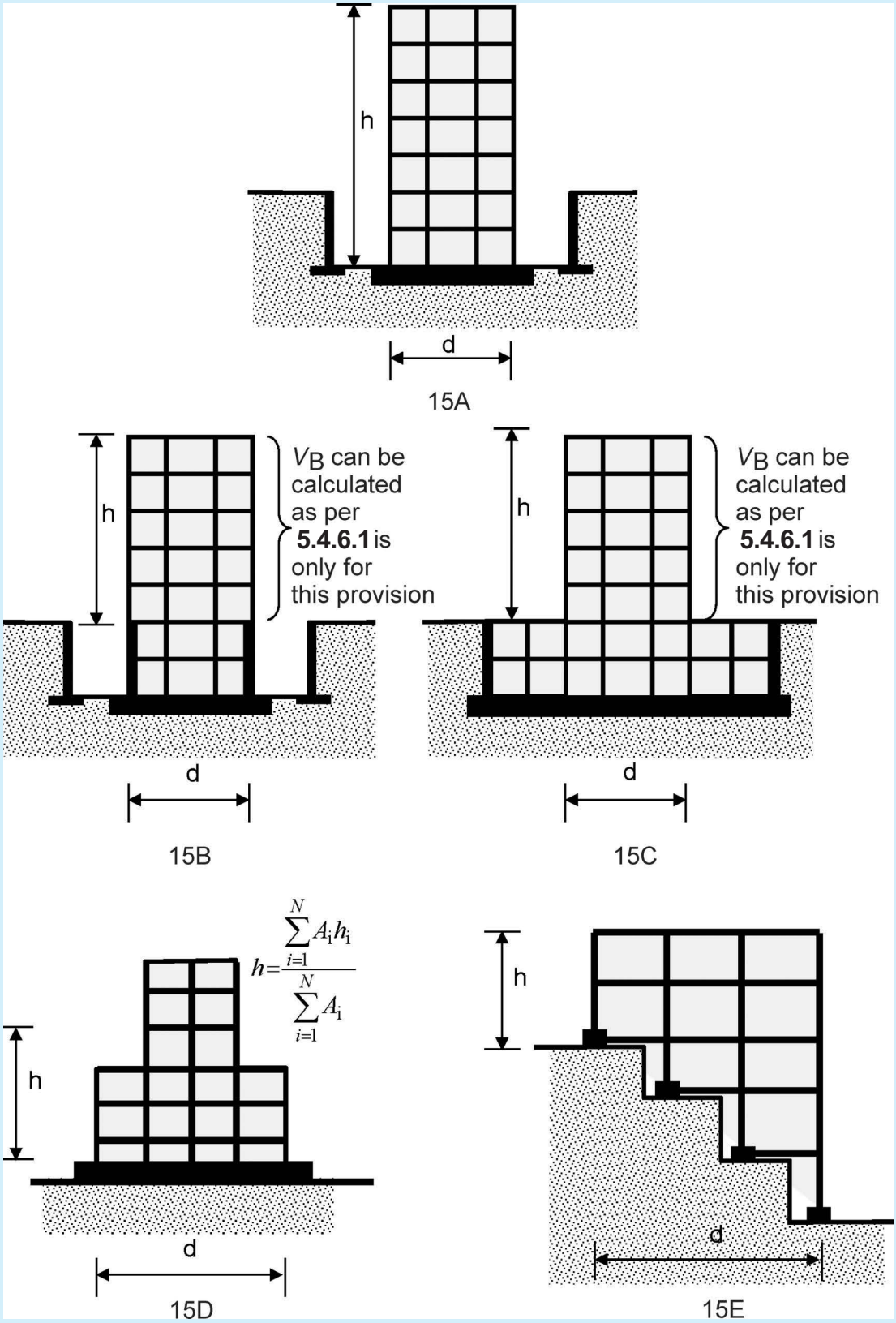


FIG. 15 DEFINITIONS OF HEIGHT AND BASE WIDTH OF BUILDINGS

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$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B,$$

where

Q_i = design lateral force at floor i;

W_i = seismic weight of floor i;

h_i = height of floor i measured from base; and

n = number of storeys in building, that is, number of levels at which masses are located.

b) *In-plan distribution of design lateral force at floor i to different lateral force resisting elements* — The design storey shear in any storey shall be calculated by summing the design lateral forces at all floor above that storey. In buildings whose floors are capable of providing rigid horizontal diaphragm action in their own plane, the design storey shear shall be distributed to the various vertical elements of lateral force resisting system in proportion to the lateral stiffness of these vertical elements.

5.4.6.4 *Diaphragm*

In buildings whose floor diaphragms cannot provide rigid horizontal diaphragm action in their own plane, design storey shear shall be distributed to the various vertical elements of lateral force resisting system considering the in-plane flexibility of the diaphragms.

A floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the diaphragm is more than 1.2 times the average displacement of the entire diaphragm (*see* Fig. 16).

Usually, reinforced concrete monolithic slab-beam floors or those consisting of prefabricated or precast elements with reasonable reinforced screed concrete (at least a minimum of 50 mm on floors and of 75 mm on roof, with at least a minimum reinforcement of 6 mm bars spaced at 150 mm centres) as topping, and of plan aspect ratio less than 3, can be considered to be providing rigid diaphragm action.

5.4.7 *Dynamic Analysis Method*

5.4.7.1 Linear dynamic analysis shall be performed to obtain the design lateral force (design seismic base shear, and its distribution to different levels along the height of the building, and to various lateral load resisting elements) for all buildings, other than regular buildings lower than 15 m in Seismic Zone II.

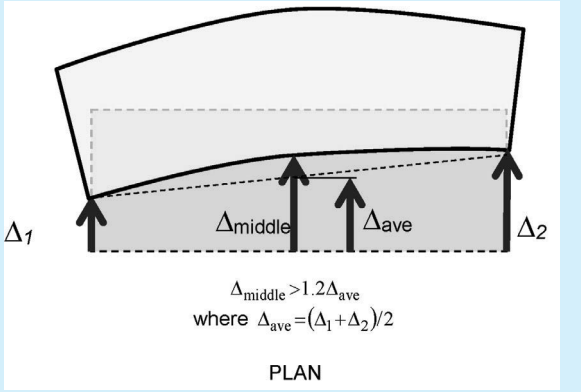


FIG. 16 DEFINITION OF FLEXIBLE FLOOR DIAPHRAGM

5.4.7.2 The analytical model for dynamic analysis of buildings with unusual configuration should be such that it adequately represents irregularities present in the building configuration.

5.4.7.3 Dynamic analysis may be performed by either the Time History Method or the Response Spectrum Method. When either of the methods is used, the design base shear V_B estimated shall not be less than the design base shear $\overline{V}_B$ calculated using a fundamental period T_a, where T_a is as per **5.4.6.2**.

When V_B is less than $\overline{V}_B$, the force response quantities (for example member stress resultants, storey shear forces, and base reactions) shall be multiplied by $\overline{V}_B/V_B$.

For earthquake shaking considered along,

a) the two mutually perpendicular plan directions X and Y, separate multiplying factors shall be calculated, namely $\overline{V}_{BX}/V_{BX}$ and $\overline{V}_{BY}/V_{BY}$, respectively; and

b) the vertical Z direction, the multiplying factor shall be taken as

Max $[\overline{V}_{BX}/V_{BX}; \overline{V}_{BY}/V_{BY}]$

5.4.7.4 *Time history method*

Time history method shall be based on an appropriate ground motion (preferably compatible with the design acceleration spectrum in the desired range of natural periods) and shall be performed using accepted principles of earthquake structural dynamics.

5.4.7.5 *Response spectrum method*

Response spectrum method may be performed for any building using the design acceleration spectrum

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specified in **5.3.4.2**, or by a site-specific design acceleration spectrum mentioned in **5.3.4.7**.

5.4.7.5.1 *Natural modes of oscillation*

Undamped free vibration analysis of the entire building shall be performed as per established methods of structural dynamics using appropriate mass and elastic stiffness of the structural system, to obtain natural periods T_k and mode shapes $\{\phi\}_k$ of those of its N_m modes of oscillation [$k \in [1, N_m]$] that need to be considered as per **5.4.7.5.2**.

5.4.7.5.2 *Number of modes to be considered*

The number of modes N_m to be used in the analysis for earthquake shaking along a considered direction, should be such that the sum total of modal masses of these modes considered is at least 90 percent of the total seismic mass.

If modes with natural frequencies beyond 33 Hz are to be considered, the modal combination shall be carried out only for modes with natural frequency less than 33 Hz; the effect of modes with natural frequencies more than 33 Hz shall be included by the missing mass correction procedure following established principles of structural dynamics. If justified by rigorous analysis, designers may use a cut off frequency other than 33 Hz.

5.4.7.5.3 *Combination of modes*

The responses of different modes considered shall be combined by one of the two methods given below:

a) Peak response quantities (for example member forces, displacements, storey forces, storey shears, and base reactions) may be combined as per Complete Quadratic Combination (CQC) method, as given below:

$$\lambda = \sqrt{\sum_{i=1}^{N_m} \sum_{j=1}^{N_m} \lambda_i \ \rho_{ij} \ \lambda_j}$$

where

λ = estimate of peak response quantity;

λ_i = response quantity in mode *i* (with sign);

λ_{ij} = response quantity in mode *j* (with sign);

ρ_{ij} = cross-modal correlation co-efficient

$$= \frac{8\zeta^2(1+\beta)\beta^{1.5}}{(1-\beta^2)^2 + 4\zeta^2\beta(1+\beta)^2};$$

N_m = number of modes considered;

ζ = modal damping coefficient ratio which shall be taken as 0.05;

β = natural frequency ratio = $\frac{\omega_j}{\omega_i}$;

ω_j = circular natural frequency in mode *j*; and

ω_i = circular natural frequency in mode *i*.

b) Alternatively, the peak response quantities may be combined as follows:

1) If building does not have closely-spaced modes, then net peak response quantity λ due to all modes considered shall be estimated as:

$$\lambda = \sqrt{\sum_{k=1}^{N_m} (\lambda_k)^2}$$

where

λ_k = peak response quantity in mode *k*, and

N_m = number of modes considered.

2) If building has a few closely-spaced modes, then net peak response quantity λ^* due to these closely space modes alone shall be obtained as:

$$\lambda^* = \sum_c |\lambda_c|$$

where

λ_c = peak response quantity in closely spaced mode *c*. The summation is for closely spaced modes only. Then, this peak response quantity λ^* due to closely spaced modes is combined with those of remaining well-separated modes by method described above.

5.4.7.5.4 *Simplified method of dynamic analysis of buildings*

Regular buildings may be analysed as a system of masses lumped at the floor levels with each mass having one degree of freedom, that of lateral displacement in the direction under consideration. In such a case, the following expressions shall hold in the computation of the various quantities:

a) *Modal mass* — Modal mass M_k of mode *k* is given by:

$$M_k = \frac{\left[\sum_{i=1}^{n} W_i \phi_{ik}\right]^2}{g \sum_{i=1}^{n} W_i (\phi_{ik})^2}$$

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where

g = acceleration due to gravity,

ϕ_{ik} = mode shape coefficient at floor i in mode k,

W_i = seismic weight of floor i of the structure, and

n = number of floors of the structure.

b) *Mode participation factor* — Mode participation factor P_k of mode k is given by:

$$P_k = \frac{\sum_{i=1}^{n} W_i \phi_{ik}}{\sum_{i=1}^{n} W_i (\phi_{ik})^2}$$

c) *Design lateral force at each floor in each mode* — Peak lateral force Q_{ik} at floor i in mode k is given by:

$$Q_{ik} = A_k \phi_{ik} P_k W_i$$

where

A_k = design horizontal acceleration spectrum value as per **5.3.4.2** using natural period of oscillation T_k of mode k obtained from dynamic analysis.

d) *Storey shear forces in each mode* — Peak *shear force* V_{ik} acting in storey i in mode k is given by:

$$V_{ik} = \sum_{j=i+1}^{n} Q_{ik}$$

e) *Storey shear force due to all modes considered* — Peak storey shear force V_i in storey i due to all modes considered, shall be obtained by combining those due to each mode in accordance with **5.4.7.5.3**.

f) *Lateral forces at each storey due to all modes considered* — Design lateral forces F_{roof} at roof level and F_i at level of floor i shall be obtained as:

$$F_{roof} = V_{roof}, \text{ and}$$

$$F_i = V_i - V_{i+1}.$$

5.4.8 *Torsion*

5.4.8.1 Provision shall be made in all buildings for increase in shear forces on the lateral force resisting elements resulting from twisting about the vertical axis of the building, arising due to eccentricity between the centre of mass and centre of resistance at the floor levels. The design forces calculated as in **5.4.6** and **5.4.7.5** shall be applied at the displaced centre of mass so as to cause design eccentricity (as given by **5.4.8.2**) between the displaced centre of mass and centre of resistance.

5.4.8.2 *Design eccentricity*

While performing structural analysis by the Seismic Coefficient Method or the Response Spectrum Method, the design eccentricity e_{di} to be used at floor i shall be taken as:

$$e_{di} = \begin{cases} 1.5e_{si} + 0.05b_i \\ e_{si} - 0.05b_i \end{cases}$$

whichever gives the more severe effect on lateral force resisting elements;

where

e_{si} = static eccentricity at floor i,

= distance between centre of mass and centre of stiffness, and

b_i = floor plan dimension of floor i, perpendicular to the direction of force.

The factor 1.5 represents dynamic amplification factor, and $0.05b_i$ represents the extent of accidental eccentricity. The above amplification of 1.5 need not be used, when performing structural analysis by the Time History Method.

5.4.9 *RC Frame Buildings with Unreinforced Masonry Infill Walls*

5.4.9.1 In RC buildings with moment resisting frames and unreinforced masonry (URM) infill walls, variation of storey stiffness and storey strength shall be examined along the height of the building considering in-plane stiffness and strength of URM infill walls. If storey stiffness and strength variations along the height of the building render it to be irregular as per Table 45, the irregularity shall be corrected especially in Seismic Zones III, IV and V.

5.4.9.2 The estimation of in-plane stiffness and strength of URM infill walls shall be based on provisions given hereunder.

5.4.9.2.1 The modulus of elasticity E_m (in MPa) of masonry infill wall shall be taken as:

$$E_m = 550 f_m$$

where f_m is the compressive strength of masonry prism (in MPa) obtained as per good practice [6-1(19)] or given by expression:

$$f_m = 0.433 f_b^{0.64} f_{mo}^{0.36}$$

where

f_b = compressive strength of brick, in MPa and

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f_{mo} = compressive strength of mortar, in MPa.

5.4.9.2.2 URM infill walls shall be modeled by using equivalent diagonal struts as below:

a) Ends of diagonal struts shall be considered to be pin-jointed to RC frame;

b) For URM infill walls without any opening, width w_{ds} of equivalent diagonal strut (*see* Fig. 17) shall be taken as:

$$w_{ds} = 0.175\alpha_h^{-0.4} L_{ds}$$

where

$$\alpha_h = h\left(\sqrt[4]{\frac{E_m t \sin 2\theta}{4E_f I_c h}}\right)$$

where E_m and E_f are the moduli of elasticity of the materials of the URM infill and RC MRF, I_c the moment of inertia of the adjoining column, t the thickness of the infill wall, and θ the angle of the diagonal strut with the horizontal;

c) For URM infill walls with openings, no reduction in strut width is required; and

d) Thickness of the equivalent diagonal strut shall be taken as thickness t of original URM infill wall, provided $h/t < 12$ and $l/t < 12$, where h is clear height of URM infill wall between the top beam and bottom floor slab, and l clear length of the URM infill wall between the vertical RC elements (columns, walls or a combination thereof) between which it spans.

5.4.10 *RC Frame Buildings with Open Storeys*

5.4.10.1 RC moment resisting frame buildings, which have open storey(s) at any level, such as due to discontinuation of unreinforced masonry (URM) infill walls or of structural walls, are known to have flexible and weak storeys as per Table 45. In such buildings, suitable measures shall be adopted, which increase both stiffness and strength to the required level in the open storey and the storeys below. These measures shall be taken along both plan directions as per requirements laid down under **5.4.10.2** to **5.4.10.4**. The said increase may be achieved by providing measures, like:

a) RC structural walls, or

b) Braced frames, in select bays of the building.

5.4.10.2 When the RC structural walls are provided, they shall be,

a) founded on properly designed foundations;

b) continuous preferably over the full height of the building; and

c) connected preferably to the moment resisting frame of the building.

5.4.10.3 When the RC structural walls are provided, they shall be designed such that the building does NOT have the following:

a) Additional torsional irregularity in plan than that already present in the building. In assessing this, lateral stiffness shall be included of all elements that resist lateral actions at all levels of the building;

b) Lateral stiffness in the open storey(s) is less

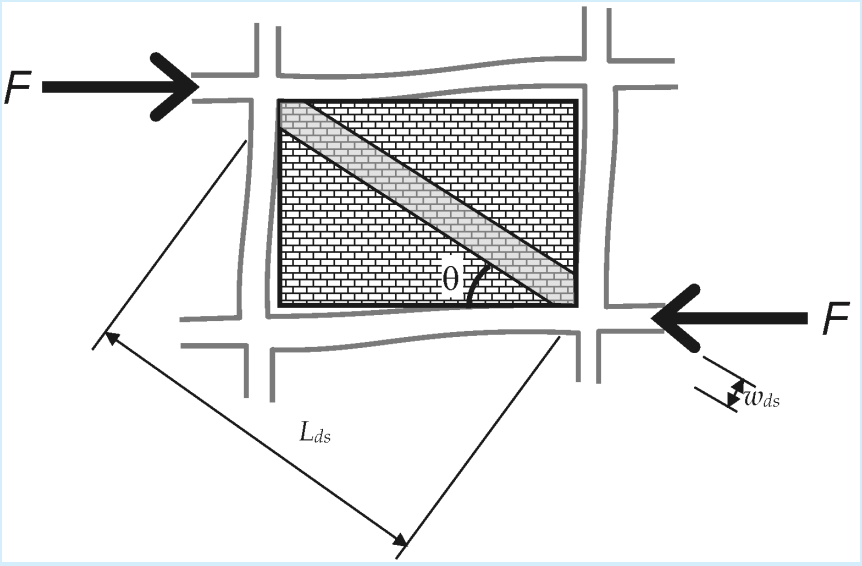


FIG. 17 EQUIVALENT DIAGONAL STRUT OF URM INFILL WALL

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than 80 percent of that in the storey above; and

c) Lateral strength in the open storey(s) is less than 90 percent of that in the storey above.

5.4.10.4 When the RC structural walls are provided, the RC structural wall plan density ρ_{sw} of the building shall be at least 2 percent along each principal direction in Seismic Zones III, IV and V. These walls shall be well distributed in the plan of the building along each plan direction. RC structural walls of this measure can be adopted even in regular buildings that do not have open storey(s).

5.4.10.5 RC structural walls in buildings located in Seismic Zones III, IV and V shall be designed and detailed to comply with all requirements of good practice [6-1(8)].

5.4.11 *Deformation*

Deformation of RC buildings shall be obtained from structural analysis using a structural model based on section properties given in **5.3.4.3**.

5.4.11.1 *Storey drift limitation*

5.4.11.1.1 Storey drift in any storey shall not exceed 0.004 times the storey height, under the action of design base of shear V_B with no load factors mentioned in **5.3.3**, that is, with partial safety factor for all loads taken as 1.0.

5.4.11.1.2 Displacement estimates obtained from dynamic analysis methods shall not be scaled as given in **5.4.7.3.**

5.4.11.2 *Deformation capability of non-seismic members*

For buildings located in Seismic Zones III, IV and V, it shall be ensured that structural components, that are not a part of seismic force resisting system in considered direction of ground motion but are monolithically connected, do not lose their vertical load-carrying capacity under induced net stress resultants, including additional bending moments and shear forces resulting from storey deformations equal to R times storey displacements calculated as per **5.4.11.1**, where R is specified in Table 48.

5.4.11.3 *Separation between adjacent units*

Two adjacent buildings, or two adjacent units of the same building with separation joint between them, shall be separated by a distance equal to R times sum of storey displacements Δ_1 and Δ_2 calculated as per **5.4.11.1** of the two buildings or two units of the same building, to avoid pounding as the two buildings or two units of the same building oscillate towards each other.

When floor levels of the adjacent units of a building or buildings are at the same level, the separation distance shall be calculated as $(R_1\Delta_1 + R_2\Delta_2)/2$, where R_1 and Δ_1 correspond to building 1, and R_2 and Δ_2 to building 2.

5.4.12 *Miscellaneous*

5.4.12.1 *Foundations*

Isolated RC footings without tie beams or unreinforced strip foundations, shall not be adopted in buildings rested on soft soils (with corrected $N < 10$) in any Seismic Zone. Use of foundations vulnerable to significant differential settlement due to ground shaking shall be avoided in buildings located in Seismic Zones III, IV and V.

Individual spread footings or pile caps shall be interconnected with ties (*see* **5.3.4.1** of good practice [6-1(20)]), except when individual spread footings are directly supported on rock, in buildings located in Seismic Zones IV and V. All ties shall be capable of carrying, in tension and in compression, an axial force equal to $A_h/4$ times the larger of the column or pile cap load, in addition to the otherwise computed forces, subject to a minimum of 5 percent of larger of column or pile cap loads. Here, A_h is as per **5.3.4.2**.

Pile shall be designed and constructed to withstand maximum curvature imposed (structural response) by earthquake ground shaking. Design of anchorage of piles into the pile cap shall consider combined effects, including that of axial forces due to uplift and bending moments due to fixity to pile cap.

5.4.12.2 *Cantilever projections*

5.4.12.2.1 *Vertical projections*

Small-sized facilities (like towers, tanks, parapets, smoke stacks/chimneys) and other vertical cantilever projections attached to buildings and projecting vertically above the roof, but not a part of the structural system of the building, shall be designed and checked for stability for five times the design horizontal seismic coefficient A_h specified in **5.3.4.2** for that building. In the analysis of the building, weights of these projecting elements shall be lumped with the roof weight.

5.4.12.2.2 *Horizontal projections*

All horizontal projections of buildings (like cantilever structural members at the porch level or higher) or attached to buildings (like brackets, cornices and balconies) shall be designed for five times the design

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vertical coefficient A_v specified in **5.3.4.6** for that building.

5.4.12.2.3 The increased design forces specified in **5.4.12.2.1** and **5.4.12.2.2** are only for designing the projecting parts and their connections with the main structures, and NOT for the design of the main structure.

5.4.12.3 *Compound walls*

Compound walls shall be designed for the design horizontal coefficient A_h of $1.25Z$, that is, A_h calculated using **5.3.4.2** with $I = 1$, $R = 1$ and $S_a/g = 2.5$.

5.4.12.4 *Connections between parts*

All small items and objects of a building shall be tied to the building or to each other to act as single unit, except those between the separation joints and seismic joints. These connections shall be made capable of transmitting the forces induced in them, but not less than 0.05 times weight of total dead and imposed load reactions; frictional resistance shall not be relied upon in these calculations.

6 SNOW LOAD

6.1 This clause deals with snow loads on roofs of buildings. Roofs should be designed for the actual load due to snow or for the imposed loads specified in **3**, whichever is more severe.

NOTE — Mountainous regions in northern parts of India are subjected to snow fall. In India, part of Jammu and Kashmir (Baramulla District, Srinagar District, Anantnag District, and Leh and Kargil District); Punjab and Himachal Pradesh (Chamba, Kullu, Kinnaur District, Mandi District, Sirmaur District and Simla District); and Uttarakhand (Dehra Dun District, Tehri Garhwal District, Almora District, Pithoragarh District and Nainital District) experience snow fall of varying depths two or three times in a year.

6.2 Notations

a) μ (Dimensionless) — Nominal values of the shape coefficients, taking into account snow drifts, sliding snow, etc, with subscripts, if necessary.

b) l_i (metre) — Horizontal dimension with numerical subscripts, if necessary.

c) h_i (metre) — Vertical dimensions with numerical subscripts, if necessary.

d) β_i (degree) — Roof slope.

e) s_o (pascal) — Snow load on ground.

f) s_i (pascal) — Snow load on roofs.

6.3 Snow Load in Roof(s)

6.3.1 The minimum design snow load on a roof area or any other area above ground which is subjected to snow accumulation is obtained by multiplying the snow load on ground, s_o by the shape coefficient μ, as applicable to the particular roof area considered, expressed as:

$$s = \mu s_o$$

where

s = design snow load on plan area of roof, in Pa;

μ = shape coefficient (*see* **6.4**); and

s_o = ground snow load, in Pa (1 Pa=1 N/m^2).

NOTE — Ground snow load at any place depends on the critical combination of the maximum depth of undisturbed aggregate cumulative snow fall and its average density. In due course the characteristic snow load on ground for different regions will be included based on studies. Till such time the users of this code are advised to contact either Snow and Avalanches Study Establishment (Defence Research and Development Organization), Manali (HP) or India Meteorological Department (IMD), Pune in the absence of any specific information for any location.

6.4 Shape Coefficients

6.4.1 *General Principles*

In perfectly calm weather, falling snow would cover roofs and the ground with a uniform blanket of snow, and the design snow load could be considered as a uniformly distributed load. Truly uniform loading conditions, however, are rare and have usually only been observed in areas that are sheltered on all sides by high trees, buildings, etc. In such a case, the shape coefficient would be equal to unity.

In most regions, snow-falls are accompanied or followed by winds. The winds will redistribute the snow, and on some roofs especially multilevel roofs, the accumulated drift load may reach a multiple of the ground load. Roofs which are sheltered by other buildings, vegetation, etc, may collect more snow load than the ground level. The phenomenon is of the same nature as that illustrated for multilevel roofs in **6.4.2.4**.

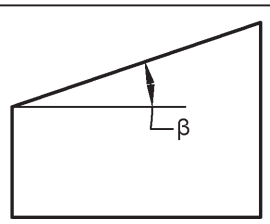
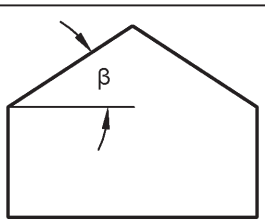
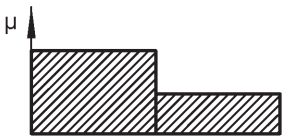
So far, sufficient data are not available to determine the shape coefficient on a statistical basis. Therefore, a nominal value is given. A representative sample of roofs is shown in **6.4.2**. However, in special cases such as strip loading, cleaning of the roof periodically by deliberate heating of the roof, etc, have to be treated separately.

The distribution of snow in the direction parallel to the caves is assumed to be uniform.

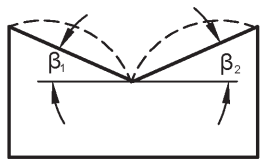
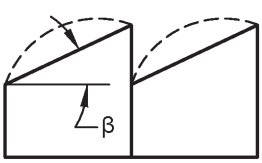
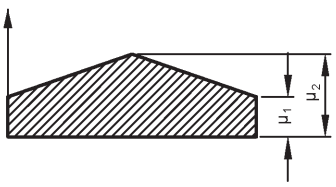
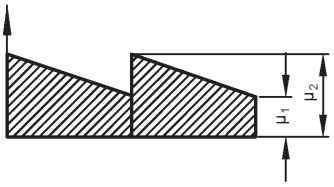
6.4.2 *Shape Coefficients for Selected Types of Roofs*

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6.4.2.1

	Simple Flat and Monopitch Roofs	Simple Pitched Roofs (Positive Roof Slope)[1)]
		
		
$0° < \beta \leq 30°$	$\mu_1 = 0.8$	$\mu_2 = \mu_1 = 0.8$
$15° < \beta \leq 30°$		$\mu_2 = 0.8 + 0.4\left(\frac{\beta - 15}{15}\right)$ $\mu_1 = 0.8$
$30° < \beta \leq 60°$	$\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1.2\left(\frac{60 - \beta}{30}\right)$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_1 = 0$	$\mu_2 = \mu_1 = 0$

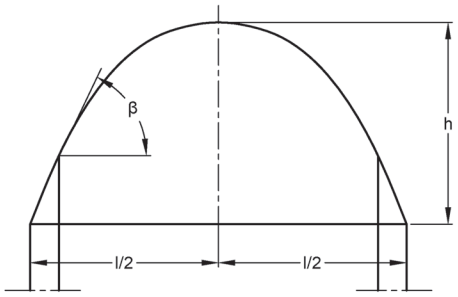
6.4.2.2

	Simple or Multiple Pitched Roofs (Negative Roof Slope)	Two-Span or Multispan Roof
	 $\beta = \frac{\beta_1 + \beta_2}{2}$	
		
$0° < \beta < 30°$	$\mu_1 = 0.8\left(\frac{30 + \beta}{30}\right)$ $\mu_1 = 0.8$	$\mu_1 = 0.8\left(\frac{30 + \beta}{30}\right)$ $\mu_1 = 0.8$
$30° < \beta < 60°$	$\mu_2 = 1.6$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$	$\mu_2 = 1.6$ $\mu_1 = 0.8\left(\frac{60 - \beta}{30}\right)$
$\beta > 60°$	$\mu_2 = 1.6$ $\mu_1 = 0$	$\mu_2 = 1.6$ $\mu_1 = 0$

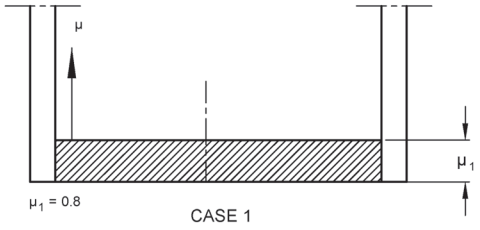
[1)] For asymetrical simple pitched roofs, each side of the roof shall be treated as one half of corresponding symmetrical roofs.

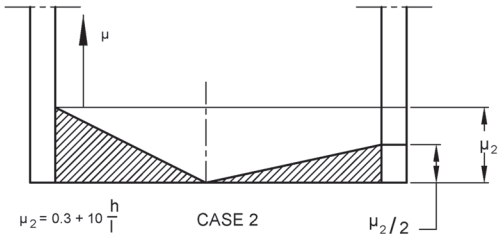
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6.4.2.3 *Simple curved roofs*



THE FOLLOWING CASES 1 AND 2 MUST BE EXAMINED



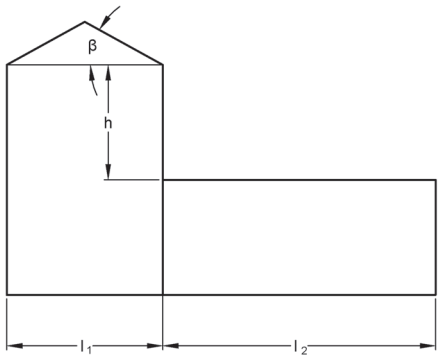


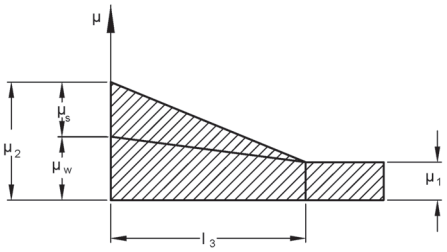
Restriction:

$m_2 \leq 2.3$

$m = 0$, if $b > 60°$

6.4.2.4 *Multilevel roofs*[1)]





$\mu_1 = 0.8$

$\mu_1 = \mu_s + \mu_w$

where

μ_s = due to sliding

μ_w = due to wind

l_3 = $2h$ [2)] *but is restricted as follows:*

$5\,\text{m} \leq l_3 \leq 15\,\text{m}$

$$\mu_w = \frac{l_1 + l_2}{2h} \leq \frac{kh}{s_o}$$

with the restriction $0.8 \leq \mu_w \leq 4.0$

where

h is in metres

s_o is in kilopascals (kilonewtons per square metre)

k = 2 kN/m^2

$\beta \geq 15°$: μ_s is determined from an additional load amounting to 50 percent of the maximum total load on the adjacent slope of the upper root [3)] and is distributed linearly as shown in the figure.

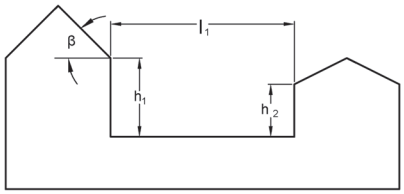
$\beta \leq 15°$: $\mu_s = 0$

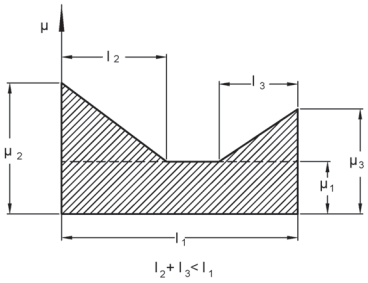
[1)] A more extensive formula for μ_w is described in Annex L.

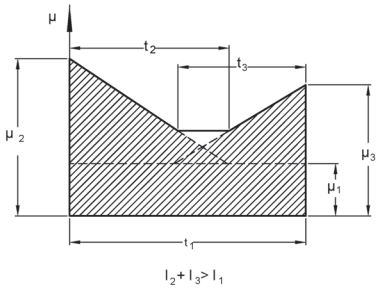
[2)] If $l_2 < l_3$ the coefficient μ is determined by interpolation between μ_1 and μ_2.

[3)] The load on the upper roof is calculated according to **6.4.2.1**.

6.4.2.5 *Complex multilevel roofs*







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$$l_2 = 2h_1 : l_3 = 2h_2 : \mu_{1=0.8}$$

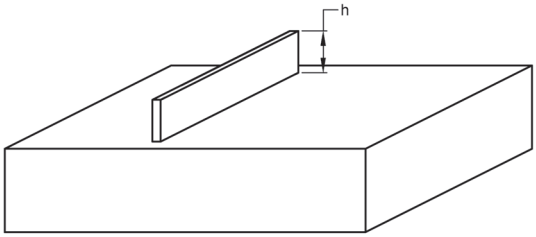
Restriction:

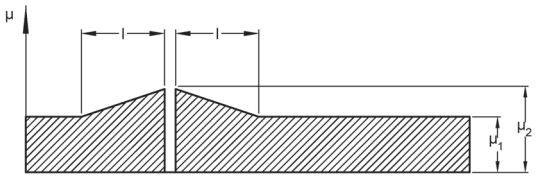
$$5\ \text{m} < l_2 \leq 15\ \text{m};$$

$$5\ \text{m} < l_3 \leq 15\ \text{m};$$

μ_2 and $\mu_3 = \mu_2 + \mu_w$, are calculated according to **6.4.2.1, 6.4.2.2** and **6.4.2.4**

6.4.2.6 *Roofs with local projections and obstructions*





$$\mu_2 = \frac{kh}{s_o}$$

h is in metres

s_o is in kilopascals (kilonewtons per square metre)

$k = 2\ \text{kN/m}^2$

$\mu = 0.8$

Restrictions:

$0.8 \leq \mu_w \leq 2.0$

$5\text{m} \leq l \leq 15\text{m}$

6.4.3 *Shape Coefficients in Areas Exposed to Wind*

The shape coefficients given in **6.4.2** and Annex L may be reduced by 15 percent, provided the designer has demonstrated that the following conditions are fulfilled:

a) The building is located in an exposed location such as open level terrain with only scattered buildings, trees or other obstructions so that the roof is exposed to the winds on all sides and is not likely to become shielded in the future by obstructions higher than the roof within a distance from the building equal to ten times the height of the obstruction above the roof level; and

b) The roof does not have any significant projections such as parapet walls which may prevent snow from being blown off the roof.

NOTE — In some areas, winter climate may not be of such a nature as to produce a significant reduction of roof loads from the snow load on the ground. These areas are:

a) Winter calm valleys in the mountains where sometimes layer after layer of snow accumulates on roofs without any appreciable removal of snow by wind; and

b) Areas (that is, high temperature) where the maximum snow load may be the result of single snowstorm, occasionally without appreciable wind removal.

In such areas, the determination of the shape coefficients shall be based on local experience with due regard to the likelihood of wind drifting and sliding.

7 SPECIAL LOADS

7.1 This clause gives guidance on loads and load effects due to temperature changes, soil and hydrostatic pressures, internally generating stresses (due to creep, shrinkage, differential settlement, etc), accidental loads, etc, to be considered in the design of buildings as appropriate. This clause also includes guidance on load combinations. The nature of loads to be considered for a particular situation is to be based on engineering judgment (*see also* **3.6**)

7.2 Temperature Effects

7.2.1 Expansion and contraction due to changes in temperature of the materials of a structure shall be considered in design. Provision shall be made either to relieve the stress by the provision of expansion/ contraction joints in accordance with good practice [6-1(21)] or design the structure to carry additional stresses due to temperature effects as appropriate to the problem.

7.2.1.1 The temperature range varies for different regions and under different diurnal and seasonal conditions. The absolute maximum and minimum temperature which may be expected in different localities in the country are indicated in Annex B of good practice [6-1(22)]. These figures may be used for guidance in assessing the maximum variations of temperature.

7.2.1.2 The temperatures indicated are the air temperatures in the shade. The range of variation in temperature of the building materials may be appreciably greater or less than the variation of air temperature and is influenced by the condition of exposure and the rate at which the materials composing the structure absorb or radiate heat. This difference in temperature variations of the material and air should be given due consideration.

7.2.1.3 The structural analysis shall take account of changes of the mean (through the section) temperature in relation to the initial (st) and the temperature gradient through the section.

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a) It should be borne in mind that the changes of mean temperature in relation to the initial are liable to differ as between one structural element and another in buildings or structures, as for example, between the external walls and the internal elements of a building. The distribution of temperature through section of single-leaf structural elements may be assumed linear for the purpose of analysis.

b) The effect of mean temperature changes t_1 and t_2, and the temperature gradients v_1 and v_2 in the hot and cold seasons for single-leaf structural elements shall be evaluated on the basis of analytical principles.

NOTES

1 For portions of the structure below ground level, the variation of temperature is generally insignificant. However, during the period of construction, when the portions of the structure are exposed to weather elements, adequate provision should be made to encounter adverse effects, if any.

2 If it can be shown by engineering principles, or if it is known from experience, that neglect of some or all the effects of temperature do not affect the structural safety and serviceability, they need not be considered in design.

7.3 Hydrostatic and Soil Pressure

7.3.1 In the design of structures or parts of structures below ground level such as retaining walls and other walls in basement floors, the pressure exerted by the soil or water or both shall be duly accounted for on the basis of established theories. Due allowance shall be made for possible surcharge from stationary or moving loads. When a portion or whole of the soil is below the free water surface, the lateral earth pressure shall be evaluated for weight of soil diminished by buoyancy and the full hydrostatic pressure.

7.3.1.1 All foundation slabs and other footings subjected to water pressure shall be designed to resist a uniformly distributed uplift equal to the full hydrostatic pressure. Checking of overturning of foundation under submerged condition shall be done considering buoyant weight of foundation.

7.3.2 While determining the lateral soil pressure on column like structural members such as pillars which rest in sloping soils, the width of the member shall be taken as follows (*see* Fig. 18):

Actual Width of Member	*Ratio of Effective Width to Actual Width*
Less than 0.5 m	3.0
Beyond 0.5 m and up to 1 m	3.0 to 2.0
Beyond 1 m	2.0

The relieving pressure of soil in front of the structural member concerned may generally not be taken into account.

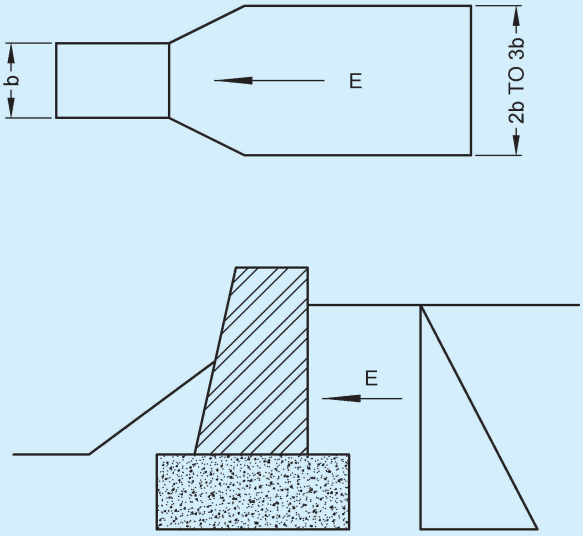


FIG. 18 SKETCH SHOWING EFFECTIVE WIDTH OF PILLAR FOR CALCULATING SOIL PRESSURE

7.3.3 Safe-guarding of structures and structural members against overturning and horizontal sliding shall be verified. Imposed loads having favourable effect shall be disregarded for the purpose. Due consideration shall be given to the possibility of soil being permanently or temporarily removed.

7.4 Fatigue

7.4.1 *General*

Fatigue cracks are usually initiated at points of high stress concentration. These stress concentrations may be caused by or associated with holes (such as bolt or rivet holes in steel structures), welds including stray or fusions in steel structures, defects in materials, and local and general changes in geometry of members. The cracks usually propagate if the loading is cyclic and repetitive.

Where there is such cyclic and repetitive loading, sudden changes of shape of a member or part of a member, especially in regions of tensile stress and/or local secondary bending, shall be avoided. Suitable steps shall be taken to avoid critical vibrations due to wind and other causes.

7.4.2 Where necessary, permissible stresses shall be reduced to allow for the effects of fatigue. Allowance for fatigue shall be made for combinations of stresses due to dead load and imposed load. Stresses due to wind and earthquakes may be ignored, when fatigue is being considered, unless otherwise specified in relevant Codes of practice.

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Each element of the structure shall be designed for the number of stress cycles of each magnitude to which it is estimated that the element is liable to be subjected during the expected life of the structure. The number of cycles of each magnitude shall be estimated in the light of available date regarding the probable frequency of occurrence of each type of loading.

NOTE — Apart from the general observations made herein, the Section is unable to provide any precise guidance in estimating the probabilistic behaviour and response of structures of various types arising out of repetitive loading approaching fatigue conditions in structural members, joints, materials, etc.

7.5 Structural Safety During Construction

7.5.1 All loads required to be carried by the structures or any part of it due to storage or positioning of construction materials and erection equipment including all loads due to operation of such equipment, shall be considered as erection loads. Proper provision shall be made, including temporary bracings, to take care of all stresses due to erection loads. The conjunction with the temporary bracings shall be capable of sustaining these erection loads, without exceeding the permissible stresses specified in respective Codes of practice. Dead load, wind load and such parts of imposed load, as would be imposed on the structure during the period of erection, shall be taken as acting together with erection loads.

7.6 Accidental Loads

The occurrence of which, with a significant value, is unlikely on a given structure over the period of time under consideration, and also in most cases, is of short duration. The occurrence of an accidental load could, in many cases, be expected to cause severe consequences, unless special measures are taken.

The accidental loads arising out of human action include the following:

a) Impacts and collisions,
b) Explosions, and
c) Fire.

Characteristic of the above stated loads are that they are not a consequence of normal use and that they are undesired, and that extensive effects are made to avoid them. As a result, the probability of occurrence of an accidental load is small whereas the consequences may be severe.

The causes of accidental loads may be,

1) inadequate safety of equipment (due to poor design or poor maintenance); and
2) wrong operation (due to insufficient teaching or training, indisposition, negligence or unfavourable external circumstances).

In most cases, accidental loads only develop under a combination of several unfavourable occurrences. In practical applications, it may be necessary to neglect the most unlikely loads. The probability of occurrence of accidental loads, which are neglected, may differ for different consequences of a possible failure. A data base for a detailed calculation of the probability will seldom be available.

7.6.1 *Impact and Collisions*

7.6.1.1 *General*

During an impact, the kinetic impact energy has to be absorbed by the vehicle hitting the structure and by the structure itself. In an accurate analysis, the probability of occurrence of an impact with a certain energy object hitting the structure and the structure itself at the actual place shall be considered. Impact energies for dropped object should be based on the actual loading capacity and lifting height.

Common sources of impact are:

a) Vehicles;
b) Dropped objects from cranes, fork lifts, etc;
c) Cranes out of control, crane failures; and
d) Flying fragments.

The codal requirements regarding impact from vehicles and cranes are given in **7.6.1.2** and **7.6.1.3**.

7.6.1.2 The requirements for loads as a result of collision between vehicle and structural or non-structural elements shall be as per **7.6.1.2.1** and **7.6.1.2.2.**

7.6.1.2.1 *Collisions between vehicles and structural elements*

In road traffic, the requirement that a structure shall be able to resist collision may be assumed to be fulfilled, if it is demonstrated that the structural element is able to stop a fictitious vehicle, as described below. It is assumed that the vehicle strikes the structural element at a height of 1.2 m in any possible direction and at a speed of 10 m/s (36 km/h).

The fictitious vehicle shall be considered to consist of two masses m_1 and m_2 which during compression of the vehicle, produce an impact force increasing uniformly from zero, corresponding to the rigidities C_1 and C_2. It is assumed that the mass m_1 is broken completely before the breaking of mass m_2 begins.

The following numerical values should be used:

m_1 = 400 kg, C_1 = 10 000 kN/m, the vehicle is compressed.

m_2 = 12 000 kg, C_2 = 300 kN/m, the vehicle is compressed.

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NOTE — The described fictitious collision corresponds in the case of a non-elastic structural element to a maximum static force of 630 kN for the mass m_1 and 600 kN for the mass m_2 irrespective of the elasticity, it will therefore be on the safe side to assume the static force to be 630 kN.

In addition, breaking of the mass m_1 will result in an impact wave, the effect of which will depend, to a great extent, on the kind of structural element concerned. Consequently, it will not always be sufficient to design for the static force.

7.6.1.2.1.1 *For structural elements in stilts and car parking levels*

For structural elements in stilts and car parking levels, where driveways and car parking are provided in the buildings which have limited vehicle speeds, the design shall take care of the following considerations:

a) Speed of the vehicle to be 20 km/h maximum (since within a building and inside the car parks, speed of the vehicle may not generally be more than 20 km/h).
b) Impact to be considered at a height of 450 mm to 600 mm.

Structural elements such as columns, RC walls or vertical load resisting elements shall be designed for loads due to the above unless protected by separate resisting system.

7.6.1.2.2 *Collision between vehicles and non-structural elements*

Non-structural elements, such as vehicle barriers for car parks shall be designed to resist the impact and the momentum as outlined below:

a) The horizontal force F (in kN), normal to and uniformly distributed over any length of 1.5 m of a barrier for a car park, required to withstand the impact of a vehicle shall be as given below:

$$F = \frac{0.5mv^2}{\delta_c + \delta_b}$$

where

m = gross mass of the vehicle, in kg;
v = velocity of the vehicle normal to the barrier, in m/s;
δ_c = deformation of the vehicle, in mm;
δ_b = deflection of the barrier, in mm.

b) Where the car park has been designed on the basis that the gross mass of the vehicles using it will not exceed 2 500 kg, the following values shall be used to determine the force F:

m = 1 500 kg;
v = 4.5 m/s;
δ_c = 100 mm;

For a rigid barrier, for which δ_b may be taken as zero, the force, F, appropriate to vehicles up to 2 500 kg gross mass, shall be taken as 150 kN.

c) Where the car park has been designed for vehicles whose gross mass exceeds 2 500 kg, the following values shall be used to determine the force F:

m = actual mass of the vehicle for which the car park is designed, in kg;
v = 4.5 m/s; and
δ_c = 100 mm.

d) The force determined as in (b) or (c) may be considered to act at bumper height. In the case of car parks intended for motor cars whose gross mass does not exceed 2 500 kg, this height may be taken as 375 mm above the floor level.
e) Barriers to access ramps of car parks have to withstand one-half of the force determined in (b) or (c) acting at a height of 610 mm above the ramp.

Opposite to the ends of straight ramps intended for downward travel, which exceed 20 m in length, the barrier shall be designed to withstand twice the force determined in (b) or (c) acting at a height of 610 mm above the ramp.

NOTE — The mass of 1 500 kg is taken as being more representative of the vehicle population than the extreme value of 2 500 kg.

7.6.1.3 *Safety railings*

With regard to safety, railings put up to protect structures against collision due to road traffic, it should be shown that the railings are able to resist the impact as described in **7.6.1.2**.

NOTE — When a vehicle collides with safety railings, the kinetic energy of the vehicle will be absorbed partly by the deformation of the railings and partly by the deformation of the vehicle. The part of the kinetic energy which the railings should be able to absorb without breaking down may be determined on the basis of the assumed rigidity of the vehicle during compression.

7.6.1.4 *Crane impact load on buffer stop*

The basic horizontal load P_y (tonne), acting along the crane track produced by impact of the crane on the buffer stop, is calculated by the following formula:

$$P_y = MV^2/F$$

where

V = speed at which the crane is traveling at the moment of impact (assumed equal to half the nominal value) (m/s).
F = maximum shortening of the buffer, assumed

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equal to 0.1 m for light duty, medium-duty and heavy-duty cranes with flexible load suspension and loading capacity not exceeding 50 t, and 0.2 m in every other cranes.

M = reduced crane mass, (t.s^2/m); and is obtained by the formula:

$$M = \frac{1}{g}\left[\frac{P_h}{2} + \left(P_t + kQ\right)\frac{L_k - l}{L_k}\right]$$

where

g = acceleration due to gravity (9.81 m/s^2);

P_h = crane bridge weight (t);

P_t = crab bridge weight (t);

Q = crane loading capacity (t);

k = coefficient, assumed equal to zero for cranes with flexible load suspension and to one for cranes with rigid suspension;

L_k = crane span (m); and

l = nearness of crab (m).

7.6.2 *Explosions*

7.6.2.1 *General*

Explosions may cause impulsive loading on a structure. The following types of explosions are particularly relevant:

a) Internal gas explosions which may be caused by leakage of gas piping (including piping outside the room), evaporation from volatile liquids or unintentional evaporation from surface material (for example, fire);

b) Internal dust explosions;

c) Boiler failure;

d) External gas cloud explosions; and

e) External explosions of high explosives (TNT, dynamite).

The codal requirement regarding internal gas explosions is given in **7.6.2.2**.

7.6.2.2 *Explosion effect in closed rooms*

Gas explosion may be caused, for example by leaks in gas pipes (inclusive of pipes outside for room), evaporation from volatile liquids or unintentional evaporation of gas from wall sheathings (for example, caused by fire).

NOTES

1 The effect of explosions depends on the exploding medium, the concentration of the explosion, the shape of the room, possibilities of ventilation of the explosion, and the ductility and dynamic properties of the structure. In rooms with little possibility for relief of the pressure from the explosion, very large pressures may occur.

Internal over pressure from an internal gas explosion in rooms of sizes comparable to residential rooms and with ventilation areas consisting of window glass breaking at a pressure of 4 kN/m^2 (3-4 mm machine made glass) may be calculated from the following method:

a) The over pressure is assumed to depend on a factor A/V, where A is the total windows area, in m^2, and V is the volume, in m^3, of the room considered;

b) The internal pressure is assumed to act simultaneously upon all walls and floors in one closed room; and

c) The action q_o may be taken as static action.

If account is taken of the time curve of the action, the schematic correspondence between pressure and time is assumed (*see* Fig. 19), where t_1 is the time from the start of combustion until maximum pressure is reached and t_2 is the time from maximum pressure to the end of combustion. For t_1 and t_2, the most unfavourable values should be chosen in relation to the dynamic properties of the structures. However, the values should be chosen within the intervals as given in Fig. 20.

2 Figure 19 is based on tests with gas explosions in room corresponding to ordinary residential flats and should, therefore, not be applied to considerably different conditions. The figure corresponds to an explosion caused by town gas and it might, therefore, be somewhat on the safe side in rooms where there is only the possibility of gases with a lower rate of combustion.

The pressure may be applied solely in one room or in more rooms at the same time. In the latter case, all rooms are incorporated in the volume V. Only windows or other similarly weak and light weight structural elements may be taken to be ventilation areas even though certain limited structural parts break at pressures less than q_o.

Figure 19 is given purely as guide and probability of occurrence of an explosion should be checked in each case using appropriate values.

7.6.3 *Vertical Load on Air Raid Shelters*

7.6.3.1 *Characteristic values*

As regards buildings in which the individual floors are acted upon by a total characteristic imposed action of up to 5.0 kN/m^2, vertical actions on air raid shelters generally located below ground level, for example, basement, etc, should be considered to have the following characteristic values:

a)	Buildings with up to 2 storeys	: 28 kN/m^2
b)	Buildings with 3-4 storeys	: 34 kN/m^2
c)	Buildings with more than 4 storeys	: 41 kN/m^2
d)	Buildings of particularly stable construction irrespective of the number of storeys	: 28 kN/m^2

In the case of buildings with floors that are acted upon by a characteristic imposed action larger than 5.0 kN/m^2, the above values should be increased by the difference between the average imposed action on all storeys above the one concerned and 5.0 kN/m^2.

NOTES

1 By storeys it is understood, every utilizable storey above the shelter.

2 By buildings of a particular stable construction, it is understood, buildings in which the load- bearing structures are made from reinforced *in-situ* concrete.

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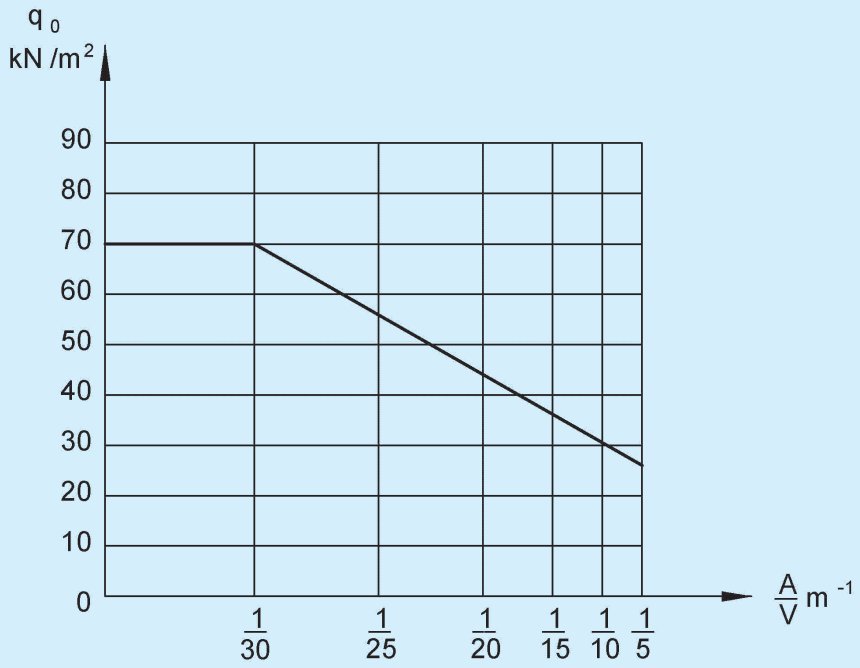


FIG. 19 SKETCH SHOWING RELATION BETWEEN PRESSURE AND TIME

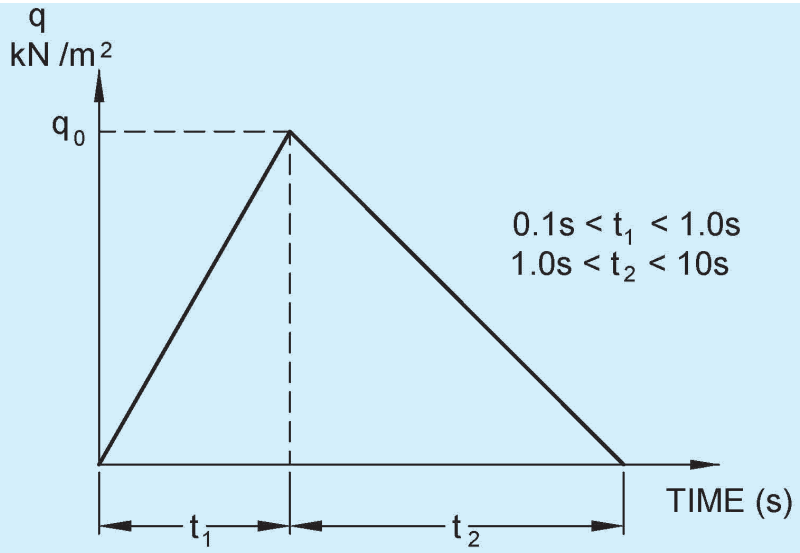


FIG. 20 SKETCH SHOWING TIME INTERVAL AND PRESSURE

7.6.4 *Fire*

7.6.4.1 *General*

Possible extraordinary loads during a fire may be considered as accidental actions. Examples are loads from people along escape routes and loads on another structure from structure failing because of a fire.

7.6.4.2 *Thermal effects during fire*

The thermal effect during fire may be determined from one of the following methods:

a) Time-temperature curve and the required fire resistance (in min), and

b) An energy balance method.

If the thermal effect during fire is determined from an energy balance method, the fire load is taken to be:

$$q = 12\ t_b$$

where

q = fire action (kJ/m^2 floor), and

t_b = required fire resistance (in min) {*see* good practice [6-1(23)]}.

NOTE — The fire action is defined as the total quantity of heat produced by complete combustion of all combustible material

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in the fire compartment, inclusive of stored goods and equipment together with building structures and building materials.

7.7 Vibrations

For general details on loads due to vibrations, reference may be made to Annex M.

7.8 Blast Loads

For provisions related to blast loads, *see* Annex N.

7.9 Other Loads

Other loads not included in this Section, such as special loads due to technical process, moisture and shrinkage effects, etc, should be taken into account where stipulated by building design codes or established in accordance with the performance requirement of the structure.

7.10 For additional information regarding loads, forces and effects about cyclone resistant buildings and landslide control aspects, reference may be made to good practices [6-1(6)] and [6-1(24)] to [6-1(28)], respectively.

8 LOAD COMBINATIONS

8.1 General

A judicious combination of the loads keeping in view the probability of,

a) their acting together; and
b) their disposition in relation to other loads and severity of stresses or deformations caused by the combinations of the various loads is necessary to ensure the required safety and economy in the design of a structure.

8.2 Load Combinations

Keeping the aspect specified in **8.1**, the various loads should, therefore, be combined in accordance with the stipulation in the relevant design Codes. In the absence of such recommendations, the following loading combinations, whichever combination produces the most unfavourable effect in the building, foundation or structural member concerned may be adopted (as a general guidance). It should also be recognized in load combinations that the simultaneous occurrence of maximum values of wind, earthquake, imposed and snow loads is not likely:

a) *DL*
b) *DL* and *IL*
c) *DL* and *WL*
d) *DL* and *EL*
e) *DL* and *TL*
f) *DL, IL* and *WL*
g) *DL, IL* and *EL*
h) *DL, IL* and *TL*
j) *DL,* WL and *TL*
k) *DL, EL* and *TL*
m) *DL, IL, WL* and *TL*
n) *DL, IL, EL* and *TL*

(*DL* = dead load, *IL* = imposed load, *WL* = wind load, *EL* = earthquake load and *TL* = temperature load).

NOTES

1 When snow load is present on roofs, replace imposed load by snow load for the purpose of above load combinations.

2 The relevant design codes shall be followed for permissible stresses when the structure is designed by working stress method and for partial safety factors when the structure is designed by limit state design method for each of the above load combinations.

3 Whenever imposed load (*IL*) is combined with earthquake load (*EL*), the appropriate part of imposed load as specified in **5** should be used, both for evaluating earthquake effect and also for combined load effects used in such combination.

4 For the purpose of stability of the structure as a whole against overturning, the restoring moment shall be not less than 1.2 times the maximum overturning moment due to dead load plus 1.4 times the maximum overturning moment due to imposed loads. In cases where dead load provides the restoring moment, only 0.9 times the dead load shall be considered. The restoring moments due to imposed loads shall be ignored. In case of high water table, the effects of buoyancy have to be suitably taken into consideration.

5 In case of high water able, the factor of safety of 1.2 against uplift alone shall be provided.

6 The structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied loads/forces. In this case, only 0.9 times the dead load shall be taken into account.

7 Where the bearing pressure on soil due to wind alone is less than 25 percent of that due to dead load and imposed load, it may be neglected in design where this exceeds 25 percent, foundation may be so proportioned that the pressure due to combined effect of dead load, imposed load and wind load does not exceed the allowable bearing pressure by more than 25 percent. When earthquake effect is included, the permissible increase in allowable bearing pressure in the soil shall be in accordance with **5**.

Reduced imposed load specified in **3** for the design of supporting structures should not be applied in combination with earthquake forces.

8 Other loads and accidental load combination not included should be dealt with appropriately.

9 Crane load combinations are covered in **3.6.4**.

9 MULTI-HAZARD RISK IN VARIOUS DISTRICTS OF INDIA

9.1 Multi-Hazard Risk Concept

The commonly encountered hazards are:

a) Earthquake,
b) Cyclone,

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c) Wind storm,
d) Floods,
e) Landslides,
f) Liquefaction of soils,
g) Extreme winds,
h) Cloud bursts, and
j) Failure of slopes.

A study of the earthquake, wind/cyclone, and flood hazard maps of India indicate that there are several areas in the country which run the risk of being affected by more than one of these hazards.

Further there may be instances where one hazard may cause occurrence or accentuation of another hazard such as landslides may be triggered/accelerated by earthquakes and wind storms and floods by the cyclones.

It is important to study and examine the possibility of occurrence of multiple hazards, as applicable to an area. However, it is not economically viable to design all the structures for multiple hazards. The special structures such as nuclear power plants, and life line structures such as hospitals and emergency rescue shelters may be designed for multiple hazards. For such special structures, site specific data have to be collected and the design be carried out based on the accepted levels of risk. The factors that have to be considered in determining this risk are:

1) The severity of the hazard characterized by M.M. (or M.S.K.) intensity in the case of earthquake; the duration and velocity of wind in the storms; and unprotected or protected situation of flood prone areas; and
2) The frequency of occurrence of the severe hazards.

Till such time that risk evaluation procedures are formalized, the special structures may be designed for multiple hazards using the historical data, that can be obtained for a given site and the available Code for loads already covered. The designer may have to consider the loads due to any one of the hazards individually or in combination as appropriate.

9.2 Multi-Hazard Prone Areas

The criteria adopted for identifying multi-hazard prone areas may be as follows:

a) *Earthquake and flood risk prone* — Districts which have seismic zone of Intensity 7 or more and also flood prone unprotected or protected area. Earthquake and flood can occur separately or simultaneously.
b) *Cyclone and flood risk prone* — Districts which have cyclone and flood prone areas. Here floods can occur separately from cyclones, but simultaneous also along with possibility of storm surge too.
c) *Earthquake, cyclone and flood risk prone* — Districts which have earthquake zone of intensity 7 or more, cyclone prone as well as flood prone (protected or unprotected) areas. Here the three hazards can occur separately and also simultaneously as in (a) and (b) but earthquake and cyclone will be assumed to occur separately only.
d) *Earthquake and cyclone risk prone* — Districts which have earthquake zone of intensity 7 or more and prone to cyclone hazard too. The two will be assumed to occur separately.

Based on the approach given above, the districts with multi-hazard risk are given in Annex P.

9.3 Use of the List of the District with Multi-Hazard Risk

The list provides some ready information for use of the authorities involved in the task of disaster mitigation, preparedness and preventive action. This information gives the districts which are prone to high risk for more than one hazard. This information will be useful in establishing the need for developing housing design to resist such multi-hazard situation.

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ANNEX A

[*Clause* 3.3.2.1(b)]

ILLUSTRATIVE EXAMPLE SHOWING REDUCTION OF UNIFORMLY DISTRIBUTED IMPOSED FLOOR LOADS IN MULTI-STOREYED BUILDINGS FOR DESIGN OF COLUMNS

A-1 The total imposed loads from different floor levels (including the roof) coming on the central column of a multi-storeyed building (with mixed occupancy) is shown in Fig. 21. Calculate the reduced imposed load for the design of column members at different floor levels using **3.3.2.1**. Floor loads do not exceed 5.0 kN/m^2.

A-1.1 Applying reduction coefficients in accordance with **3.3.2.1**, total reduced floor loads on the column at different levels is indicated along with Fig. 21.

FLOOR NO. FROM TOP INCLUDING ROOF	IMPOSED FLOOR LOADS ON COLUMNS AT DIFFERENT FLOORS, kN	DISCOUNTED IMPOSED LOADING ON COLUMNS, kN
1	30	ROOF
2	40	30
3	50	(30 + 40) (1 - 0.1) = 63
4	50	(30 + 40 + 50) (1 - 0.2) = 96
5	40	(30 + 40 + 50 + 50) (1 - 0.3) = 119
6	45	(30 + 40 + 50 + 50 + 40) (1 - 0.4) = 126
7	50	(30 + 40 + 50 + 50 + 40 + 45) (1 - 0.4) = 153
8	50	(30 + 40 + 50 + 50 + 40 + 45 + 50) (1 - 0.4) = 183
9	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50) (1 - 0.4) = 213
10	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40) (1 - 0.4) = 237
11	40	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40) (1 - 0.4) = 261
12	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40) (1 - 0.5) = 237.5 < 261 adopt 261 for design
13	55	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55) (1 - 0.5) = 265
14	70	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55) (1 - 0.5) = 292.5
15	80	(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70) (1 - 0.5) = 327.5
		(30 + 40 + 50 + 50 + 40 + 45 + 50 + 50 + 40 + 40 + 40 + 55 + 55 + 70 + 80) (1 - 0.5) = 367.5

FIG. 21 LOADING DETAILS

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ANNEX B

(*Clause* 4.2)

NOTATIONS

A = Surface area of a structure or part of a structure

A_e = Effective frontal area

A_z = Effective frontal area of the building at height z

b = Breadth of a structure or structural member normal to the wind stream in the horizontal plane

B_s = Background factor

C_d = Drag coefficient

C_f = Force coefficient

C_{fn} = Normal force coefficient

C_{ft} = Transverse force coefficient

C_f' = Frictional drag coefficient

C_p = Pressure coefficient

C_{pe} = External pressure coefficient

C_{pi} = Internal pressure coefficient

C_{fs} = Cross-wind force spectrum coefficient

$C_{f,z}$ = Drag force coefficient of the building corresponding to the area A_z

C = Coefficient, which depends on q_s, used in the evaluation of k_3 factor

d = Depth of a structure or structural member parallel to wind stream in the horizontal plane

d_w = Wake width

D = Diameter of cylinder or sphere

E = Wind energy factor

F_z = Along wind load on the building/structure at any height z

F = Force normal to the surface

f_a = First mode natural frequency of the building/ structure in along wind direction, in Hz

f_c = First mode natural frequency of the building/ structure in across wind direction, in Hz

f_s = Vortex shedding frequency

F_n = Normal force

F_t = Transverse force

F' = Frictional force

G = Gust factor

g_R = Peak factor for resonant response

g_v = Peak factor for upwind velocity fluctuations

h = Height of structure above mean ground level

h_x = Height of development of a velocity profile at a distance x down wind from a change in terrain category

H_s = Height factor for resonant response

H = Height above mean ground level on the topography feature

I = Turbulence intensity

$I_{h,i}$ = Turbulence intensity at height h in terrain category i

$I_{z,i}$ = Turbulence intensity at height z in terrain category i

IF = Interference factor

k = Mode shape power exponent

k_1, k_2, k_3, k_4 = Wind speed modification factors

$\overline{k}_{2,i}$ = Hourly mean wind speed factor

K = Force coefficient multiplication factor for individual members of finite length

K_a = Area averaging factor

K_c = Combination factor

K_d = Wind directionality factor

l = Length of the member or larger horizontal dimension of a building

L = Actual length of upwind slope

L_e = Effective length of upwind slope

L_h = Integral turbulence length scale at the height, h

m_0 = Average mass per unit height of the structure

M_a = Design peak along wind base bending moment

M_c = Design peak across wind base bending moment

N = Effective reduced frequency

p_d = Design wind pressure

p_z = Design wind pressure at height z

$\overline{p}_d$ = Design hourly mean wind pressure corresponding to $\overline{V}_{z,d}$

p_e = External pressure

p_i = Internal pressure

r = Roughness factor which is twice the longitudinal turbulence intensity at height h, $I_{h,i}$

R_e = Reynolds number

s = Level on a building/structure for the evaluation of along wind load effects

S_o = Factor, which depends on H and X, used for the evaluation of k_3 factor

S_t = Strouhal number

S = Size reduction factor

V_b = Regional basic wind speed

V_z = Design wind speed at height z

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$\overline{V}_d$ = Design hourly mean wind speed

$\overline{V}_{z,d}$ = Design hourly mean wind speed at height z

$\overline{V}_{z,H}$ = Hourly mean wind speed at height z

w = Lesser horizontal dimension of a building, or a structural member

w' = Bay width in multi-bay building

$\hat{\ddot{x}}$ = Peak acceleration at the top of the building/ structure in along wind direction, in m/s^2;

x = Distance down wind from a change in terrain category

X = Distance from the summit or crest of topography feature relative to the effective length, L_e

$\hat{\ddot{y}}$ = Peak acceleration at the top of the building/ structure in across wind direction

z = Height or distance above the ground

$z_{0,i}$ = Aerodynamic roughness height for i^{th} terrain

Z = Effective height of the topography feature

α = Inclination of the roof to the horizontal

β = Damping coefficient of the building/structure

η = Shielding factor

ϕ = Factor to account for the second order turbulence intensity

Φ = Solidity ratio

Φ_e = Effective solidity ratio

ε = Average height of the surface roughness

θ_s = Upwind slope of the topography feature in the wind direction

θ = Wind angle from a given axis

ANNEX C

(*Clause* 4.4.2)

BASIC WIND SPEED AT 10 m HEIGHT FOR SOME IMPORTANT CITIES/TOWNS

City/Town	*Basic Wind Speed m/s*	*City/Town*	*Basic Wind Speed m/s*
Agra	47	Delhi	50
Ahmedabad	39	Durgapur	47
Ajmer	47	Gangtok	47
Almora	47	Guwahati	50
Amritsar	50	Gaya	39
Asansol	47	Gorakhpur	47
Aurangabad	39	Hyderabad	44
Bahraich	47	Imphal	47
Barauni	47	Jabalpur	47
Bareilly	47	Jaipur	47
Bengaluru	33	Jamshedpur	47
Bhatinda	47	Jhansi	47
Bhilai	39	Jodhpur	47
Bhopal	47	Kanpur	47
Bhubaneswar	50	Kohima	44
Bhuj	50	Kolkata	50
Bikaner	47	Kozhikode	39
Bokaro	47	Kurnool	39
Chandigarh	47	Lakshadweep	39
Chennai	50	Lucknow	50
Coimbatore	39	Ludhiana	47
Cuttack	50	Madurai	39
Darbhanga	55	Mandi	39
Darjeeling	47	Mangaluru	39
Dehra Dun	47	Moradabad	47

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City/Town	*Basic Wind Speed m/s*
Mumbai	44
Mysuru	33
Nagpur	44
Nainital	47
Nashik	39
Nellore	50
Panaji	39
Patiala	47
Patna	47
Port Blair	44
Puducherry	50
Pune	39
Raipur	44
Rajkot	39
Ranchi	39
Roorkee	39
Rourkela	39
Shimla	39
Srinagar	39
Surat	44
Tiruchirappalli	47
Thiruvananthpuram	39
Udaipur	47
Vadodara	44
Varanasi	47
Vijayawada	50
Visakhapatnam	50

ANNEX D

[*Clause* 4.4.3.2.4 (2) (ii)]

CHANGES IN TERRAIN CATEGORIES

D-1 LOW TO HIGH TERRAIN CATEGORY NUMBER

In cases of transition from a low terrain category number (corresponding to a low terrain roughness) to a higher terrain category number (corresponding to a rougher terrain), the velocity profile over the rougher terrain shall be determined as follows:

a) Below height h_x, the velocities shall be determined in relation to the rougher terrain; and

b) Above height h_x, the velocities shall be determined in relation to the less rough (more distant) terrain.

D-2 HIGH TO LOW TERRAIN CATEGORY NUMBER

In cases of transition from a more rough to a less rough terrain, the velocity profile shall be determined as follows:

a) Above height h_x, the velocities shall be determined in accordance with the rougher (more distant) terrain; and

b) Below height h_x, the velocity shall be taken as the lesser of the following:

1) That determined in accordance with the less rough terrain, and

2) The velocity at height h_x as determined in relation to the rougher terrain

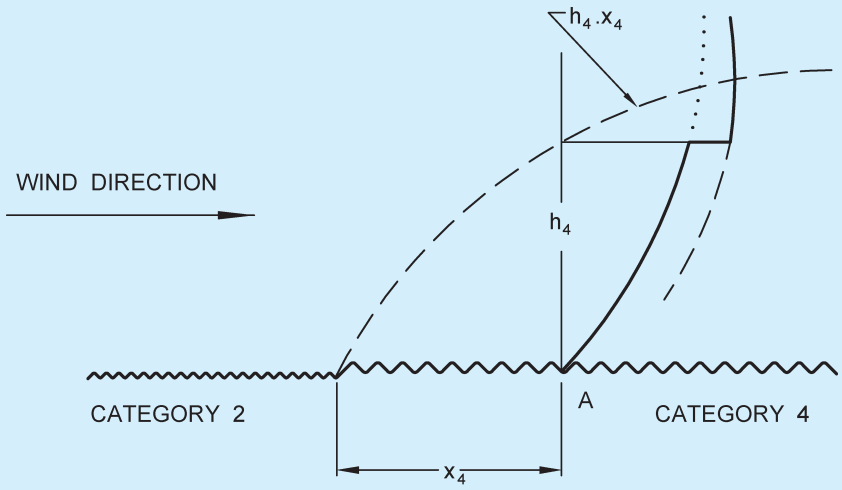
NOTE — Examples of determination of velocity profiles in the vicinity of a change in terrain category are shown in Fig. 22A and Fig. 22B.

D-3 MORE THAN ONE CATEGORY

Terrain changes involving more than one category shall be treated in similar way to that described in **D-1** and **D-2**.

NOTE — Examples involving three terrain categories are shown in Fig. 22B.

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x_4 = FETCH, h_4 = HEIGHT FOR CATEGORY 4

PROFILE FOR CATEGORY 4

PROFILE FOR CATEGORY 2

DESIGN PROFILE AT A

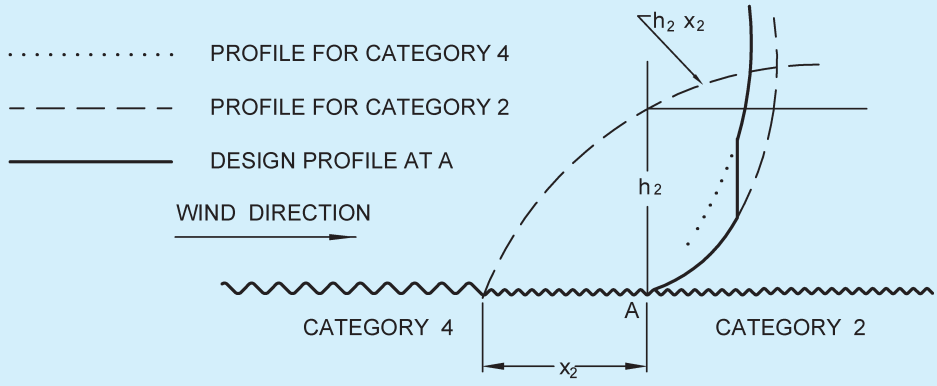
22A DETERMINATION OF VELOCITY PROFILE NEAR A CHANGE IN TERRAIN CATEGORY
(Less rough to more rough)

x_4 = FETCH, h_4 = HEIGHT FOR CATEGORY 2

PROFILE FOR CATEGORY 4

PROFILE FOR CATEGORY 2

DESIGN PROFILE AT A



22B DETERMINATION OF VELOCITY PROFILE NEAR A CHANGE IN TERRAIN CATEGORY
(More rough to less rough)

FIG. 22 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY — (*Continued*)

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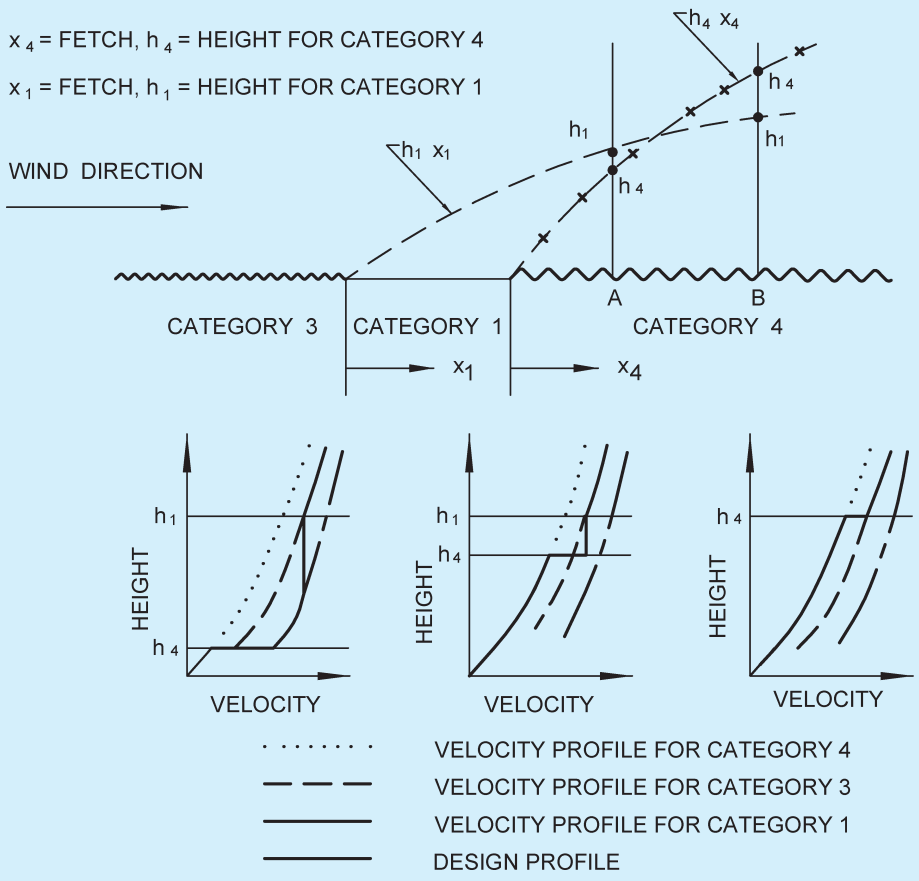


FIG. 22 VELOCITY PROFILES IN THE VICINITY OF A CHANGE IN TERRAIN CATEGORY

ANNEX E

(*Clause* 4.4.3.3)

EFFECT OF A CLIFF OR ESCARPMENT ON EQUIVALENT HEIGHT ABOVE GROUND (k_3 FACTOR)

E-1 The influence of the topographic feature is considered to extend 1.5 L_e upwind and 2.5 L_e downwind of the summit of crest of the feature where L_e is the effective horizontal length of the hill depending on slope as indicated below (*see* Fig. 23):

Slope	L_e
$3° < \theta_s \leq 17°$	L
$\theta_s > 17°$	$Z / 0.3$

where

L = actual length of the upwind slope in the wind direction,

Z = effective height of the topography feature, and

θ_s = upwind slope in the wind direction.

In case, the zone in downwind side of the crest of the feature is relatively flat ($\theta_s < 3°$) for a distance exceeding L_e, then the feature should be treated as an escarpment. Otherwise the feature should be treated as a hill or ridge. Examples of typical features are given in Fig. 23.

NOTES

1 No difference is made, in evaluating k_3 between a three dimensional hill and two dimensional ridge.

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2 In undulating terrain, it is often not possible to decide whether the local topography to the site is significant in terms of wind flow. In such cases, the average value of the terrain upwind of the site for a distance of 5 km should be taken as the base level from wind to assess the height, Z, and the upwind slope θ, of the feature.

E-2 TOPOGRAPHY FACTOR, K_3

The topography factor K_3 is given by the following:

$$K_3 = 1 + C\, s_0$$

where C has the following values:

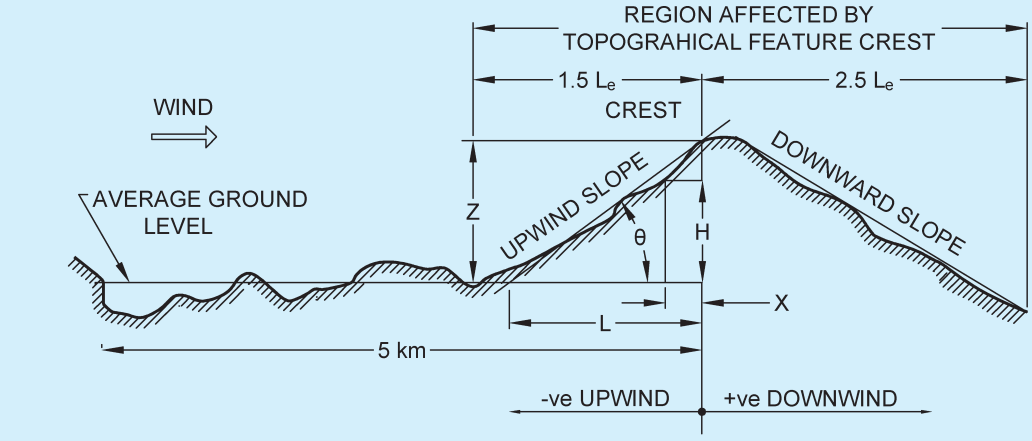
Slope	*C*
$3° < \theta_s \leq 17°$	1.2 (Z/L)
$\theta_s > 17°$	0.36

and s_0 is a factor derived in accordance with **E-2.1** appropriate to the height, H above mean ground level and the distance, X, from the summit or crest relative to the effective length, L_e

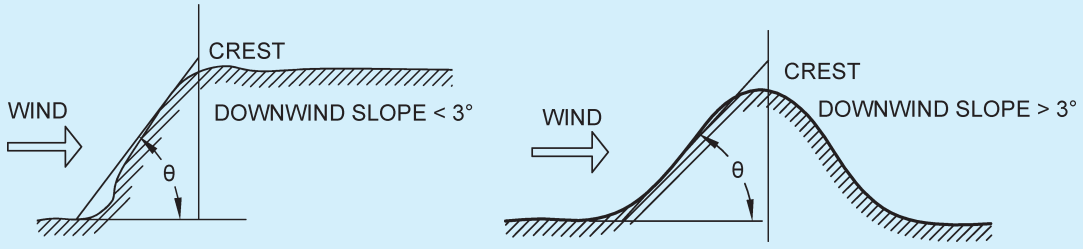
E-2.1 The factor, s_0 should be determined from:

a) Figure 24 for cliffs and escarpments, and
b) Figure 25 for ridges and hills.

NOTE — Where the downwind slope of a hill or ridge is more than 3°, there will be large regions of reduced accelerations or even shelter and it is not possible to give general design rules to cater for these circumstances. Values of s_0 from Fig. 25 may be used as upper bound values.



23A General Notations



23B Cliff and Escarpment

23C Hill and Ridge

FIG. 23 DEFINITION OF TOPOGRAPHICAL DIMENSIONS

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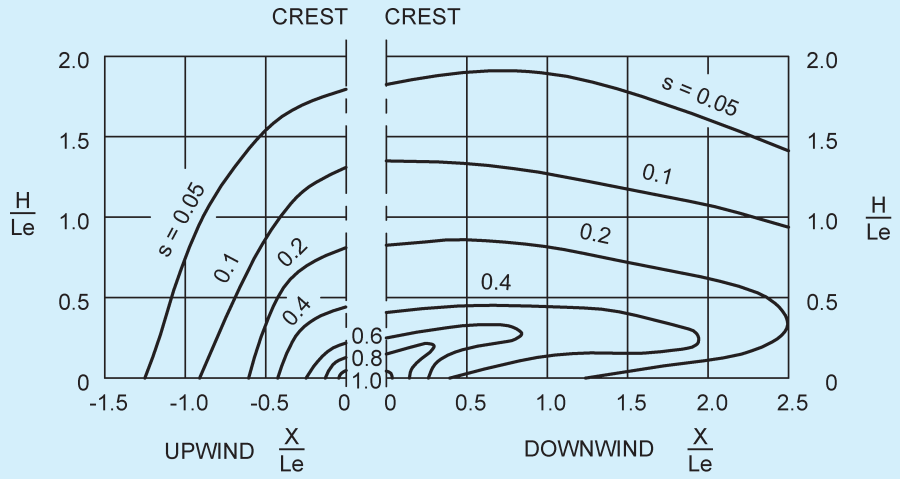


FIG. 24 FACTOR S_0 FOR CLIFF AND ESCARPMENT

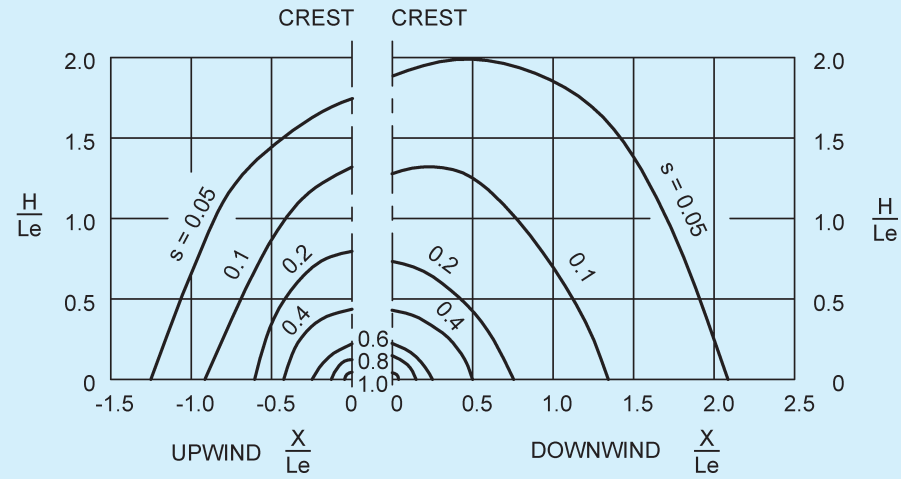


FIG. 25 FACTOR S_0 FOR RIDGE AND HILL

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ANNEX F

[*Clauses* 4.5.4.2.2, 4.5.4.3.2 (c) *and* 4.5.4.3.3]

WIND FORCE ON CIRCULAR SECTIONS

F-1 The wind force on any object is given by:

$$F = C_f A_e \rho_d$$

where

C_f = force coefficient;

A_e = effective area of the object normal to the wind direction; and

ρ_d = design pressure of the wind.

For most shapes, the force coefficient remains approximately constant over the whole range of wind speeds likely to be encountered. However, for objects of circular cross-section, it varies considerably.

For a circular section, the force coefficient depends on the way in which the wind flows around it and is dependent upon the velocity and kinematic viscosity of the wind and diameter of the section. The force coefficient is usually quoted against a non-dimensional parameter, called the Reynolds number, which takes into account of the velocity and viscosity of the flowing medium (in this case the wind), and the member diameter.

$$\text{Reynolds number, } R_e = \frac{D\bar{V}_d}{\nu}$$

where

D = diameter of the member,

$\bar{V}_d$ = design hourly mean wind speed, and

ν = kinematic viscosity of the air which is 1.46×10^{-5} m^2/s at 15°C and standard atmospheric pressure.

Since in most natural environments likely to be found in India, the kinematic viscosity of the air is fairly constant, it is convenient to use $D\bar{V}_d$ as the parameter instead of Reynolds number and this has been done in this Section.

The dependence of a circular section's force coefficient on Reynolds number is due to the change in the wake developed behind the body.

At a low Reynolds number, the wake is as shown in Fig. 26 and the force coefficient is typically 1.2. As Reynolds number is increased, the wake gradually changes to that shown in Fig. 27, that is, the wake width d_w decreases and the separation point, denoted as *sp*, moves from front to the back of the body.

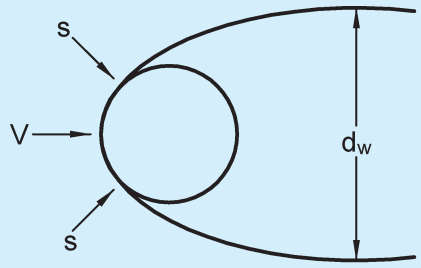


FIG. 26 WAKE IN SUB-CRITICAL FLOW

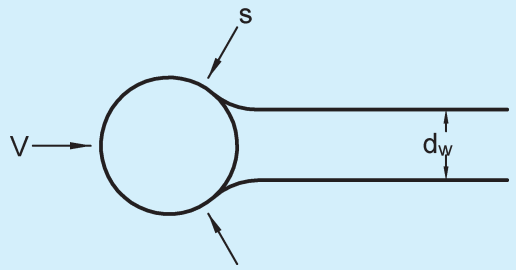


FIG. 27 WAKE IN SUPER-CRITICAL FLOW

As a result, the force coefficient shows a rapid drop at a critical value of Reynolds number followed by a gradual rise as Reynolds number is increased still further.

The variation of C_f with parameter $D\bar{V}_d$ is shown in Fig. 5 for infinitely long circular cylinders having various values of relative surface roughness (ε/D) when subjected to wind having an intensity and scale of turbulence typical of built-up urban areas. The curve for a smooth cylinder ($\varepsilon/D = 1 \times 10^{-5}$) in a steady air stream, as found in a low-turbulence wind tunnel, is also shown for comparison.

It can be seen that the main effect of free-stream turbulence is to decrease the critical value of the parameter. For subcritical flows, turbulence can produce a considerable reduction in C_f below the steady air-stream values. For supercritical flows, this effect becomes significantly smaller.

If the surface of the cylinder is deliberately roughened, such as by incorporating flutes, riveted construction, etc, then the data given in Fig. 5 for appropriate value of $\varepsilon/D > 0$ shall be used.

NOTE — In case of uncertainty regarding the value of e to be used for small roughness, ε/D shall be taken as 0.001.

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ANNEX G

(*Clause* 5)

SYMBOLS

G -1 The symbols and notations given below apply to the provisions of **5** of this Code:

A_h = Design horizontal earthquake acceleration coefficient

A_k = Design horizontal earthquake acceleration spectrum value for mode k of oscillation

b_i = Plan dimension of floor i of the building, perpendicular to direction of earthquake shaking

C = Index for the closely-spaced modes

d = Base dimension (in metre) of the building in the direction in which the earthquake shaking is considered

DL = Response quantity due to dead load

e_{di} = Design eccentricity to be used at floor i calculated as per **5.4.8.2**

e_{si} = Static eccentricity at floor i defined as the distance between centre of mass and centre of resistance

EL_X = Response quantity due to earthquake load for horizontal shaking along X-direction

EL_Y = Response quantity due to earthquake load for horizontal shaking along Y-direction

EL_Z = Response quantity due to earthquake load for horizontal shaking along Z-direction

F_{roof} = Design lateral forces at the roof due to all modes considered

F_i = Design lateral forces at the floor i due to all modes considered

g = Acceleration due to gravity

h = Height (in metre) of structure

h_i = Height measured from the base of the building to floor i

I = Importance factor

IL = Response quantity due to imposed load

K_i = Lateral translational stiffness of storey i

L = Dimension of a building in a considered direction

M_k = Modal mass of mode k

n = Number of storeys or floors

N = Corrected SPT value for soil

N_m = Number of modes to be considered as per **5.4.7.5.2**

P_k = Mode participation factor of mode k

Q_i = Lateral force at floor i

Q_{ik} = Design lateral force at floor i in mode k

R = Response reduction factor

S_a/g = Design / Response acceleration coefficient for rock or soil sites as given by Fig. 12 and **5.3.4.2** based on appropriate natural period

S_i = Lateral shear strength of storey i

T = Undamped natural period of oscillation of the structure (in second)

T_a = Approximate fundamental period (in second)

T_k = Undamped natural period of mode k of oscillation (in second)

T_1 = Fundamental natural period of oscillation (in second)

V_B = Design seismic base shear

$\overline{V}_B$ = Design base shear calculated using the approximate fundamental period T_a

V_i = Peak storey shear force in storey i due to all modes considered

V_{ik} = Shear force in storey i in mode k

V_{roof} = Peak storey shear force in the top storey due to all modes considered

W = Seismic weight of the building

W_i = Seismic weight of floor i

Z = Seismic zone factor

ϕ_{ik} = Mode shape coefficient at floor i in mode k

λ = Peak response (for example, member forces, displacements, storey forces, storey shears or base reactions) due to all modes considered

λ_k = Absolute value of maximum response in mode k

λ_c = Absolute value of maximum response in mode c, where mode c is a closely-spaced mode

λ^* = Peak response due to the closely-spaced modes only

ρ_{ji} = Coefficient used in complete quadratic combination (CQC) method while combining responses of modes i and j

ω_i = Circular frequency (in rad/s) in mode i

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ANNEX H

(*Clause* 5.1.11)

MSK 1964 INTENSITY SCALE

H-1 The following description shall be applicable.

a) *Type of Structures (Buildings)*

1) *Type A* — Building in field-stone, rural structures, un-burnt brick houses, clay houses

2) *Type B* — Ordinary brick buildings, buildings of large block and prefabricated type, half timbered structures, buildings in natural hewn stone

3) *Type C* — Reinforced buildings, well-built wooden structures

b) *Definition of Quantity*

1) Single, few : About 5 percent

2) Many : About 50 percent

3) Most : About 75 percent

c) *Classification of Damage to Buildings*

Classification	*Damage*	*Description*
Grade 1	Slight damage	Fine cracks in plaster; fall of small pieces of plaster
Grade 2	Moderate	Small cracks in walls; damage fall of fairlylarger pieces of plaster; pantiles slip off; cracks in chimneys parts of chimney fall down
Grade 3	Heavy damage	Large and deep cracks in walls; fall of chimneys
Grade 4	Destruction	Gaps in walls; parts of buildings may collapse; separate parts of the buildings lose their cohesion; and inner walls collapse
Grade 5	Total damage	Total collapse of the buildings

H-2 MSK INTENSITY SCALE

H-2.1 The following introductory letters (i), (ii) and (iii) have been used throughout the intensity scales (I to XII), describing the following:

i) Persons and surroundings,

ii) Structures of all kinds, and

iii) Nature.

I Not Noticeable

i) The intensity of the vibration is below the limits of sensibility; the tremor is detected and recorded by seismograph only.

ii) —

iii) —

II Scarcely Noticeable (Very Slight)

i) Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.

ii) —

iii) —

III Weak, Partially Observed

i) The earthquake is felt indoors by a few people, outdoors only in favourable circumstances. The vibration is like that due to the passing of a light truck. Attentive observers notice a slight swinging of hanging objects.

ii) —

iii) —

IV Largely Observed

i) The earthquake is felt indoors by many people, outdoors by few. Here and there people awake, but no one is frightened. The vibration is like that due to the passing of a heavily loaded truck. Windows, doors, and dishes rattle. Floors and walls crack. Furniture begins to shake. Hanging objects swing slightly. Liquid in open vessels are slightly disturbed. In standing motor cars the shock is noticeable.

ii) —

iii) —

V Awakening

i) The earthquake is felt indoors by all, outdoors by many. Many people awake. A few run outdoors. Animals become uneasy. Buildings tremble throughout. Hanging objects swing considerably. Pictures knock against walls or swing out of place. Occasionally pendulum clocks stop. Unstable objects overturn or shift. Open doors and windows are thrust open and slam back again. Liquids spill in small amounts from well-filled open containers. The

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sensation of vibration is like that due to heavy objects falling inside the buildings.

ii) Slight damages in buildings of Type A are possible.

iii) Slight waves on standing water. Sometimes changes in flow of springs.

VI Frightening

i) Felt by most indoors and outdoors. Many people in buildings are frightened and run outdoors. A few persons loose their balance. Domestic animals run out of their stalls. In few instances, dishes and glassware may break, and books fall down, pictures move, and unstable objects overturn. Heavy furniture may possibly move and small steeple bells may ring.

ii) Damage of Grade 1 is sustained in single buildings of Type B and in many of Type A. Damage in some buildings of Type A is of Grade 2.

iii) Cracks up to widths of 10 mm possible in wet ground; in mountains occasional landslips: change in flow of springs and in level of well water are observed.

VII Damage of Buildings

i) Most people are frightened and run outdoors. Many find it difficult to stand. The vibration is noticed by persons driving motor cars. Large bells ring.

ii) In many buildings of Type C damage of Grade 1 is caused; in many buildings of Type B damage is of Grade 2. Most buildings of Type A suffer damage of Grade 3, few of Grade 4. In single instances, landslides of roadway on steep slopes: crack in roads; seams of pipelines damaged; cracks in stone walls.

iii) Waves are formed on water, and water is made turbid by mud stirred up. Water levels in wells change, and the flow of springs changes. Sometimes dry springs have their flow restored and existing springs stop flowing. In isolated instances parts of sand and gravelly banks slip off.

VIII Destruction of Buildings

i) Fright and panic; also persons driving motor cars are disturbed. Here and there branches of trees break off. Even heavy furniture moves and partly overturns. Hanging lamps are damaged in part.

ii) Most buildings of Type C suffer damage of Grade 2, and few of Grade 3. Most buildings of Type B suffer damage of Grade 3. Most buildings of Type A suffer damage of Grade 4. Occasional breaking of pipe seams. Memorials and monuments move and twist. Tombstones overturn. Stone walls collapse.

iii) Small landslips in hollows and on banked roads on steep slopes; cracks in ground up to widths of several centimetres. Water in lakes become turbid. New reservoirs come into existence. Dry wells refill and existing wells become dry. In many cases, change in flow and level of water is observed.

IX General Damage of Buildings

i) General panic; considerable damage to furniture. Animals run to and fro in confusion and cry.

ii) Many buildings of Type C suffer damage of Grade 3, and a few of Grade 4. Many buildings of Type B show a damage of Grade 4 and a few of Grade 5. Many buildings of Type A suffer damage of Grade 5. Monuments and columns fall. Considerable damage to reservoirs; underground pipes partly broken. In individual cases, railway lines are bent and roadway damaged.

iii) On flat land overflow of water, sand and mud is often observed. Ground cracks to widths of up to 100 mm, on slopes and river banks more than 100 mm. Furthermore, a large number of slight cracks in ground; falls of rock, many landslides and earth flows; large waves in water. Dry wells renew their flow and existing wells dry up.

X General Destruction of Buildings

i) —

ii) Many buildings of Type C suffer damage of Grade 4, and a few of Grade 5. Many buildings of Type B show damage of Grade 5. Most of Type A has destruction of Grade 5. Critical damage to dykes and dams. Severe damage to bridges. Railway lines are bent slightly. Underground pipes are bent or broken. Road paving and asphalt show waves.

iii) In ground, cracks up to widths of several centimetres, sometimes up to 1 m, parallel to water courses occur broad fissures. Loose ground slides from steep slopes. From river banks and steep coasts, considerable landslides are possible. In coastal areas, displacement of sand and mud; change of water level in wells; water from canals, lakes, rivers, etc, thrown on land. New lakes occur.

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XI Destruction

i) —

ii) Severe damage even to well-built buildings, bridges, water dams and railway lines. Highways become useless. Underground pipes destroyed.

iii) Ground considerably distorted by broad cracks and fissures, as well as movement in horizontal and vertical directions. Numerous landslips and falls of rocks. The intensity of the earthquake requires to be investigated specifically.

XII Landscape Changes

i) —

ii) Practically all structures above and below ground are greatly damaged or destroyed.

iii) The surface of the ground is radically changed. Considerable ground cracks with extensive vertical and horizontal movements are observed. Falling of rock and slumping of river banks over wide areas, lakes are dammed; waterfalls appear and rivers are deflected. The intensity of the earthquake requires to be investigated specially.

ANNEX J

(*Clauses* 5.1.12 *and* 5.3.3.5.3)

SIMPLIFIED PROCEDURE FOR EVALUATION OF LIQUEFACTION POTENTIAL

J-1 Due to the difficulties in obtaining and testing undisturbed representative samples from potentially liquefiable sites, *in-situ* testing is the approach preferred widely for evaluating the liquefaction potential of a soil deposit. Liquefaction potential assessment procedures involving both the SPT and CPT are widely used in practice. The most common procedure used in engineering practice for the assessment of liquefaction potential of sands and silts is the simplified procedure. The procedure may be used with either standard penetration test (SPT) blow count or cone penetration test (CPT) tip resistance or shear wave velocity V_s measured within the deposit as described below:

Step 1 — The subsurface data used to assess liquefaction susceptibility should include the location of the water table, either SPT blow count N or tip resistance q_c of a CPT cone or shear wave velocity V_s, unit weight, and fines content of the soil (percent by weight passing the IS Sieve No. 75μ).

Step 2 — Evaluate total vertical overburden stress σ_{vo} and effective vertical overburden stress σ'_{vo} at different depths for all potentially liquefiable layers within the deposit.

Step 3 — Evaluate stress reduction factor r_d using:

$$r_d = \begin{cases} 1 - 0.007\ 65z & 0 < z \le 9.15 \text{ m} \\ 1.174 - 0.026\ 7z & 9.15 < z \le 23.0 \text{ m} \end{cases}$$

where z is the depth (in metre) below the ground surface.

Step 4 — Calculate cyclic stress ratio CSR induced by the earthquake using:

$$CSR = 0.65\left(\frac{a_{max}}{g}\right)\left(\frac{\sigma_{vo}}{\sigma'_{vo}}\right)r_d,$$

where

a_{max} = peak ground acceleration (PGA) preferably in terms of g,

g = acceleration due to gravity, and

r_d = stress reduction factor.

If value of PGA is not available, the ratio (a_{max}/g) may be taken equal to seismic zone factor Z (as per Table 42).

Step 5 — Obtain cyclic resistance ratio CRR by correcting standard cyclic resistance ratio $CRR_{7.5}$ for earthquake magnitude, high overburden stress level and high initial static shear stress using:

$$CRR = CRR_{7.5}\left(MSF\right)K_\sigma K_\alpha,$$

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where

$CRR_{7.5}$ = standard cyclic resistance ratio for a 7.5 magnitude earthquake obtained using values of SPT or CPT or shear wave velocity (as per Step 6), and

MSF = magnitude scaling factor given by following equation:

$$MSF = 10^{2.24} / M_W^{2.56}$$

This factor is required when the magnitude is different than 7.5. The correction for high overburden stresses K_σ is required when overburden pressure is high (depth > 15 m) and can be found using following equation:

$$K_\sigma = (\sigma'_{vo} / P_a)^{(f-1)}$$

where σ'_{vo} effective overburden pressure and P_a atmospheric pressure are measured in the same units and f is an exponent and its value depends on the relative density D_r. For D_r = 40 percent ~ 60 percent, f = 0.8 ~ 0.7 and for D_r = 60 percent ~ 80 percent, f = 0.7 ~ 0.6. The correction for static shear stresses K_α is required only for sloping ground and is not required in routine engineering practice. Therefore, in the scope of this Section, value of K_α shall be assumed unity.

For assessing liquefaction susceptibility using:

a) SPT, go to Step 6(a) or
b) CPT, go to Step 6(b) or
c) Shear wave velocity, go to Step 6(c).

Step 6 — Obtain cyclic resistance ratio, $CRR_{7.5}$

6(a) *Using values of SPT*

Evaluate the SPT (standard penetration test) blow count N_{60}, for a hammer efficiency of 60 percent. Specifications for standardized equipment are given in Table 50. If equipment used is of non-standard type, N_{60} shall be obtained using measured value (N):

$$N_{60} = NC_{60},$$

where

$$C_{60} = C_{HT} C_{HW} C_{SS} C_{RL} C_{BD}$$

Factors C_{HT}, C_{Hw}, C_{SS}, C_{RL}, and C_{BD}, recommended by various investigators for some common non-standard SPT configurations are provided in Table 51. For SPT conducted as per accepted standard [6-1(29)], the energy delivered to the drill rod is about 60 percent therefore, C_{60} may be assumed as 1. The computed N_{60}, is normalized to an effective overburden pressure of approximately 100 kPa using overburden correction factor C_N, using:

$$(N_1)_{60} = C_N N_{60}$$

where

$$C_N = \sqrt{\frac{P_a}{\sigma'_{vo}}} \le 1.7,$$

The cyclic resistance ratio $CRR_{7.5}$ is estimated from Fig. 28, using $(N_1)_{60}$ value.

Effect of fines content FC (in percent) can be rationally accounted by correcting $(N_1)_{60}$ and finding $(N_1)_{60CS}$ as follows:

$$(N_1)_{60CS} = \alpha + \beta (N_1)_{60}$$

where

$\alpha = 0$	$\beta = 1$	for $FC \le 5$ percent
$\alpha = e^{\left[1.76 - \left(\frac{190}{FC^2}\right)\right]}$	$\beta = 0.99 + \frac{FC^{1.5}}{1\,000}$	for 5 percent $< FC < 35$ percent
$\alpha = 0.5$	$\beta = 1.2$	for $FC \ge 35$ percent

Again, Fig. 28 can be used to estimate $CRR_{7.5}$, where $(N_1)_{60,CS}$ shall be used instead of $(N_1)_{60}$ and only SPT clean sand based curve shall be used irrespective of fines contents. The $CRR_{7.5}$ can be estimated using following equation, instead of Fig. 28:

$$CRR_{7.5} = \frac{1}{34 - (N_1)_{60CS}} + \frac{(N_1)_{60CS}}{135} + \frac{50}{\left[10 \times (N_1)_{60CS} + 45\right]^2} - \frac{1}{200}$$

6(b) *Using values of CPT*

The CPT procedure requires normalization of measured cone tip resistance q_c using atmospheric pressure P_a and correction for overburden pressure C_Q as follows:

$$q_{C1N} = C_Q \left(\frac{q_c}{P_a} \right)$$

where q_{c1N} is normalized dimensionless cone penetration resistance and

$$C_Q = \left(\frac{P_a}{\sigma'_{vo}} \right)^n$$

$$n = \begin{cases} 0.5 & \text{for sand,} \\ 1 & \text{for clay.} \end{cases}$$

The normalized penetration resistance q_{C1N} for silty sands is corrected to an equivalent clean sand value $(q_{C1N})_{CS}$ by the following relation:

$$(q_{C1N})_{CS} = k_C q_{C1N}$$

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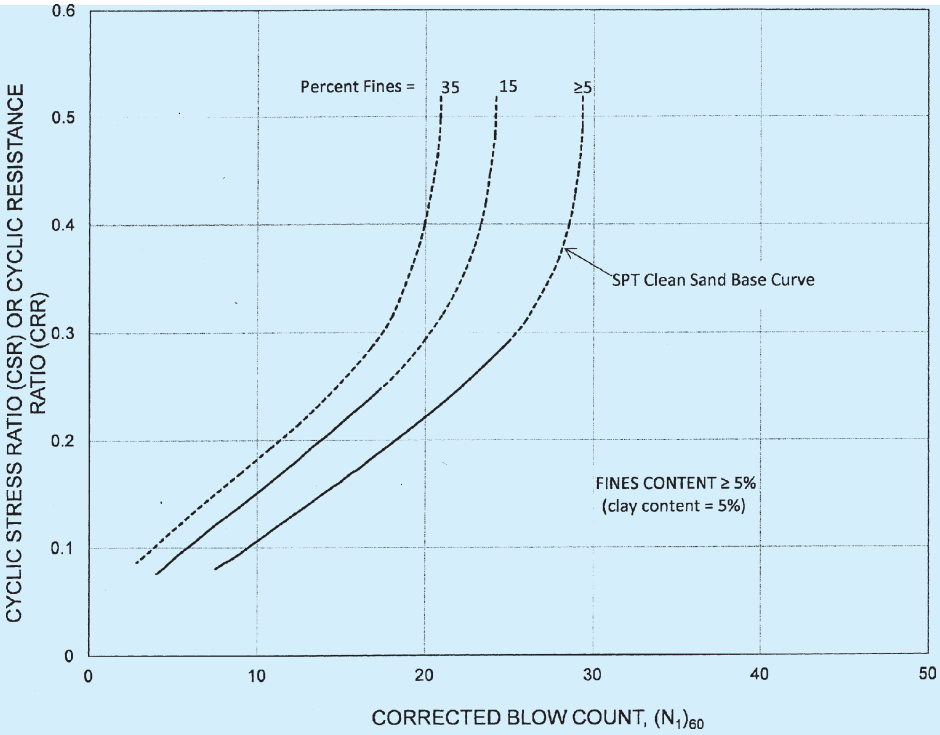


FIG. 28 RELATION BETWEEN *CRR* AND $(N_1)_{60}$ FOR SAND FOR M_w 7.5 EARTHQUAKES

where

k_c = Correction factor to account for grain characteristics

$$= \begin{cases} 1.0 \quad (\text{for } I_c \le 1.64) \\ -0.403I_c^4 + 5.581I_c^3 - 21.63I_c^2 + \\ 33.75I_c - 17.88 \quad (\text{for } I_c > 1.64), \text{ and} \end{cases}$$

$$I_c = \sqrt{(3.47 - \log Q)^2 + (1.22 - \log F)^2}$$

$$Q = \left(\frac{q_c - \sigma_{vo}}{P_a}\right)\left(\frac{P_a}{\sigma'_{vo}}\right)^n$$

$$F = 100\left(\frac{f_s}{q_c - \sigma_{vo}}\right) \text{ percent, and}$$

where f_s = measured sleeve friction.

Using $(q_{C1N})_{CS}$ find the value of $CRR_{7.5}$ using Fig. 29. Alternatively, the $CRR_{7.5}$ can be found using following equations:

$$CRR_{7.5} = \begin{cases} 0.833\left(\dfrac{(q_{C1N})_{CS}}{1\,000}\right) + 0.05, & 0 < (q_{C1N})_{CS} < 50 \\ 93\left(\dfrac{(q_{C1N})_{CS}}{1\,000}\right)^3 + 0.08, & 50 \le (q_{C1N})_{CS} < 160 \end{cases}$$

6(c) *Using shear wave velocity*

Apply correction for overburden stress to shear wave velocity V_s for clean sands using:

$$V_{s1} = \left(\frac{P_a}{\sigma'_{vo}}\right)^{0.25} V_s$$

where (V_{s1}) is overburden stress corrected shear wave velocity. Using V_{s1} find the value of $CRR_{7.5}$ using Fig. 30. Alternatively, the $CRR_{7.5}$ can be found using following equation:

$$CRR_{7.5} = a\left(\frac{V_{s1}}{100}\right)^2 + b\left(\frac{1}{V_{s1}^* - V_{s1}} - \frac{1}{V_{s1}^*}\right)$$

where V_{s1}^* is limiting upper value of V_{s1} for liquefaction occurrence; a and b are curve fitting parameters. The values of a and b in Fig. 30 are 0.022 and 2.8, respectively. V_{s1}^* can be assumed to vary linearly from 200 m/s for soils with fine content of 35 percent, to 215 m/s for soils with fine contents of 5 percent or less.

Step 7 — Calculate the factor of safety *FS* against initial liquefaction using:

$$FS = \frac{CRR}{CSR},$$

where *CSR* is as estimated in Step 4 and *CRR* in Step 5. When the design ground motion is conservative, earthquake related permanent ground deformation is generally small, if $FS \ge 1.2$.

Step 8 — If $FS < 1$, then the soil is assumed to liquefy.

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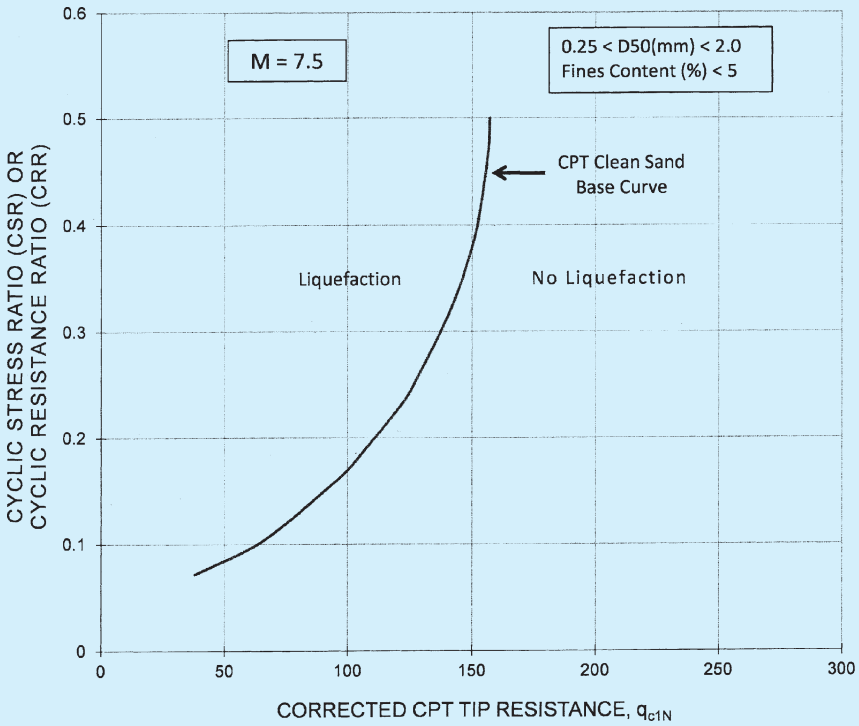


FIG. 29 RELATION BETWEEN *CRR* AND $(q_{C1N})_{cs}$ FOR M_w 7.5 EARTHQUAKES

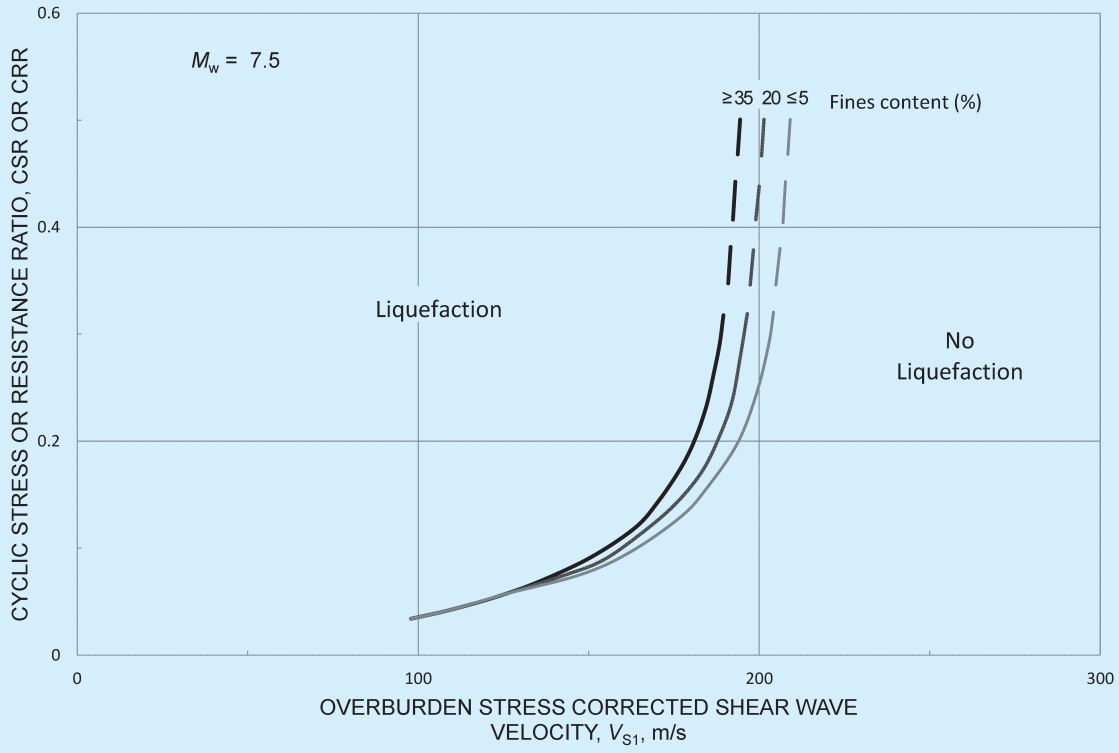


FIG. 30 RELATION BETWEEN *CRR* AND V_{s1} FOR M_w 7.5 EARTHQUAKES

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Table 50 Recommended Standardized SPT Equipment {*see* Accepted Standard [6-1(29)]}
[*Clause* J-1, *Step*: 6(a)]

Sl No.	Element	Standard Specification
(1)	(2)	(3)
i)	Sampler	Standard split-spoon sampler with, Outside diameter, *OD* = 51 mm; and Inside diameter, *ID* = 35 mm (constant, that is, no room for liners in the barrel).
ii)	Drill rods	*A or AW* type for depths less than 15.2 m; *N* or *NW* type for greater depths
iii)	Hammer	Standard (safety) hammer with, a) weight = 63.5 kg; and b) drop height = 762 mm (delivers 60 percent of theoretical free fall energy)
iv)	Rope	Two wraps of rope around the pulley
v)	Borehole	100-130 mm diameter rotary borehole with bentonite mud for borehole stability (hollow stem augers where SPT is taken through the stem)
vi)	Drill bit	Upward deflection of drilling mud (tricone or baffled drag bit)
vii)	Blow count rate	30 to 40 blows per minute
viii)	Penetration resistant count	Measured over range of 150 mm – 450 mm of penetration into the ground

Table 51 Correction Factors for Non-Standard SPT Procedures and Equipment
[*Clause* J-1, Step: 6(a)]

Sl No.	Correction for	Correction Factor
(1)	(2)	(3)
i)	Non-standard hammer type	$C_{HT} = \begin{cases} 0.75 & \text{(for Donut hammer with rope and pulley)} \\ 1.33 & \text{(for Donut hammer with trip/auto)} \end{cases}$ and Energy ratio = 80 percent,
ii)	Non-standard hammer weight or height of fall	$C_{HW} = \frac{HW}{48\ 387}$ where H = height of fall (mm), and W = hammer weight (kg)
iii)	Non-standard sampler setup (standard samples with room for liners, but used without liners)	$C_{SS} = \begin{cases} 1.1 & \text{(for loose sand)} \\ 1.2 & \text{(for dense sand)} \end{cases}$
iv)	Non-standard sampler setup (standard samples with room for liners, but liners are used)	$C_{SS} = \begin{cases} 0.9 & \text{(for loose sand)} \\ 0.8 & \text{(for dense sand)} \end{cases}$
v)	Short rod length	C_{RL} = 0.75 (for rod length 0-3 m) C_{RL} = 0.80 (for rod length 3-4 m) C_{RL} = 0.85 (for rod length 4-6 m) C_{RL} = 0.95 (for rod length 6-10 m) C_{RL} = 1.0 (for rod length 10-30 m)
vi)	Non-standard borehole diameter	$C_{BD} = \begin{cases} 1.00 & \text{(for bore hole diameter of 65-115 mm)} \\ 1.05 & \text{(for bore hole diameter of 150 mm)} \\ 1.15 & \text{(for bore hole diameter of 200 mm)} \end{cases}$

NOTES

1 N= Uncorrected SPT blow count.

2 $C_{60} = C_{HT} C_{HW} C_{SS} C_{RL} C_{BD}$

3 $N_{60} = NC_{60}$

4 C_N = Correction factor for overburden pressure $(N_1)_{60} = C_N C_{60} N$.

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ANNEX K

(*Clause* 5.3.4.2)

LIST OF SOME IMPORTANT TOWNS AND THEIR SEISMIC ZONE FACTOR (Z)

Town	*Zone*	*Z*	*Town*	*Zone*	*Z*
Agra	III	0.16	Jhansi	II	0.10
Ahmedabad	III	0.16	Jodhpur	II	0.10
Ajmer	II	0.10	Jorhat	V	0.36
Allahabad	II	0.10	Kakrapara	III	0.16
Almora	IV	0.24	Kalpakkam	III	0.16
Ambala	IV	0.24	Kanchipuram	III	0.16
Amritsar	IV	0.24	Kanpur	III	0.16
Asansol	III	0.16	Karwar	III	0.16
Aurangabad	II	0.10	Kochi	III	0.16
Bahraich	IV	0.24	Kohima	V	0.36
Barauni	IV	0.24	Kolkata	III	0.16
Bareilly	III	0.16	Kota	II	0.10
Bathinda	III	0.16	Kurnool	II	0.10
Belgaum	III	0.16	Lucknow	III	0.16
Bengaluru	II	0.10	Ludhiana	IV	0.24
Bhilai	II	0.10	Madurai	II	0.10
Bhopal	II	0.10	Mandi	V	0.36
Bhubaneswar	III	0.16	Mangaluru	III	0.16
Bhuj	V	0.36	Mungher	IV	0.24
Bijapur	III	0.16	Moradabad	IV	0.24
Bikaner	III	0.16	Mumbai	III	0.16
Bokaro	III	0.16	Mysuru	II	0.10
Bulandshahr	IV	0.24	Nagpur	II	0.10
Burdwan	III	0.16	Nagarjunasagar	II	0.10
Calicut (Kozhikode)	III	0.16	Nainital	IV	0.24
Chandigarh	IV	0.24	Nashik	III	0.16
Chennai	III	0.16	Nellore	III	0.16
Chitradurga	II	0.10	Osmanabad	III	0.16
Coimbatore	III	0.16	Panjim	III	0.16
Cuddalore	II	0.10	Patiala	III	0.16
Cuttack	III	0.16	Patna	IV	0.24
Darbhanga	V	0.36	Pilibhit	IV	0.24
Darjeeling	IV	0.24	Pondicherry (Puducherry)	II	0.10
Dharwad	III	0.16	Pune	III	0.16
Dehra Dun	IV	0.24	Raipur	II	0.10
Dharampuri	III	0.16	Rajkot	III	0.16
Delhi	IV	0.24	Ranchi	II	0.10
Durgapur	III	0.16	Roorkee	IV	0.24
Gangtok	IV	0.24	Rourkela	II	0.10
Guwahati	V	0.36	Sadiya	V	0.36
Gulbarga	II	0.10	Salem	III	0.16
Gaya	III	0.16	Shillong	V	0.36
Gorakhpur	IV	0.24	Shimla	IV	0.24
Hyderabad	II	0.10	Sironj	II	0.10
Imphal	V	0.36	Solapur	III	0.16
Jabalpur	III	0.16	Srinagar	V	0.36
Jaipur	II	0.10	Surat	III	0.16
Jamshedpur	II	0.10	Tarapur	III	0.16

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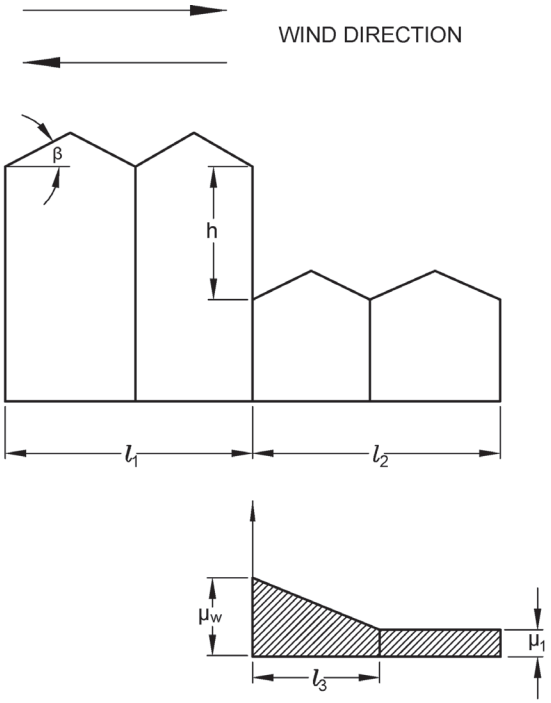
Town	*Zone*	*Z*	*Town*	*Zone*	*Z*
Tezpur	V	0.36	Udaipur	II	0.10
Thane	III	0.16	Vadodara	III	0.16
Thanjavur	II	0.10	Varanasi	III	0.16
Thiruvananthapuram	III	0.16	Vellore	III	0.16
Tiruchirappalli	II	0.10	Vijayawada	III	0.16
Tiruvannamalai	III	0.16	Vishakhapatnam	II	0.10

ANNEX L

(*Clause* 6.4.3)

SHAPE COEFFICIENTS FOR MULTILEVEL ROOFS

L-1 A more comprehensive formula for the shape coefficient for multilevel roofs than that given in **6.4.2** is as follows:



$$\mu_w = 1 + \frac{1}{h}(m_1 l_1 + m_2 l_2)(l_2 - 2h)$$

$$\mu_1 = 0.8$$

$$l_3 = 2h$$

(h and l in m)

Restriction:

$$\mu_w \leq \frac{kh}{S_o}$$

where

S_o is in kilopascals (kilonewtons per square metre).

k is in newtons per cubic metre.

$l_3 \leq 15\ m$

Values of $m_1(m_2)$ for the higher (lower) root depend on its profile and are taken as equal to:

0.5 for plane roofs with slopes $\beta \leq 20°$ and vaulted roofs with $\frac{f}{l} \leq \frac{1}{18}$

0.3 for plane roofs with slopes $\beta > 20°$ and vaulted roofs with $\frac{f}{l} > \frac{1}{18}$

The coefficient m_1 and m_2 may be adjusted to take into account conditions for transfer of snow on the roof surface (that is wind, temperature, etc).

NOTE — The other condition of loading shall also be tried.

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ANNEX M

(*Clause* 7.7)

VIBRATIONS IN BUILDINGS

M-1 GENERAL

In order to design the buildings safe against vibrations, it is necessary to identify the source and nature of vibration. Vibrations may be included in the buildings due to various actions, such as,

a) human induced vibrations, for example, the walking or running or a single person or a number of persons or dancing or motions in stadia or concert halls;
b) machine induced vibrations;
c) wind induced vibrations;
d) blast induced vibrations;
e) traffic load, for example, due to rail, fork-lift, trucks, cars, or heavy vehicles;
f) airborne vibrations;
g) crane operations; and
h) other dynamic actions such as wave loads or earthquake actions.

The dynamic response of buildings for the above mentioned causes of vibration of buildings may have to be evaluated by adopting standard mathematical models and procedures.

The severity or otherwise of these actions have to be assessed in terms of the limits set for dynamic response (frequencies and amplitude of motion) of the buildings related to (a) human comfort, (b) serviceability requirements such as deflections and drifts and separation distances to avoid damage due to pounding, and (c) limits set on the frequencies and amplitude of motion for machines and other installations.

In order to verify that the set limits are not exceeded, the actions may be modelled in terms of force-time histories for which the structural responses may be determined as time histories of displacements or accelerations by using appropriate analytical/numerical methods.

M-2 SERVICEABILITY LIMIT STATE VERIFICATION OF STRUCTURE SUSCEPTIBLE TO VIBRATIONS

M-2.1 While giving guidance for serviceability limit state verification of structure susceptible to vibrations, here it is proposed to deal with the treatment of the action side, the determination of the structural response and the limits to be considered for the structural response to ensure that vibrations are not harmful or do not lead to discomfort.

M-2.2 Source of Vibrations

Vibrations may be included by the following sources:

a) By the movement of persons as in pedestrian bridges, floors where people walk, floors meant for sport or dancing activities, and floors with fixed seating and spectator galleries;
b) By working of machines as in machine foundations and supports, vibrations transmitted through the ground, and pile driving operations;
c) By wind blowing on buildings, towers, chimneys and masts, guyed masts, pylons, bridges, cantilevered roofs, airborne vibrations;
d) Induced by traffic on rail or road bridges and car park structures and exhibition halls; and
e) By earthquakes.

M-2.3 Modelling of Actions and Structures

For serviceability limit states, the modelling of these actions and of the structure depends on how the serviceability limits are formulated. The serviceability limit states may refer to,

(a) human comfort;
(b) limits for the proper functioning of machines and other installations; and
(c) maximum deformation limits to avoid damage or pounding.

In order to verify that these limits are not exceeded, the actions may be modeled in terms of force-time histories, for which the structural responses may be determined as time histories of displacements or accelerations by using appropriate analytical/numerical methods. Where the structural response may significantly influence the force-time histories to be applied, these interactions have to be considered either in modeling a combined load-structure vibration system or by appropriate modifications of the force time histories. In addition to the levels of vibration for which presently limits have been specified, the possible deformations of structural members and systems using different clauses in the relevant codes have to be evaluated by adopting standard mathematical models and procedures.

M-2.4 Force-Time Histories

The force-time histories used in the dynamic analysis

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should adequately represent the relevant loading situations for which the serviceability limits are to be verified. The force-time histories may model,

a) human induced vibrations, for example the walking or running of a single person or a number of persons or dancing or motions in stadia or concert halls;
b) machine induced vibrations, for example by force vectors due to mass eccentricities and frequencies, that may be variable with time;
c) wind induced vibrations;
d) blast induced vibrations;
e) traffic load, for example rail, fork-lift, trucks, cars, or heavy vehicles;
f) airborne vibrations;
g) crane operations; and
h) other dynamic actions such as wave loads or earthquake actions.

ANNEX N

(*Clause* 7.8)

BLAST LOAD

N-1 BLAST LOAD

Behaviour of structures subjected to blast loads is highly complex and has to be properly understood before designing blast resistant structures. First step towards this is to compute the blast load time history acting on the structures. Magnitude of charge and its distance from the structure are the two basic parameters governing the design (Kinney and Graham, 1985). In addition to these, height of the blast charge above ground, overall length of the structure and breadth of the structure facing the shock front are also important in computation of blast loads acting on the structure. Typical time history of blast pressure is shown in Fig. 31.

N-2 Following are the steps in computation of blast load on structures:

a) Determine ground zero distance by assuming that angle between the vertical line through the point of burst and the slant line joining the burst point with the point of incidence of spherical shock on ground is between 40° and 50°.

b) Find whether the structure lies in regular reflection region or Mach reflection region (*see* Fig. 32).

c) Compute the peak over pressure, P_{so} using:

$$\frac{P_{so}}{p_a} = \frac{808\ \left[1+(Z/4.5)^2\right] C}{\sqrt{\left[1+(Z/0.048)^2\right]\left[1+(Z/0.32)^2\right]\left[1+(Z/1.35)^2\right]}}$$

where

p_a = atmospheric pressure, in MPa;
C = 0.986 for air-burst (regular region); and
C = 1.883 for surface-burst (Mach region).

d) Compute the positive phase duration, t_d

For regular region using:

$$t_d = \frac{980\left[1+(Z/0.54)^{10}\right] W^{1/3}}{\left[1+(Z/0.02)^3\right]\left[1+(Z/0.74)^6\right]\sqrt{\left[1+(Z/6.9)^2\right]}}$$

For a Mach region using:

$$t_d = \left[1.93\ln(Z)+0.17\right] W^{1/3}$$

e) Obtain the decay of peak overpressure with time using:

$$P(t) = P_{so}\left(1-\frac{t-t_a}{t_d}\right)e^{-\alpha\frac{(t-t_a)}{t_d}} \quad \text{for} \quad t \geq t_a$$

where

P(t) = pressure at any time 't';
t_a = arrival time; and
α = wave form parameter.

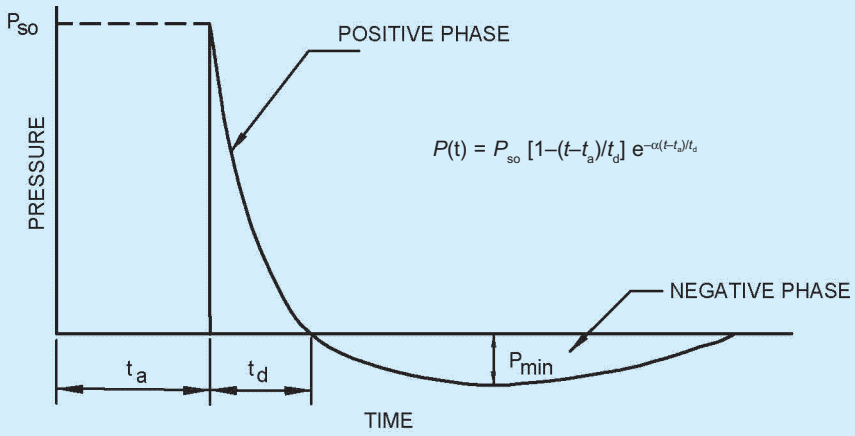
f) The wave form parameter is given by:

$$\alpha = 3.18Z^{-0.58}$$

g) Compute the peak reflected pressure, P_{ro} acting on the structure from:

$$P_{ro} = C_r P_{so}$$

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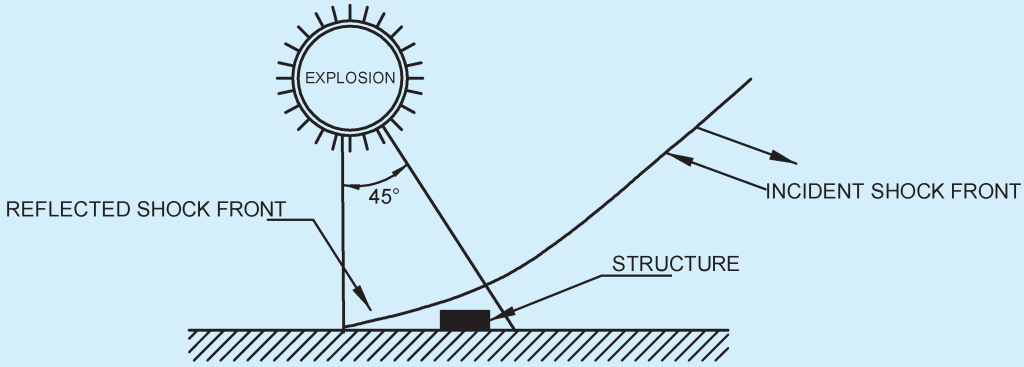
where

α = wave form parameter;
t_a = arrival time;
t_d = duration of positive phase;
W = weight of charge, in kg
t = $1.25W^{1/3}$;
P_{min} = –0.35/Z (Z>1.6);
P_{so} = side-on over pressure in MPa;

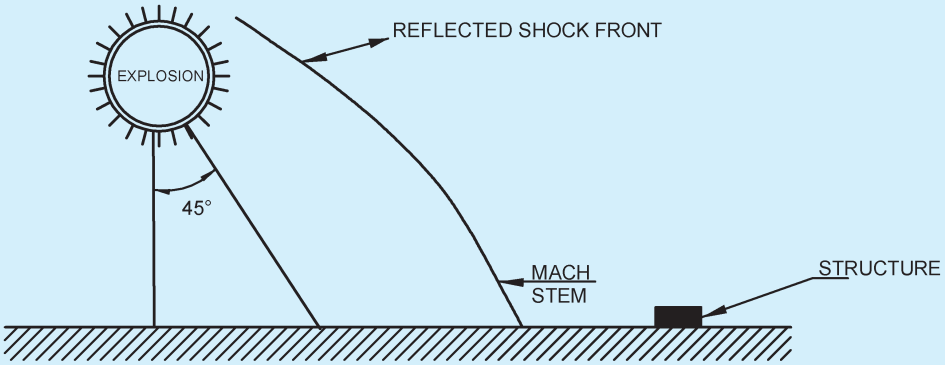
Z = scaled distance, in m/kg$^{1/3}$, given by $Z = \frac{d}{W^{1/3}}$; and

d = actual/radial distance, in m, between the point of burst and point, where peak over pressure is calculated.

FIG. 31 TIME HISTORY OF BLAST PRESSURE



32A Structure Located in Region of Regular Reflection Surface-Burst Environment



32B Structure Located in Region of Mach Reflection Surface-Burst Environment

FIG. 32 BLAST LOADING OF STRUCTURES WITH RESPECT TO LOCATION OF THE STRUCTURE

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where

C_r = reflection coefficient obtained from Fig. 33.

Angle of incidence, θ between the line of wave propagation and outer normal of the face of the structure on which blast load acts is determined using standard procedures. If θ exceeds 90°, reflection coefficient is determined as:

$$C_r = 1.5 - \frac{\theta}{180}$$

h) Critical distance for maximum blast effect, d_d is given by:

$$d_d = H_b + (H_s H_b / 0.07)^{1/2}$$

where

H_b = height of burst above ground, and

H_s = height of structure.

j) Equivalent duration t_e, of the triangular pulse is obtained by equating the impulse of exponentially decaying curve (positive phase) with that of triangular pulse

$$t_e = \frac{2I}{P_{so}}$$

where I is the positive impulse of the exponentially decaying blast time history given by:

$$I = \frac{0.067\sqrt{1+(Z/0.23)^4}}{Z^2\left[1+(Z/1.55)^4\right]^{1/3}}$$

N-3 CLOSED RECTANGULAR STRUCTURES

For closed rectangular structures, Table 52 provides the blast pressure definitions for various faces of the structure due to above ground blasts.

N-4 USE OF LACED REINFORCED CONCRETE IN BLAST RESISTANT CONSTRUCTION

Blast resistant structures are of two types. One type is in which structure is located far from burst point and are designed for far off design range. Other type is located close to a potential explosion and falls under close-in design range. In far off design range, the blast loads are fairly uniform and deflections required to absorb the load are comparatively small. Reinforced concrete with some additional detailing are adequate to resist such loads. Close-in detonations produce non-uniform, high intensity blast loads. Local failure of structural elements is possible due to concentration of pressure at some points. For such structures, reinforced concrete is not sufficient and a material that can permit large deflections and maintain the structural integrity is required. Laced reinforced concrete has enhanced ductility and is suitable for close-in design range. Based on the duration of the impulse load, design can be either impulse design or pressure design as per **J-5** and **J-6,** respectively.

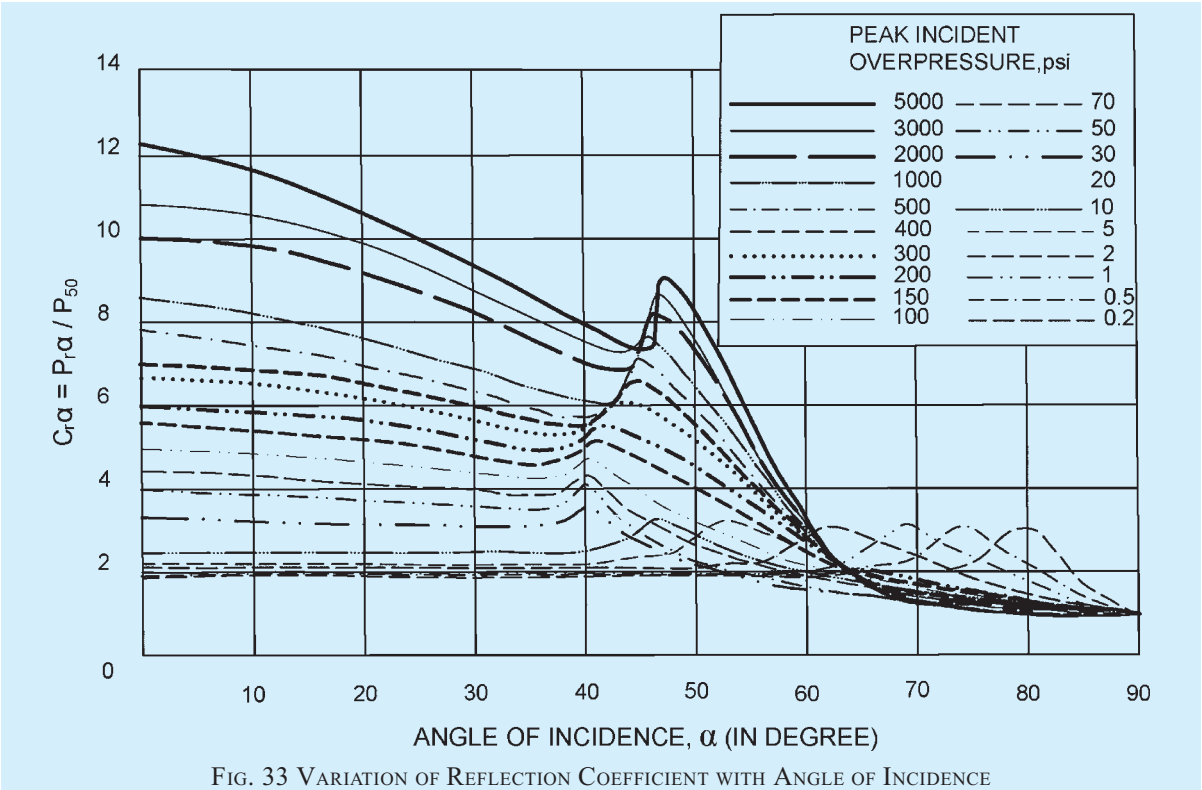
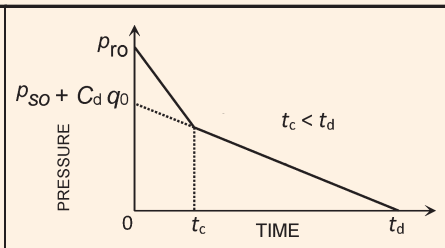
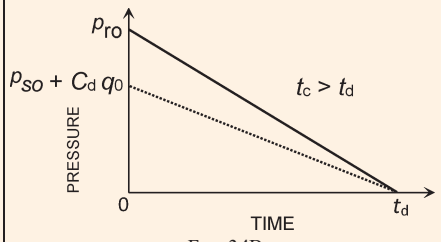
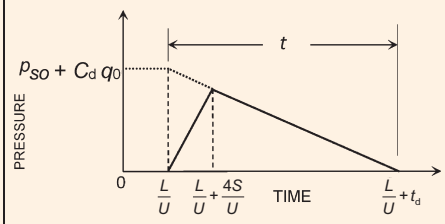
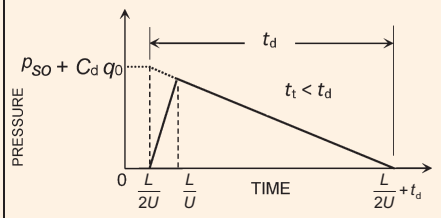
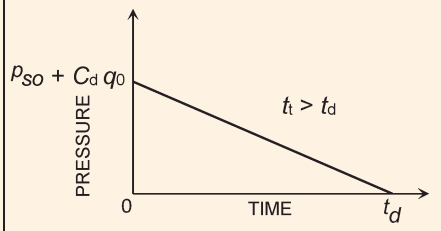
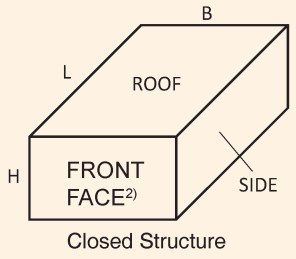


FIG. 33 VARIATION OF REFLECTION COEFFICIENT WITH ANGLE OF INCIDENCE

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Table 52 Blast Pressure Definitions

(*Clause* N-3)

Sl No. (1)	Face of the Structure[1] (2)	Blast Pressure Description (3)	Blast Pressure *Versus* Time (4)	Parameters (5)
i)	Front	Peak reflected pressure, p_{ro} is greater of: $p_{so}\left(2+\frac{6p_{so}}{p_{so}+7p_a}\right)$ and $p_{so}+C_dq_0$ (*see* Fig. 34A and 34B)	 FIG. 34A  FIG. 34B	q_0 = peak dynamic pressure to be obtained from Table 1 of good practice [6-1(30)]; C_d = coefficient of drag to be taken from Table 2 of good practice [6-1(30)], depending upon the shape of the structure; t_c = clearance time in which reflected pressure drops to over-pressure (= L/U). U = shock wave velocity = Ma; M = Mach number of the incident pulse = $\sqrt{1+6p_{so}/7p_a}$; a = velocity of sound in air; S = least of H and $B/2$. t_t = transit time = L/U.
ii)	Rear	Using the pressures from actual explosion, the average loading is taken as shown in Fig. 35.	 FIG. 35	
iii)	Sides and roof	When pulse duration, t_d is greater than transit time t_t of the wave from front to the sides or roof, pressure varies as shown in Fig. 36A.	 FIG. 36A	
		When pulse duration, t_d is less than transit time t_t of the wave from front to the sides or roof, the pressure may be considered as a moving pulse as shown in Fig. 36B.	 FIG. 36B	

[1] The blast pressure definitions given in this table are valid for a closed type structure with less than 5 percent opening.
[2] Front face is the vertical face of the structure on which the blast wave strikes.

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N-5 IMPULSE DESIGN

In close-in design range, the design load can be taken as an impulse, that is, area under pressure time curve. The duration of such an impulsive load is generally small in comparison to the time period of the structural element. The criteria for impulse design is:

$$t_m / t_d > 3$$

where t_d is the duration of the blast load and t_m is the time to reach the maximum response

N-6 PRESSURE DESIGN

Sometimes, in the close-in design range, the duration of blast loads is also quite large. In this case, the structural element is designed for pressure. The criteria for this type of design is,

$$t_m / t_d < 3$$

It should be clearly understood that laced reinforced concrete (LRC) construction is to be used in situations where the potential explosion site is very near to the structure. In the event of an explosion, the LRC element will serve as a barrier and will undergo plastic deformations without complete collapse. This will ensure safety of other nearby structures. Use of LRC for far off design range may prove uneconomical. Therefore, the designer should clearly analyze the situation before employing the LRC technique.

N-6.1 TNT Equivalence

Magnitude of an explosion is based on the amount of energy released. It is expressed in terms of explosion yields, which a relative measure based on TNT yield. Effective charge weight, W is expressed as:

$$W = \frac{H^d_{EXP}}{H^d_{TNT}} W_{EXP}$$

where

W_{EXP} = weight of explosive in question,

H^d_{EXP} = heat of detonation of explosive in question, and

H^d_{TNT} = heat of detonation of TNT.

N-7 INTERNAL BLAST LOADING ON STRUCTURES

Method for prediction of blast pressures due to confined explosion is summarized in Fig. 37. Pressure time variation at a point on the wall of the confinement is generated by considering both the shock wave and gas pressure loading phases. For the shock wave loading phase, it is assumed that second shock has half the amplitude and impulse of the initial reflected shock, the third shock has half the amplitude of the second shock and that all later reflections are insignificant (*see* Fig. 38). Durations of the reflected pulses are the same as that of the initial pulses. The time of

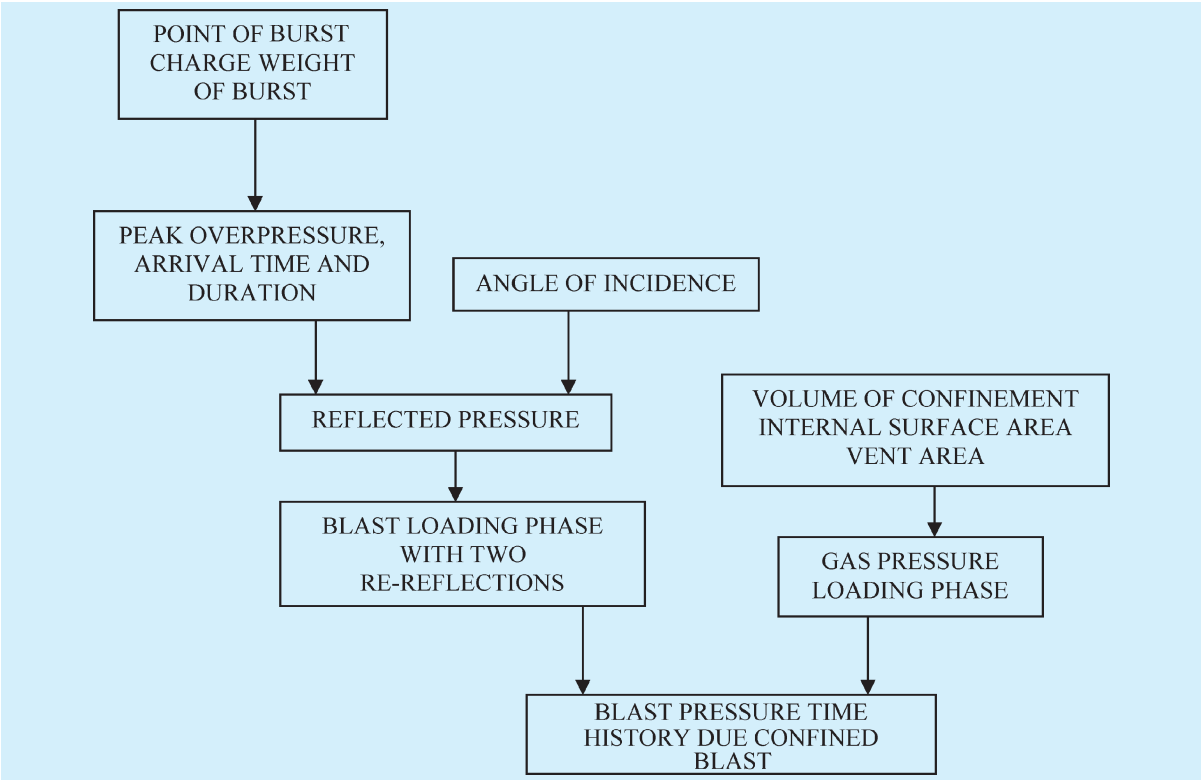


FIG. 37 METHOD FOR PREDICTION OF BLAST PRESSURE DUE TO CONFINED EXPLOSION

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reverberation, that is, the time delay between the arrivals of successive reflected shocks, are nearly twice the time of arrival at the point where the blast pressures are calculated.

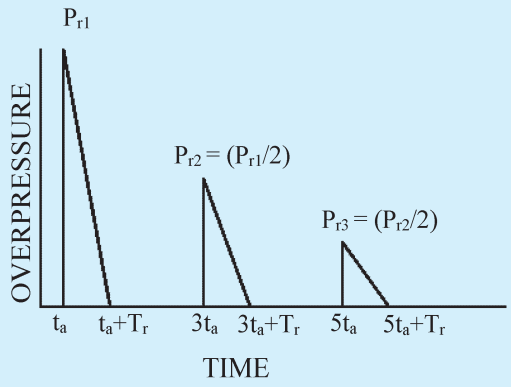


FIG. 38 REFLECTED PHASE LOADING

Estimation of the blast parameters, namely, peak over pressure, time of arrival, time duration, is carried out using the earlier procedure. The gas venting pressure is simplified to the form shown in Fig. 39.

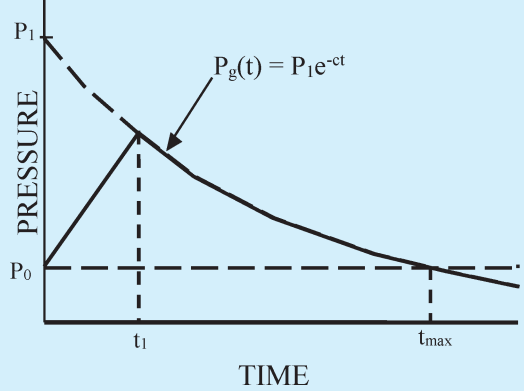


FIG. 39 GAS PRESSURE LOADING

$$P_{I} = P_{QS} + P_0$$

where

P_{QS} = maximum value for the quasi-static overpressure in the gas venting phase of the loading.

$$t_1 = 5t_a + T_r$$

$$c = 2.13\left(\frac{\alpha_e A_s a_o}{V}\right)$$

where

α_e = effective vent area ratio,

A_s = internal surface area of the structure,

V = internal volume of the structure, and

a_o = sound velocity of air.

Maximum gas overpressure, P_{QS}, which depends on the quantity of explosive charge, W and the internal volume of confinement, V is obtained from Fig. 40.

The value of t_{max} can be obtained from:

$$t_{max} = \bar{\tau}_{max}\left(\frac{V}{\alpha_e A_s a_o}\right)$$

where $\bar{\tau}_{max}$ is given by the expression:

$$\bar{\tau}_{max} = 0.469\ 5\ \ln\ (\bar{P}_1)$$

in which, $\bar{P}_1$ is equal to,

$$\bar{P}_1 = \frac{(P_{QS} + P_0)}{P_0}$$

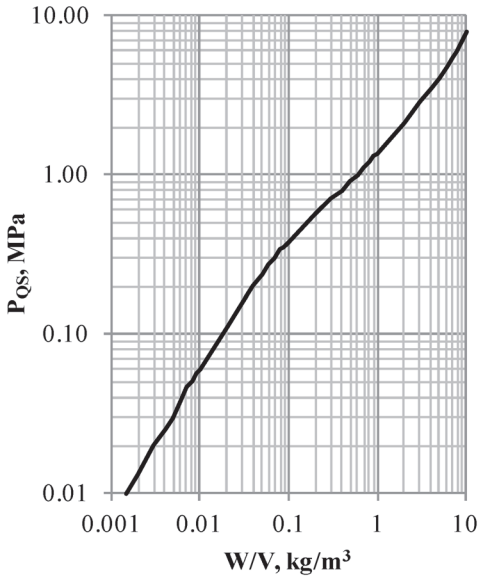


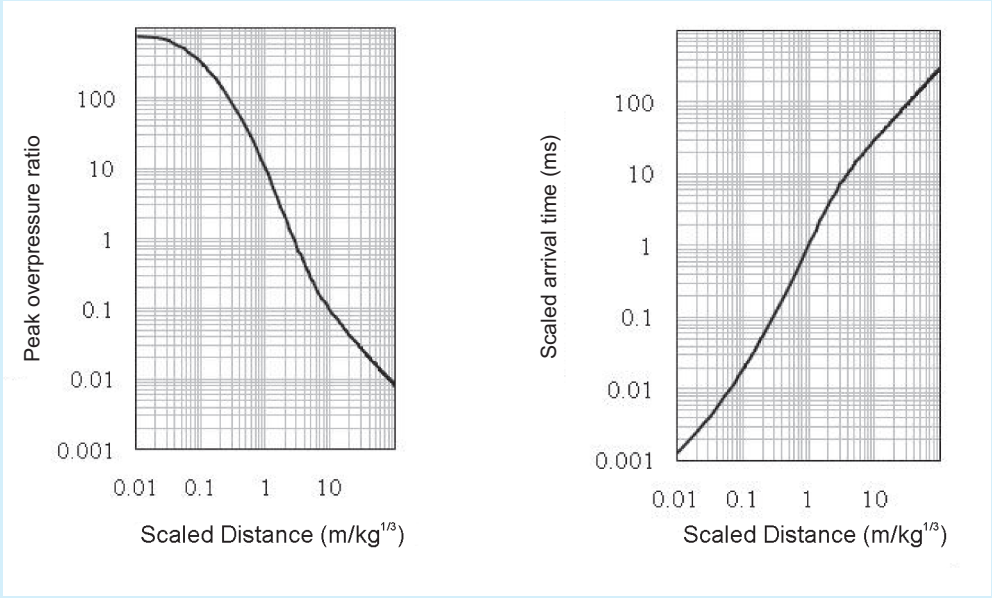
FIG. 40 PEAK QUASI-STATIC PRESSURE FOR TNT EXPLOSION IN CHAMBER

Figure 41 provides the charts for calculation of internal blast pressure for a given scaled distance.

N-8 For design of structures for blast effects of explosions above ground, *see also* good practice [6-1(30)].

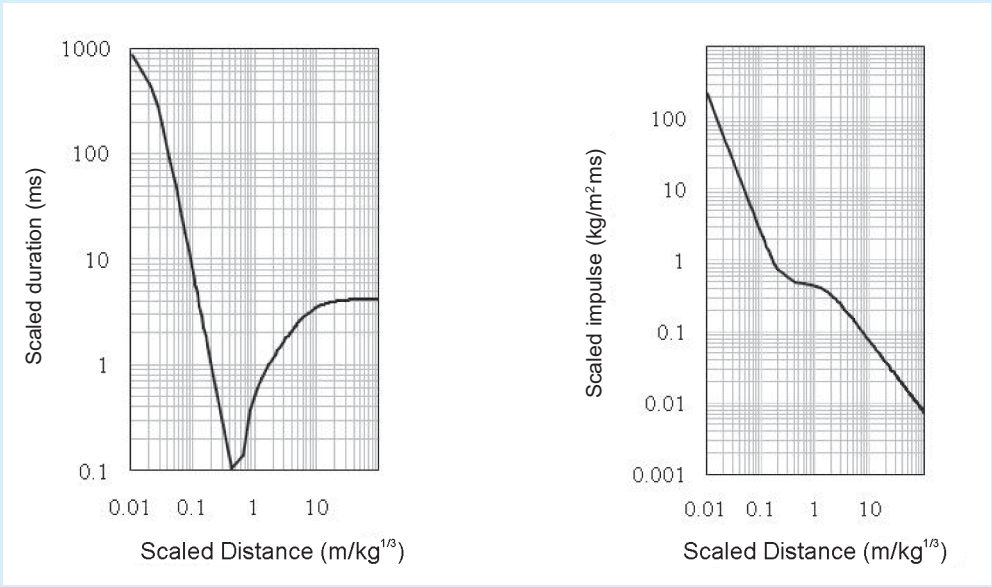
For safety of structures during underground blasting, *see also* good practice [6-1(31)].

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41A PEAK OVERPRESSURE RATIO

41B SCALED ARRIVAL TIME



41C SCALED DURATION

41D SCALED IMPULSE

FIG. 41 CHARTS FOR INTERNAL BLAST PRESSURE PARAMETERS

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ANNEX P

(*Clause* 9.2)

SUMMARY OF DISTRICTS HAVING SUBSTANTIAL MULTI-HAZARD RISK AREAS

State	*Name of Districts Having Substantial Multi-Hazard Prone Area*			
	E.Q. and Flood	Cyclone and Flood	E.Q., Cyclone and Flood	E.Q. and Cyclone
(1)	(2)	(3)	(4)	(5)
Andhra Pradesh	Adilabad, Karim Nagar, Khammam	Krishna, Nellore, Srikakulam, Visakhapatnam, Vizianagram	East Godavari, Guntur, Prakasam, West Godavari	–
Assam	All 22 districts listed in Table 53 could have M.S.K IX or more with flooding	No cyclone, but speed can be 50 m/s in districts of Table 53 causing local damage except Dhubri	–	–
Bihar	All 25 districts listed in Table 53	–	–	–
Goa	–	–	–	North and South Goa
Gujarat	Banaskantha, Danthe GS, Gandhinagar, Kheda, Mahesana, Panchmahals, Vadodara	–	Ahmedabad, Bharuch, Surat, Valsad	Amreli, Bhavnagar, Jamnagar, Rajkot, Junagad, Kachcha
Haryana	All 8 districts listed in Table 53	–	–	–
Kerala	Idukki, Kottayam, Palakkad, Pathanamthitta	–	Alappuzha, Ernakulum, Kannur, Kasargod, Kollam, Kozhikode, Malappuram, Thiruvanathapuram, Thrissur	–
Maharashtra	–	–	–	Mumbai, Rayagad, Ratnagiri, Sindhudurg, Thane
Orissa	–	Ganjam	Baleshwar, Cuttack, Puri	Dhenkanal
Punjab	All 12 districts listed in Table 53	–	–	–
Uttar Pradesh and Uttarakhand	All 50 districts listed in Table 53	–	–	–
West Bengal	Birbhum, Darjeeling, Jalpaiguri, Cooch Behar, Malda, Murshidabad, West Dinajpur	–	Bardhaman, Kolkata, Hugli, Howrah, Midnapore, Nadia, North and South 24 Parganas	Bankura
Union Territories	Delhi	–	Yanam (Py)	Diu
India	**139 Districts**	**6 Districts**	**29 Districts**	**16 Districts**

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Table 53 Multi-Hazard Prone Districts
(*Annex* P)

Assam
Barpeta, Bongaigaon, Cachar[1)], Darrang, Dhemaji, Dhuburi, Dibrugarh, Goalpara, Golaghat, Hailaknadi[1)], Jorhat, Kamrup, Karbianglong, Karimganj[1)], Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur, Tinsukia

Bihar[2)]
Araria, Begusarai, Bhagalpur, Bhojpur, Darbhanga, Gopalganj, Katihar, Khagaria, Kishanganj, Madhepura, Madhubani, Munger, Muzaffarpur, Nalanda, Nawada, Paschim Champaran, Patna, Purbachamparan, Purnia, Samastipur, Saran, Saharsa, Sitamarhi, Siwan, Vaishali

Haryana[3)]
Ambala, Bhiwani, Faridabad, Gurgaon, Hisar, Jind, Kurukshetra, Rohtak

Table 53 — (*Concluded*)

Punjab[4)]
Amritsar, Bathinda, Faridkot, Firozpur, Gurdaspur, Hoshiarpur, Jalandhar, Kapurthala, Ludhiana, Patiala, Rupnagar, Sangrur

Uttar Pradesh and Uttarakhand[5)]
Agra, Aligarh, Allahabad, Azamgarh, Bahraich, Ballia, Barabanki, Bareilly, Basti, Bijnor, Budaun, Bulandshahr, Deoria, Etah, Etawah, Faizabad, Farrukhabad, Fatehpur, Firozabad, Ghaziabad, Ghazipur, Gonda, Gorakhpur, Hardoi, Haridwar, Jaunpur, Kanpur (Dehat), Kanpur (Nagar), Kheri, Lucknow, Maharajganj, Mainpuri, Mathura, Mau, Meerut, Mirzapur, Mordabad, Muzaffarnagar, Nainital, Pilibhit, Partapgarh, Raebareli, Rampur, Saharanpur, Shahjahanpur, Siddarth Nagar, Sitapur, Sultanpur, Unnao, Varanasi

[1)] Districts liable to cyclonic storm but no storm surge
[2)] No cyclonic storm in Bihar
[3)] No cyclonic storm in Haryana
[4)] No cyclonic storm in Punjab
[5)] No cyclonic storm in Uttar Pradesh and Uttarakhand

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section:

	IS No.	*Title*
(1)	875 (Part 1) : 1987	Code of practice for design loads (other than Earthquake) for buildings and structures: Part 1 Dead loads-unit weights of building material and stored materials (*second revision*)
(2)	8888 (Part 1) : 1993	Guide for requirements of low income housing: Part 1 Urban area (*first revision*)
(3)	807 : 2006	Code of practice for design, erection and testing (structural portion) of cranes and hoists (*second revision*)
	3177 : 1999	Code of practice for electric overhead traveling cranes and gantry cranes other than steelwork cranes (*second revision*)
(4)	14732 : 2000	Guidelines for the evaluation of the response of occupants of fixed structures, especially buildings and off-shore structures, to low-frequency horizontal motion (0.063 to 1 Hz)
(5)	15498 : 2004	Guidelines for improving the cyclone resistance of low rise houses and other buildings/ structures
(6)	4326 : 2013	Code of practice for earthquake resistant design and construction of buildings (*third revision*)
	13827 : 1993	Guidelines for improving earthquake resistance of earthen buildings
	13828 : 1993	Guidelines for improving earthquake resistance of low strength masonry buildings
	13920 : 2016	Code of practice for ductile design and detailing of reinforced concrete structures subjected to seismic forces (*first revision*)
	13935 : 1993	Guidelines for repair and seismic strengthening of buildings

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	IS No.	*Title*
	15988 : 2013	Guidelines for seismic evaluation and strengthening of existing reinforced concrete building
(7)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
	800 : 2007	Code of practice for general construction in steel (*second revision*)
(8)	13920 : 2016	Code of practice for ductile design and detailing of reinforced concrete structures subjected to seismic forces (*first revision*)
(9)	800 : 2007	Code of practice for general construction in steel (*second revision*)
(10)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
(11)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
	1343 : 2012	Code of practice for prestressed concrete (*second revision*)
(12)	IS 1893 (Part 4) : 2015	Criteria for earthquake resistant design of structures: Part 4 Industrial structures including stack-like structures (*first revision*)
(13)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
	800 : 2007	Code of practice for general construction in steel (second revision)
	1343 : 2012	Code of practice for prestressed concrete (*second revision*)
	1905 : 1987	Code of practice for structural use of unreinforced masonry (*third revision*)
	2974	Code of practice for design and construction of machine foundations:
	(Part 1) : 1982	Foundation for reciprocating type machines (*second revision*)
	(Part 2) : 1980	Foundations for impact type machines (Hammer foundations) (*first revision*)
	(Part 3) : 1992	Foundations for rotary type machines (Medium and high frequency) (*second revision*)
	(Part 4) : 1979	Foundations for rotary type machines of low frequency (*first revision*)
	(Part 5) : 1987	Foundations for impact machines other than hammer (Forging and stamping press, pig breaker, drop crusher and jolter) (*first revision*)
(14)	2974	Code of practice for design and construction of machine foundations:
	(Part 1) : 1982	Foundation for reciprocating type machines (*second revision*)
	(Part 2) : 1980	Foundations for impact type machines (Hammer foundations) (*first revision*)
	(Part 3) : 1992	Foundations for rotary type machines (Medium and high frequency) (*second revision*)
	(Part 4) : 1979	Foundations for rotary type machines of low frequency (*first revision*)
	(Part 5) : 1987	Foundations for impact machines other than hammer (Forging and stamping press, pig breaker, drop crusher and jolter) (*first revision*)
(15)	6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
(16)	1888 : 1982	Method of load test on soils (*second revision*)
(17)	1498 : 1970	Classification and identification of soils for general engineering purposes (*first revision*)
	2131 : 1981	Method of standard penetration test for soils (*first revision*)
(18)	1893	Criteria for earthquake resistant design of structures:
	(Part 1) : 2016	General provisions and buildings (*Sixth revision*)
	(Part 2) : 2014	Liquid retaining tanks (*fifth revision*)
	(Part 3) : 2014	Bridges and retaining walls
	(Part 4) : 2015	Industrial structures including stack-like structures (*first revision*)
(19)	1905 : 1987	Code of practice for structural use of unreinforced masonry (*third revision*)
(20)	4326 : 2013	Earthquake resistant design and construction of buildings — Code of Practice (*third revision*)
(21)	3414 : 1968	Code of practice for design and installation of joints in buildings
(22)	875 (Part 5) : 1987	Code of practice for design loads (other than Earthquake) for buildings and structures: Part 5 Special loads and combinations (*second revision*)

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IS No.	*Title*
(23) 1642 : 2013	Code of practice fire safety of buildings (general): Details of construction (*second revision*)
(24) 14458 (Part 1) : 1998	Guidelines for retaining wall for hill area: Part 1 Selection of type of wall
(25) 14458 (Part 2) : 1997	Guidelines for retaining wall for hill area: Part 2 Design of retaining/breast walls
(26) 14458 (Part 3) : 1998	Guidelines for retaining wall for hill area: Part 3 Construction of dry stone walls
(27) 14496 (Part 2) : 1998	Guidelines for preparation of landslide—Hazard zonation maps in mountainous terrains: Part 2 Macro-zonation
(28) 14680 : 1999	Guidelines for landslide control
(29) 2131 : 1981	Method of standard penetration test for soils (*first revision*)
(30) 4991 : 1968	Criteria for blast resistant design of structures for explosions above ground
(31) 6922 : 1973	Criteria for safety and design of structures subject to underground blasts

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 2 Soils and Foundations

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Section 2) deals with the structural design aspects of foundations and mainly covers the design principles involved in different types of foundations.

This Section was published in 1970, and subsequently revised in 1983 and 2005. In the first revision, design considerations in respect of shallow foundation were modified, provisions regarding pier foundation were added and provisions regarding raft foundation and pile foundation were revised and elaborated. In the second revision, design considerations in respect of shallow foundations were again modified, method for determining depth of fixity, lateral deflection and maximum moment of laterally loaded piles were modified and reference was made to ground improvement techniques.

As a result of experience gained in implementation of 2005 version of the Code and feedback received as well as revision of standards in the field of soils and foundations, a need to revise this Section was felt. This revision has therefore been prepared to take into account these developments. The significant changes incorporated in this revision include:

a) The scope of this Section has been extended to cover design of foundations on rock.
b) Definitions of various terms have been modified as per the prevailing engineering practice and new terms have been added, particularly those relating to pile foundation and ground improvement.
c) The clause on site investigation has been completely reviewed and number of modifications have been included, such as, new methods of soil investigation have been added; depth of exploration for pile foundations has been added; new sub-clauses on vertical interval for field tests and site investigation report have been added; etc.
d) Method for assessment of liquefaction potential of a site has been included through a cross-reference to Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.
e) Permissible differential settlements and tilt (angular distortion) for shallow foundations in soils as given in Table 3 has been modified.
f) Procedures for calculation of bearing capacity, structural capacity, factor of safety, lateral load capacity, overloading, etc, in case of pile foundations have also been modified to bring them at par with the present practices.
g) Design parameters with respect to adhesion factor, earth pressure coefficient, modulus of subgrade reaction, etc, for design of pile foundations have also been revised to make them consistence with the outcome of modern research and construction practices.
h) Provision has been made for use of any established dynamic pile driving formulae, instead of recommending any specific formula, to control the pile driving at site, giving due consideration to limitations of various formulae.
j) Other modifications have also been incorporated in provisions relating to pile foundations to bring them in coherence with the revised Indian Standards on pile foundations.
k) A reference to spun piles, which are used in deep marshy soils where conventional pile installation beyond 50 m is difficult, has been included. However, much detail is not available in the country for the purpose of codal provisions which may be shared by the users of spun pipes in the country based on their experience in use of these piles, for formulation of guidelines thereon.
m) The clause on ground improvement techniques has been elaborated and a table on summary of soil improvement methods has been added.

For detailed information regarding structural analysis and soil mechanics aspects of individual foundations, reference should be made to standard textbooks and available literature.

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The information contained in this section is mainly based on the following Indian Standards:

IS 1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*)
IS 1892 : 1979	Code of practice for subsurface investigation for foundations (*first revision*)
IS 1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
IS 2911	Code of practice for design and construction of pile foundations
(Part 1/Sec 1) : 2010	Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*second revision*)
(Part 1/Sec 2) : 2010	Concrete piles, Section 2 Bored cast *in-situ* piles (*second revision*)
(Part 1/Sec 3) : 2010	Concrete piles, Section 3 Driven precast concrete piles (*second revision*)
(Part 1/Sec 4) : 2010	Concrete piles, Section 4 Precast concrete piles in prebored holes (*first revision*)
(Part 2) : 1980	Timber piles (*first revision*)
(Part 3) : 1980	Under-reamed piles (*first revision*)
IS 2950 (Part 1) : 1981	Code of practice for design and construction of raft foundations: Part 1 Design (*second revision*)

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to the revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 2 Soils and Foundations

1 SCOPE

1.1 This Code (Part 6/Section 2) covers geotechnical design (principles) of building foundations, such as shallow foundations like continuous strip footings, combined footings, raft foundations; deep foundations like pile foundations; and other foundation systems to ensure safety and serviceability without exceeding the permissible stresses of the materials of foundations and the bearing capacity of the supporting soil/rock.

1.2 It also covers provisions relating to preliminary work required for construction of foundations and protection of excavation.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 General

2.1.1 *Clay* — An aggregate of microscopic and sub-microscopic particles derived from the chemical decomposition and disintegration of rock constituents. It is plastic within a moderate to wide range of water content. The particles are less than 0.002 mm in size.

2.1.2 *Clay, Firm* — A clay which at its natural water content can be moulded by substantial pressure with the fingers and can be excavated with a spade.

2.1.3 *Clay, Soft* — A clay which at its natural water content can be easily moulded with the fingers and readily excavated.

2.1.4 *Clay, Stiff* — A clay which at its natural water content cannot be moulded with the fingers and requires a pick or pneumatic spade for its removal.

2.1.5 *Foundation* — That part of the structure which is in direct contact with and transmits loads to the ground.

2.1.6 *Gravel* — Angular, rounded or semi-rounded particles of rock or soil of particle size between 4.75 mm and 75 mm.

2.1.7 *Peat* — A fibrous mass of organic matter in various stages of decomposition generally dark brown to black in colour and of spongy consistency.

2.1.8 *Sand* — Cohesionless aggregates of angular, sub-angular, sub-rounded, rounded, flaky or flat fragments of more or less unaltered rocks, or mineral of size between 4.75 mm and 0.075 mm IS Sieve.

2.1.9 *Sand, Coarse* — Sand of particle size between 2.0 mm and 4.75 mm IS Sieve.

2.1.10 *Sand, Fine* — Sand of particle size between 0.075 mm and 0.425 mm IS Sieve.

2.1.11 *Sand, Medium* — Sand of particle size between 0.425 mm and 2.0 mm IS Sieve.

2.1.12 *Silt* — Fine-grained soil or fine-grained portion of soil which exhibits a little or no plasticity and has a little or no strength when air dried. The size of particles ranges from 0.075 mm to 0.002 mm.

2.1.13 *Soft Rock* — A rocky cemented material which offers a high resistance to picking up with pick axes and sharp tools but which does not normally require blasting or chiselling for excavation.

2.1.14 *Soil, Black Cotton* — Inorganic clays of medium to high compressibility. They form a major soil group in India. They are predominately montmorillonitic in structure and yellowish black or blackish grey in colour. They are characterized by high shrinkage and swelling properties.

2.1.15 *Soil, Coarse Grained* — Soils which include the coarse and largely siliceous and unaltered products of rock weathering. They possess no plasticity and tend to lack cohesion when in dry state. In these soils, more than half the total material by weight is larger than 75-micron IS Sieve size.

2.1.16 *Soil, Fine Grained* — Soils consisting of the fine and altered products of rock weathering, possessing cohesion and plasticity in their natural state, the former even when dry and both even when submerged. In these soils, more than half of the material by weight is smaller than 75-micron IS Sieve size.

2.1.17 *Soil, Highly Organic and Other Miscellaneous Soil Materials* — Soils consisting of large percentages of fibrous organic matter, such as peat, and particles of decomposed vegetation. In addition, certain soils containing shells, concretions, cinders, and other non-soil materials in sufficient quantities are also grouped in this division.

2.1.18 *Total Settlement* — The total downward movement of the foundation unit under load.

2.2 Ground Improvement

2.2.1 *Ground Improvement* — Enhancement of the in-place properties of the ground by controlled application of technique suited to subsoil conditions.

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2.2.2 *Injection* — Introduction of a chemical/ cementitious material into a soil mass by application of pressure.

2.2.3 *Preloading* – Application of loads to achieve improvement of soil properties prior to imposition of structural loads.

2.2.4 *Soil Densification* — A technique to densify cohesionless soils by imparting shocks or vibrations.

2.2.5 *Soil Reinforcement* — Rods, strips or fabrics incorporated within soil mass to impart resistance to tensile, shear and compressive forces.

2.3 Shallow Foundation

2.3.1 *Back Fill* — Materials used or reused to fill an excavation.

2.3.2 *Bearing Capacity, Safe* — The maximum intensity of loading that the soil will safely carry with a factor of safety against shear failure of soil irrespective of any settlement that may occur.

2.3.3 *Bearing Capacity, Ultimate* — The intensity of loading at the base of a foundation which would cause shear failure of the supporting soil.

2.3.4 *Bearing Pressure, Allowable (Gross or Net)* — The intensity of loading which the foundation will carry without undergoing settlement in excess of the permissible value for the structure under consideration but not exceeding safe bearing capacity.

The net allowable bearing pressure is the gross allowable bearing pressure minus the surcharge intensity.

NOTE — The concept of 'gross' and 'net' used in defining the allowable bearing pressure could also be extended to safe bearing capacity, safe bearing pressure and ultimate bearing capacity.

2.3.5 *Factor of Safety (with Respect to Bearing Capacity)* — A factor by which the ultimate bearing capacity (net) shall be reduced to arrive at the value of safe bearing capacity (net).

2.3.6 *Footing* — A structure constructed in brick work, masonry or concrete under the base of a wall or column for the purpose of distributing the load over a larger area.

2.3.7 *Foundation, Raft* — A substructure supporting an arrangement of columns or walls in a row or rows transmitting the loads to the soil by means of a continuous slab, with or without depressions or openings.

2.3.8 *Made-Up Ground* — Refuse, excavated soil or rock deposited for the purpose of filling a depression or raising a site above the natural surface level of the ground.

2.3.9 *Offset* — The projection of the lower step from the vertical face of the upper step.

2.3.10 *Permanent Load* — Loads which remain on the structure for a period, or a number of periods, long enough to cause time dependent deformation/ settlement of the soil.

2.3.11 *Shallow Foundation* — A foundation whose width is generally equal to or greater than its depth. The shearing resistance of the soil in the sides of the foundation is generally neglected.

2.3.12 *Spread (or Isolated or Pad) Foundation/ Footing* — A foundation which transmits the load to the ground through one or more footings. A spread footing (or isolated or pad) is provided to support an individual column. A spread footing is circular, square or rectangular slab of uniform thickness. Sometimes, it is stepped or haunched to spread the load over a large area.

2.3.13 *Strip Foundation/Footing* — A type of shallow foundation which provides continuous and longitudinal bearing for loads carried by vertical elements, such as continuous wall foundation beams or the like. A strip footing is also provided for a row of columns which are so closely spaced that their spread footings overlap or nearly touch each other. A strip footing is also known as continuous footing.

2.4 Pile Foundation

2.4.1 *Allowable Load* — The load which may be applied to a pile after taking into account its ultimate load capacity, group effect, the allowable settlement, negative skin friction and other relevant loading conditions including reversal of loads, if any.

2.4.2 *Anchor Pile* — A pile meant for resisting pull or uplift forces.

2.4.3 *Batter Pile (Raker Pile)* — The pile which is installed at an angle to the vertical using temporary casing or permanent liner.

2.4.4 *Bored Cast in-situ Pile* — Piles formed by boring a hole in the ground by percussive or rotary method with the use of temporary/permanent casing or drilling mud and subsequently filling the hole with reinforced concrete.

2.4.5 *Bored Compaction Pile* — A bored cast *in-situ* pile with or without bulb(s) in which the compaction of the surrounding ground and freshly filled concrete in pile bore is simultaneously achieved by a suitable method. If the pile is with bulb(s), it is known as under-reamed bored compaction pile.

2.4.6 *Bored Pile* — A pile formed with or without casing by excavating or boring a hole in the ground and subsequently filling it with plain or reinforced concrete.

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2.4.7 *Cut-off Level* — It is the level where a pile is cut-off to support the pile caps or beams or any other structural components at that level.

2.4.8 *Driven Cast in-situ Pile* — The pile formed within the ground by driving a casing of uniform diameter, or a device to provide enlarged base and subsequently filling the hole with reinforced concrete. For displacing the subsoil the casing is driven with a plug or a shoe at the bottom. When the casing is left permanently in the ground, it is termed as cased pile and when the casing is taken out, it is termed as uncased pile. The steel casing tube is tamped during its extraction to ensure proper compaction of concrete.

2.4.9 *Efficiency of a Pile Group* — It is the ratio of the actual supporting value of a group of piles to the supporting value arrived at by multiplying the pile resistance of an isolated pile by their number in the group.

2.4.10 *Initial Load Test* — A test pile is tested to determine the load carrying capacity of the pile by loading either to its ultimate load or to twice the estimated safe load.

2.4.11 *Negative Skin Friction* — Negative skin friction is the force developed through the friction between the pile and the soil in such a direction as to increase the loading on the pile, generally due to drag of a consolidating soft layer around the pile resting on a stiffer bearing stratum such that the surrounding soil settles more than the pile.

2.4.12 *Pile Spacing* — The spacing of piles means the centre-to-centre distance between adjacent piles.

2.4.13 *Precast Concrete Piles in Prebored Holes* — A pile constructed in reinforced concrete in a casting yard and subsequently lowered into prebored holes and the annular space around the pile grouted.

2.4.14 *Precast Driven Pile* — The pile constructed in concrete in a casting yard and subsequently driven into the ground when it has attained sufficient strength.

2.4.15 *Routine Test* — Test carried out on a working pile with a view to check whether pile is capable of taking the working load assigned to it without exceeding permissible settlement.

2.4.16 *Safe Load* — It is the load derived by applying a factor of safety on the ultimate load capacity of the pile/pile group or as determined from load test.

2.4.17 *Ultimate Load Capacity* — The maximum load which a pile can carry before failure, that is, when the founding strata fails by shear as evidenced from the load settlement curve or the pile fails as a structural member.

2.4.18 *Under-Reamed Pile* — A bored cast *in-situ* or bored compaction concrete pile with enlarged bulb(s) made by either cutting or scooping out the soil or by any other suitable process.

An under-reamed pile having more than one bulb is termed as multi under-reamed piles. The piles having two bulbs may be called double under-reamed piles.

2.4.19 *Working Load* — The load assigned to a pile as per design.

2.4.20 *Working Pile* — A pile forming part of the foundation system of a given structure.

3 SITE INVESTIGATION

3.1 General

Site investigation is essential in determining the physical, chemical and engineering properties of subsoil to arrive at the required foundation system. However, in areas which have already been developed, information may be obtained regarding the existing local knowledge, records of trial pits, boreholes, etc, in the vicinity, and the behaviour of the existing structures, particularly those of a similar nature to those proposed. This information may be made use of for design of foundation of lightly loaded structures of not more than two storeys and also for deciding the scope of further investigation for other structures.

3.1.1 If the existing information is not sufficient or is inconclusive, the proposed site should be explored in detail as per good practice [6-2(1)], so as to obtain a knowledge of the type, uniformity, consistency, thickness, sequence and dip of the strata, hydrology of the area and also the engineering properties. In the case of lightly loaded structures of not more than two storeys the tests required to obtain the above information are optional, mainly depending on site conditions.

3.1.1.1 Site reconnaissance would help in deciding future programme of field investigations, that is, to assess the need for preliminary or detailed investigations. Information on some of these may be obtained from topographical maps, geological maps, pedological and soil survey maps, seismic maps and aerial photographs.

Geological maps of the area give valuable information of the site conditions. The general topography will often give some indications of the soil conditions and their variations. In certain cases the earlier uses of the land (like quarries, agricultural land, buried canals, etc) may have a very important bearing on the proposed new structures.

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The presence of harmful chemicals in the subsoil can be easily identified by geology or by reconnaissance.

Data regarding removal of overburden by excavation, erosion or landslides should be obtained. This gives an idea of the amount of preconsolidation the soil strata has undergone. Similarly, data regarding recent fills is also important to study the consolidation characteristics of the fill as well as the original strata. Data regarding swelling or expansive soils will be useful information.

3.1.1.2 *Ground water conditions*

The ground water level fluctuates and will depend upon the permeability of the strata and the head causing the water to flow. The water level in streams and water courses, if any and wells in the vicinity give useful indications of the ground-water levels.

3.1.1.3 Rock out, crops if any may also be indicated during reconnaissance.

3.2 Methods of Site Exploration

3.2.1 *General*

Subsurface explorations should generally be carried out in two stages, that is, preliminary and detailed.

3.2.1.1 *Preliminary exploration*

The investigation at this stage is to explore the feasibility aspects. The scope of preliminary exploration is restricted to the determination of depths, thickness, extent and composition of each soil stratum, location of rock and ground water and also to obtain approximate information regarding strength in compressibility of the various strata.

The number of boreholes to be explored depends upon the importance of the structure, the aerial extent of facility, the topography and the nature of sub-strata conditions. Less than five exploratory boreholes, few sounding tests, geophysical methods and often few trial pits are generally adequate in the case of preliminary exploration.

3.2.1.2 *Detailed exploration*

Detailed investigation follow preliminary investigation and should be planned on the basis of data obtained during review as the investigations progress. The scope of detailed exploration is generally to determine shear strength and compressibility of all types of soils, density, density index, natural moisture content and permeability. It is also necessary to determine the preconsolidation pressure of the strata from oedometer tests and consolidation characteristics beyond the preconsolidation pressure. The detailed investigation includes boring, detailed sampling and laboratory tests to determine the physical, chemical and engineering properties of soil and rock. Field tests which may be performed are *in-situ* vane shear tests (suitable in case of soft cohesive soil) and plate load tests.

In a situation of liquefaction possibility, exploratory boreholes with SPT and sampling at very close depth intervals should be carried out, while static cone penetration tests with or without pore water pressure measurement are very useful. The cross hole shear tests and laboratory cyclic shear tests are useful in assessing the liquefaction potential.

NOTE — A method for assessment of liquefaction potential of a site is given in Annex J of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

3.2.1.3 The common methods of subsoil exploration are given below:

a) The most commonly used exploration procedure is boring in which different field testing procedures, like, standard penetration tests (SPT), field vane shear tests (VST), collection of undisturbed and disturbed sampling (UDS and DS), ground water table observations and field classification are employed.

b) *Open trial pits* — The method consists of excavating trial pits and thereby exposing the subsoil surface thoroughly, enabling undisturbed samples to be taken from the sides and bottom of the trial pits. This is suitable for all types of formations, but should be used for small depths (up to 3 m). In the case of cuts which cannot stand below water table, proper bracing should be given. The method may be used for examining the suitability of borrow pits.

c) *Auger boring* — The auger is either power or hand operated with periodic removal of the cuttings. Auger boring can be adopted in soft to stiff cohesive soils above water table. Augers shall be of helical or post hole type which may be manually or power operated. While boring, care shall be taken to minimize the disturbance to the deposits below the bottom of the borehole. The cuttings brought up by the auger shall be carefully examined in the field and the description of all the strata shall be duly recorded. No water shall be introduced from the top while conducting auger boring.

d) *Shell and auger boring* — Both manual and mechanized rig can be used for vertical borings. The tool normally consists of augers for soft to stiff clays, shells for very stiff and hard clays, and shells or sand pumps for sandy strata attached to sectional boring rods.

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e) *Wash boring* — In wash boring, the soil is loosened and removed from the borehole by a stream of water or drilling mud is worked up and down or rotated in the borehole. The water or mud flow carries the soil up the annular space between the wash pipe and the casing and it overflows at ground level where the soil in suspension is allowed to settle in a pond or tank and the fluid is re-circulated as required. Samples of the settled out soil can be retained for identification purposes but this process is often unreliable. However, accurate identification can be obtained if frequent sampling is resorted to using undisturbed sample tubes.

f) *Geophysical methods like electrical resistivity method and seismic method*

g) *Percussion boring*

h) *Rotary boring* — In this system, boring is effected by the cutting action of a rotating bit and a mud-laden fluid or grout is pumped continuously down hollow drill rods and side of the hole.

j) *Core drilling* — To obtain the core samples, core drilling using double table barrel, preferably using hydraulic feed to avoid disturbance to the rock core, is used.

k) *Pressure meter test* (*PMT*) — In this, a uniform radial stress is applied to the borehole and consequent deformation is measured from which limiting pressures and modulus are obtained. This test can also be used where the sampling in hard strata becomes difficult or where there is no UDS collected. For industrial structures, 80 bars capacity energy will suffice. However for nuclear projects, higher capacity up to 200 bars may be required.

m) *Plate load test* — This test is conducted at shallow depths with an assumption that it directly determines the bearing capacity. Small size steel plates or relatively large RCC pads are used for conducting this test.

NOTE — While this procedure may be adequate for light or less important structures under normal conditions, relevant laboratory tests or field tests are essential in the case of unusual soil types and for all heavy and important structures. Plate load test, though useful in obtaining the necessary information about the soil with particular reference to design of foundation has some limitations. The test results reflect only the character of the soil located within a depth of less than twice the width of the bearing plate. Since the foundations are generally larger than the test plates, the settlement and shear resistance will depend on the properties of a much thicker stratum. Moreover, this method does not give the ultimate settlements particularly in case of cohesive soils. Thus the results of the test are likely to be misleading, if the character of the soil changes at shallow depths, which is not uncommon. A satisfactory load test should, therefore, include adequate soil exploration {*see* good practice [6-2(2)]} with due attention being paid to any weaker stratum below the level of the footing. Another limitation is the concerning of the effect of size of foundation. For clayey soils the bearing capacity (from shear consideration) for a larger foundation is almost the same as that for the smaller test plate. But in dense sandy soils the bearing capacity increases with the size of the foundation. Thus tests with smaller size plate tend to give conservative values in dense sandy soils. It may, therefore, be necessary to test with plates of at least three sizes and the bearing capacity results extrapolated for the size of the actual foundation (minimum dimensions in the case of rectangular footings).

n) *Laboratory investigation* — This gives numerical values for strength, stiffness and consolidation parameters apart from the description and classification of different soil layers.

p) *In-situ permeability test* — In case of high water table and construction extending below the water table, prior lowering of water table would be necessary. In such situations, this test may be required.

q) *Dynamic cone penetration test* (*DCPT*)

r) *Static cone penetration test* (*SCPT*) — Apart from the above methods there are few other sounding procedures like Light Cone Penetration Tests (LCPT) and Dynamic Probing Tests (DPT), in which similar sounding techniques as in the case of DCPT are used, probably more effectively. Hydraulic feed of 20 t capacity helps to obtain data even from hard soils. For small projects 10 t hydraulic rig may suffice.

3.2.2 *Number and Disposition of Test Locations*

The number and disposition of various tests shall depend upon type of structure/buildings and the soil strata variations in the area. General guidelines are, however, given below:

a) For a compact building site covering an area of about 0.4 hectare, one borehole or trial pit in each corner and one in the centre should be adequate.

b) For smaller and less important buildings, even one borehole or trial pit in the centre will suffice.

c) For very large areas covering industrial and residential colonies, the geological nature of the terrain will help in deciding the number of boreholes and trial pits. For various commercial, industrial, infrastructure, power plants, cement plants, petrochemical plants,

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steel plants, pump house on shore or offshore, etc, number of boreholes and/or trial pits should be decided considering the importance of structure and type as well as uniformity of strata. As a guide, dynamic or static cone penetration tests may be performed at every 100 m by dividing the area in a grid pattern and the number of boreholes or trial pits may be decided by examining the variation in the penetration curves. The cone penetration tests may not be possible at sites having generally gravelly/bouldery strata. In such cases, geophysical methods may be resorted to.

3.2.3 *Depth of Exploration*

The depth of exploration required depends on the type of proposed structure, its total weight, the size, shape and disposition of the loaded areas, soil profile, and the physical properties of the soil that constitutes each individual stratum. The borings should be extended to strata of adequate bearing capacity and should penetrate all deposits which are unsuitable for foundation purposes, such as, unconsolidated fill, peat, organic silt and very soft and compressible clay. Normally, it should be one and a half times the width of the footing below foundation level. In certain cases, it may be necessary to take at least one borehole or cone test or both to twice the width of the foundation. If a number of loaded areas are in close proximity the effect of each is additive. In such cases, the whole of the area may be considered as loaded and exploration should be carried out up to one and a half times the lower dimension. In weak soils, the exploration should be continued to a depth at which the loads can be carried by the stratum in question without undesirable settlement and shear failure. In any case, the depth to which seasonal variations affect the soil should be regarded as the minimum depth for the exploration of sites. But where industrial processes affect the soil characteristics, this depth may be more. The presence of fast growing and water seeking trees also contributes to the weathering processes.

NOTE — Examples of fast growing and water seeking trees are Banyan (*Ficusbengalensis*), Pipal (*Ficusreligiosa*) and Neem (*Azadirachtaindica*).

3.2.3.1 An estimate of the variation with depth of the vertical normal stress in the soil arising from foundation loads may be made on the basis of elastic theory. The net loading intensity at any level below a foundation may be obtained approximately by assuming a spread of load of two vertical to one horizontal from all sides of the foundations, due allowance being made for the overlapping effects of load from closely spaced footings. As a general guidance, the depth of exploration at the start of the work may be decided as given in Table 1, which may be modified as exploration proceeds, if required. However, for industrial plant and other main structures, the depth of exploration may be decided depending upon importance of structure, loading conditions and type as well as uniformity of strata. For piles or piers, the depth shall be at least $\frac{2}{3}L$ below the anticipated tip (that is, termination of pile) or 5.0 m in rock with rock quality designation (RQD) ≥ 50 percent, whichever is earlier.

Table 1 Depth of Exploration
(*Clause* 3.2.3.1)

Sl No.	Type of Foundation	Depth of Exploration *D*
(1)	(2)	(3)
i)	Isolated spread footing or raft	One and a half times the width (*B*) (*see* Fig. 1)
ii)	Adjacent footings with clear spacing less than twice the width	One and a half times the length (*L*) of the footing (*see* Fig. 1)
iii)	Adjacent rows of footings	*See* Fig. 1
iv)	Pile and well foundations	To a depth of one and a half times the width of structure from the bearing (tip of pile or bottom of well)
v)	a) Road cuts	Equal to the bottom width of the cut
	b) Fill	2 m below ground level or equal to the height of the fill, whichever is greater

3.2.4 *Vertical Interval for Field Tests*

Normally, once the type of foundation is decided as shallow footings based on initial findings, the test intervals shall be close to almost continuous at least for a depth equal to 1.5 times the foundation width.

Similarly, in the case of pile foundations, the test intervals shall be significantly small within a depth range of eight times the pile diameter above the pile tip and five times the pile diameter below the pile tip until incompressible stratum is encountered and confined geologically.

In case of housing colonies, the depth of borehole may be kept as 40 m or 5 m in rock with rock quality designation RQD ≥ 25 percent, whichever is earlier.

In the case of ground improvement programme like pre-loading, stone columns, compaction, etc, the field tests and sampling shall be almost continuous so that presence of thin soil layers of different texture can be identified.

3.3 Choice of Method for Site Exploration

The choice of the method depends on the following factors.

3.3.1 *Nature of Ground*

a) *Soils* — In clayey soils, borings are suitable for

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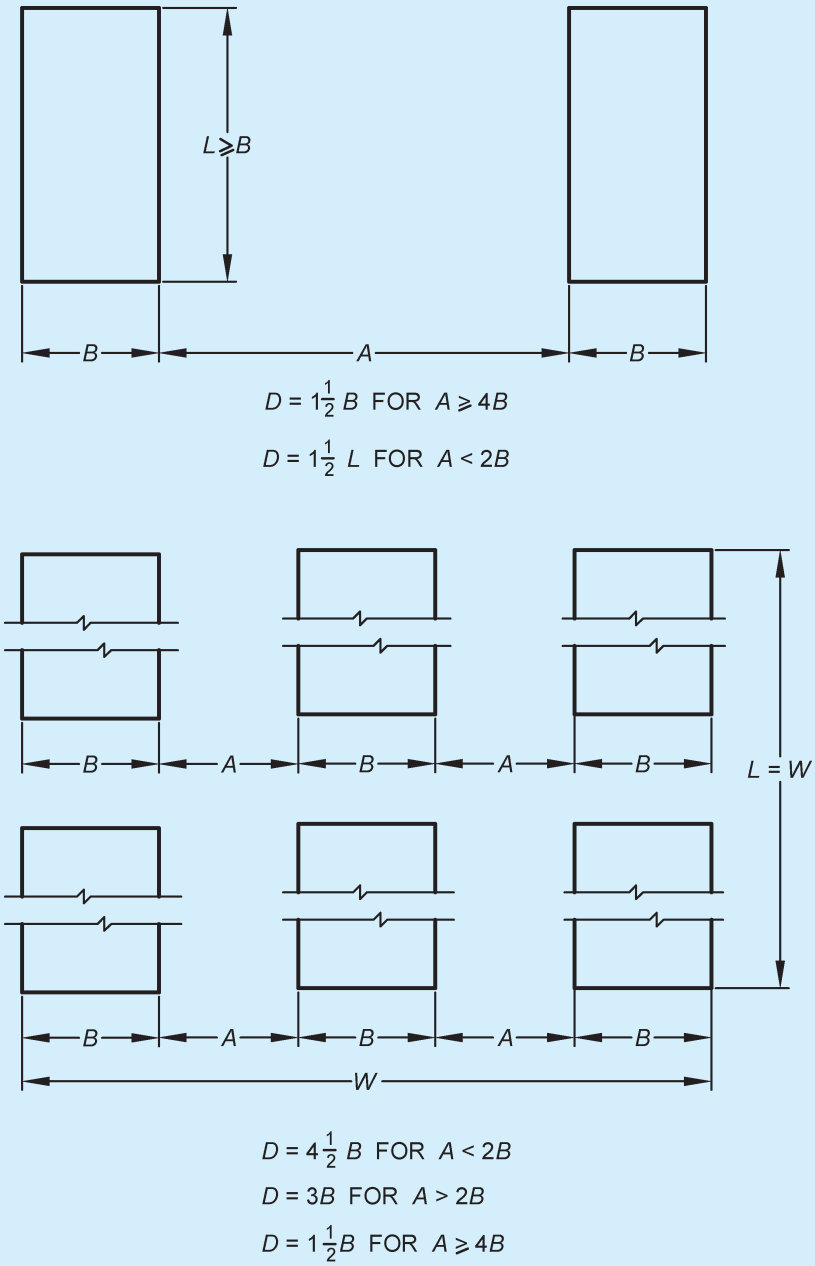


FIG. 1 DEPTH OF EXPLORATION

deep exploration and pits for shallow exploration. In case of soft sensitive clayey soils, field vane shear test may be carried out with advantage.

In sandy soils, boring is easy but special equipment, such as, Bishop or Osterberg piston samplers should be used for taking undisturbed samples below the water table. Where necessary, some form of ground water lowering is used. Standard penetration test, dynamic cone penetration test and static cone penetration test are used to assess engineering properties.

b) *Gravel-boulder deposits* — In the deposits where gravel-boulder proportion is large (>30 percent), the subsoil strata should be explored by open trial pits of about 5 m × 5 m but in no case less than 2 m × 2 m. The depth of excavation may be up to 6 m. For determining strata characteristics, *in-situ* tests should be preferred. For shear characteristics and allowable soil pressure, pressure meter tests, load tests on cast *in-situ* footing and *in-situ* shear tests that is, boulder-boulder test or concrete-boulder test are more appropriate. For detailed information on these tests reference shall be made to good practice [6-2(3)]. Depending on the structure, if required, the strata may be explored by drilling borehole using suitable method.

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c) *Rocks* — Core drillings are suitable in hard rocks and pits in soft rocks. Core borings are suitable for the identification of types of rock, but they provide limited data on joints and fissures. NX borehole camera is useful to photograph the stratification in drilled boreholes. For obtaining core, double tube core barrel with hydraulic feed is preferred. Triple tube core barrel may be used in fragmented or failure or sheared rock. Depending upon the design requirements, large diameter drilling may be explored if feasible.

3.3.2 *Topography*

In hilly country, the choice between vertical openings (for example, borings and trial pits) and horizontal openings (for example, headings) may depend on the geological structure, since steeply inclined strata are most effectively explored by headings and horizontal strata by trial pits or borings. Swamps and areas overlain by water are best explored by borings which may require use of a floating craft.

3.3.3 *Cost*

The cost of investigation varies depending upon project size, stratigraphy, location, marshy areas' access or approaches, etc. The data to be obtained for founding purpose, with a view to reducing or minimizing the surprises, is however, important. It also helps in solutions in respect of selection of appropriate type of foundation, construction materials, etc. For deep exploration, borings are usual, as deep shafts are costly. For shallow exploration in soil, the choice between pits and borings will depend on the nature of the ground and the information required by shallow exploration in rock; the cost of bringing a core drill to the site will be justified only, if several holes are required; otherwise, trial pits will be more economical.

3.4 Sampling and Testing

3.4.1 *Methods of Sampling*

a) *Disturbed samples* — These are taken by methods which modify or destroy the natural structure of the material though with suitable precautions the natural moisture content can be preserved.

b) *Undisturbed samples (UDS)* — These are taken by methods which preserve the structure and properties of the material. Thin walled tube samples may be used for undisturbed samples in soils of medium strength and tests for the same may be carried out in accordance with good practice [6-2(1)]. Minimum one UDS shall be obtained from each cohesive layer. For thick layers, the UDS shall be taken at every 3 m intervals. UDS need not be taken from cohesion less soils (silty sand, sand and gravel).

NOTE — In case of loose sandy soils and soft soils, specially below water table it may not be possible to take undisturbed sample, in which case other suitable methods may be adopted for exploration.

c) *Representative samples* — These samples have all their constituent parts preserved, but may or may not be structurally disturbed. Washed samples from rotary boring should not be collected.

3.4.1.1 The methods usually employed are:

Sl No. (1)	*Nature of Ground* (2)	*Type of Sample* (3)	*Method of Sampling* (4)
i)	Soil	a) Disturbed	Chunk samples Auger samples (for example, in clay) Shell samples (for example, in sand)
		b) Undisturbed	Chunk samples Tube samples
ii)	Rock	a) Disturbed	Wash samples from percussion or rotary drilling
		b) Undisturbed	Core barrel sampling

3.4.2 *Soil Samples*

a) *Disturbed soil samples* — The mass of sample generally required for testing purposes is given in Table 2.

Table 2 Mass of Soil Sample Required
[*Clause* 3.4.2(a)]

Sl No. (1)	Purpose of Sample (2)	Type (3)	Mass of Sample Required kg (4)
i)	Soil identification, natural moisture content tests, mechanical analysis and index properties	a) Cohesive soil	1
	Chemical tests	b) Sands and gravels	3
ii)	Compaction tests	a) Cohesive soils and sands	12.5
		b) Gravely soils	25
iii)	Comprehensive examination of construction materials including stabilization	a) Cohesive soils and sands	25 to 50
		b) Gravely soils	50 to 100

NOTES

1 The schedule for laboratory tests shall include the representative of the sub-strata layer for testing physical, engineering and chemical properties of soil and rock.

2 Additional tests, if any required for assessing suitability of borrow material may also be included.

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b) *Undisturbed soil samples* — The core diameter of the sample shall be 75 mm to 100 mm diameter and it shall preferably be 300 mm long. The upper few millimetres of the sample should be rejected as the soil at the bottom of the borehole usually gets disturbed by the boring tools.

3.4.3 *Rock Samples*

a) *Disturbed samples* — The sludge from percussion borings, or from rotary borings which have failed to yield a core, may be taken as a disturbed sample.

b) Undisturbed samples

1) *Block samples* — Such samples taken from the rock formation shall be dressed to a size convenient for packing to about 90 mm × 75 mm × 50 mm.

2) *Core samples* — Cores of rock shall be taken by means of rotary drills fitted with a coring bit with core retainer {*see also* good practice [6-2(4)]}.

3.4.4 *Water Samples*

Water samples have to be collected for chemical analysis. In cases, where mud circulation is used for advancing and stabilizing the boreholes, water samples are to be collected only after 24 h of completion of the borehole. The other option is to collect water samples from open wells in the close proximity. The sample shall be collected in a plastic container (about 500 ml) with airtight cover.

3.4.5 *Protection, Handling and Labelling of Samples*

Care should be taken in protecting, handling and subsequent transport of samples and in their full labelling, so that samples can be received in a fit state for examination and testing, and can be correctly recognized as coming from a specified trial pit or boring.

3.4.6 *Examination and Testing of Samples*

3.4.6.1 The following tests shall be carried out in accordance with accepted standard [6-2(5)]:

a) *Tests on undisturbed and disturbed samples*

1) Visual and engineering classification;
2) Sieve analysis and hydrometer analysis;
3) Liquid, plastic, and shrinkage limits;
4) Specific gravity;
5) Chemical analysis (sulphate, chloride and *p*H content of soil and ground water);
6) Swell pressure and free swell index determination;
7) Proctor compaction test; and
8) California bearing ratio.

b) *Test on undisturbed samples*

1) Bulk density and moisture content;
2) Relative density (for sand);
3) Unconfined compression test;
4) Box shear test (in case of cohesionless and c-ϕ soil);
5) Triaxial shear tests (depending on the type of soil and field conditions on undisturbed or remoulded samples):
   i) Unconsolidated undrained,
   ii) Consolidated undrained test with the measurement of pore water pressure, and
   iii) Consolidated drained;
6) Consolidation test; and
7) Laboratory permeability test.

c) *Test on rock samples*

1) Visual classification;
2) Water absorption, porosity and density;
3) Specific gravity;
4) Hardness;
5) Slake durability;
6) Unconfined compression test (both saturated and at *in-situ* water content);
7) Point load strength index; and
8) Deformability test (both saturated and dry samples).

NOTE — These tests may be reduced according to engineering requirements.

3.5 Soil Investigation Report

The soil investigation report shall generally include the following:

a) Scope of the investigation;
b) Method of drilling of borehole;
c) Sampling of boreholes;
d) Visual description of soil samples;
e) Ground levels along with ground water table level;
f) Test results (both laboratory and field);
g) Photographs of samples collected with descriptions;
h) Photo graphs of laboratory test samples after testing;
j) General observations of vicinity (streams, foundation system adopted, etc);
k) Longitudinal and transverse cross-section profiles of substrata;

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m) Analysis of field and laboratory test results;
n) Sample calculations for arriving at the allowable bearing pressure and pile capacities, if included in the scope of work; and
p) Recommendations, if included in the scope of work.

4 CLASSIFICATION AND IDENTIFICATION OF SOILS

The classification and identification of soils for engineering purposes shall be in accordance with accepted standard [6-2(6)].

5 MATERIALS

5.1 Cement, coarse aggregate, fine aggregate, lime, *Surkhi,* steel, timber and other materials go into the construction of foundations shall conform to the requirements of Part 5 'Building Materials' of the Code.

5.2 Protection Against Deterioration of Materials

Where a foundation is to be in contact with soil, water or air, that is, in a condition conducive to the deterioration of the materials of the foundation, protective measures shall be taken to minimize the deterioration of the materials.

5.2.1 *Concrete*

The concrete used for construction shall be in accordance with Part 6 'Structural Design, Section 5 Concrete' of the Code.

5.2.2 *Timber*

Where timber is exposed to soil, it shall be treated in accordance with good practice [6-2(7)].

6 GENERAL REQUIREMENTS FOR FOUNDATIONS/SUBSTRUCTURES FOR BUILDINGS

6.1 Types of Foundations

Types of foundations for buildings covered in this Section are:

a) *Shallow foundations* (*see* **7**)
   1) Pad or spread and strip foundations (*see* **7.2**),
   2) Raft foundations (*see* **7.4**),
   3) Ring foundations (*see* **7.5**), and
   4) Shell foundations (*see* **7.6**).
b) *Deep foundations*
   1) Pile Foundations
      i) Driven cast *in-situ* concrete piles (*see* **8**),
      ii) Bored cast *in-situ* concrete piles (*see* **8**),
      iii) Driven precast concrete piles (*see* **9**),
      iv) Precast concrete piles in prebored holes (*see* **10**),
      v) Under-reamed concrete piles (*see* **11**),
      vi) Timber piles (*see* **12**), and
      vii) Spun piles.

      NOTE — Spun piles are used in deep marshy soils as conventional pile installation beyond 50 m in such soils is very difficult.

c) *Other foundations/substructures/foundations for special structure*
   1) Pier foundations (*see* **13.1**),
   2) Diaphragm walls (*see* **13.2**), and
   3) Machine foundations (*see* **13.2**).

6.2 Depth of Foundations

6.2.1 The depth to which foundations should be carried depends upon the following principal factors:

a) Securing of adequate allowable capacity.
b) In the case of clayey soils, penetration below the zone where shrinkage and swelling due to seasonal weather changes, and due to trees and shrubs are likely to cause appreciable movements.
c) In fine sands and silts, penetration below the zone in which trouble may be expected from frost.
d) Maximum depth of scour, wherever relevant, should also be considered and the foundation should be located sufficiently below this depth.
e) Other factors such as ground movements and heat transmitted from the building to the supporting ground may be important.

6.2.2 All foundations shall extend to a depth of at least 500 mm below natural ground level. On rock or such other weather resisting natural ground, removal of the top soil may be all that is required. In such cases, the surface shall be cleaned and, if necessary, stepped or otherwise prepared so as to provide a suitable bearing and thus prevent slipping or other unwanted movements.

6.2.3 Where there is excavation, ditch pond, water course, filled up ground or similar condition adjoining or adjacent to the subsoil on which the structure is to be erected and which is likely to impair the stability of structure, either the foundation of such structure shall be carried down to a depth beyond the detrimental influence of such conditions, or retaining walls or similar works shall be constructed for the purpose of shielding from their effects.

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6.2.4 A foundation in any type of soil shall be below the zone significantly weakened by root holes or cavities produced by burrowing animals or works. The depth shall also be enough to prevent the rainwater scouring below the footings.

6.2.5 Clay soils, like black cotton soils, are seasonally affected by drying, shrinkage and cracking in dry and hot weather, and by swelling in the following wet weather to a depth which will vary according to the nature of the clay and the climatic condition of the region. It is necessary in these soils, either to place the foundation bearing at such a depth where the effects of seasonal changes are not important or to make the foundation capable of eliminating the undesirable effects due to relative movement by providing flexible type of construction or rigid foundations. Adequate load counteracting against swelling pressures also provide satisfactory foundations.

6.3 Foundation at Different Levels

6.3.1 Where footings are adjacent to sloping ground or where the bottoms of the footings of a structure are at different levels or at levels different from those of the footings of adjoining structures, the depth of the footings shall be such that the difference in footing elevations shall be subject to the following limitations:

a) When the ground surface slopes downward adjacent to a footing, the sloping surface shall not intersect a frustum of bearing material under the footing having sides which make an angle of 30° with the horizontal for soil and horizontal distance from the lower edge of the footing to the sloping surface shall be at least 600 mm for rock and 900 mm for soil (*see* Fig. 2).

b) In the case of footings in granular soil, a line drawn between the lower adjacent edges of adjacent footings shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 3).

c) In case of footing in clayey soils a line drawn between the lower adjacent edge of the upper footing and the upper adjacent edge of lower footing shall not have a steeper slope than one vertical to two horizontal (*see* Fig. 4).

6.3.2 The requirement given in **6.3.1** shall not apply in the condition where adequate provision is made for the lateral support (such as with retaining walls) of the material supporting the higher footing.

6.4 Effect of Seasonal Weather Changes

During periods of hot, dry weather a deficiency of water develops near the ground surface and in clay soils, that is associated with a decrease of volume or ground shrinkage and the development of cracks. The shrinkage of clay will be increased by drying effect produced by fast growing and water seeking trees. The range of influence depends on size and number of trees and it increase during dry periods. In general, it is desirable that there shall be a distance of at least 8 m between such trees. Boiler installations, furnaces, kilns, underground cables and refrigeration installations and other artificial sources of heat may also cause increased volume changes of clay by drying out the ground beneath them, the drying out can be to a substantial depth. Special precautions either in the form of insulation or otherwise should be taken. In periods of wet weather, clay soils swell and the cracks lend to close, the water deficiency developed in the previous

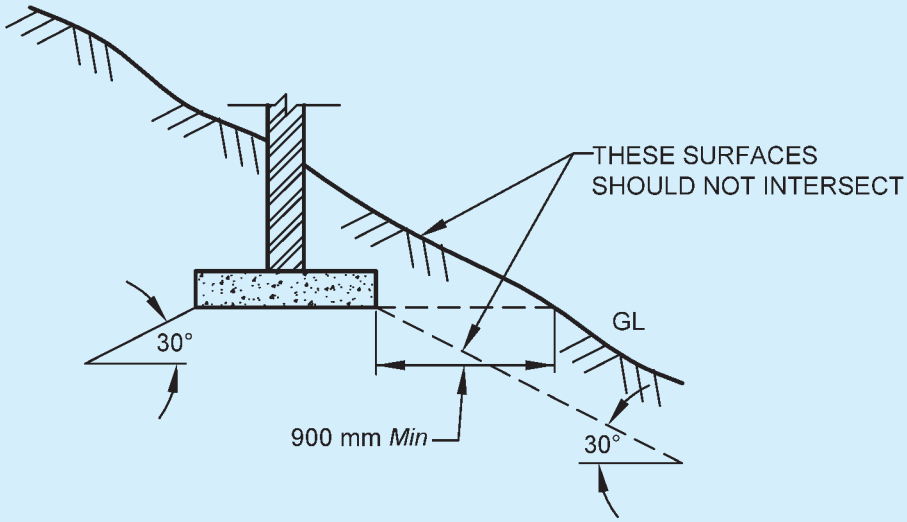


FIG. 2 FOOTING IN SLOPING GROUND

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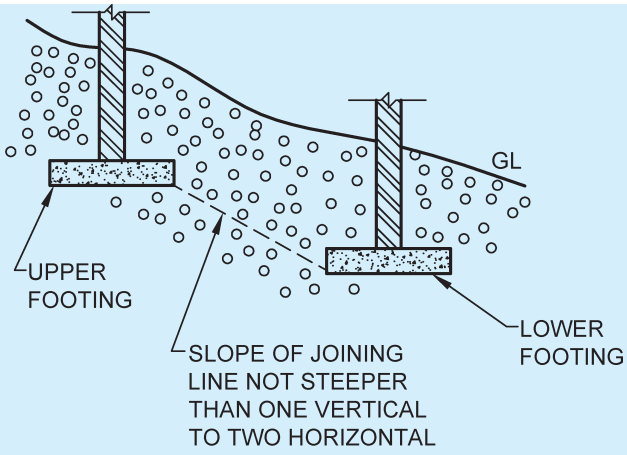


FIG. 3 FOOTING IN GRANULAR SOIL

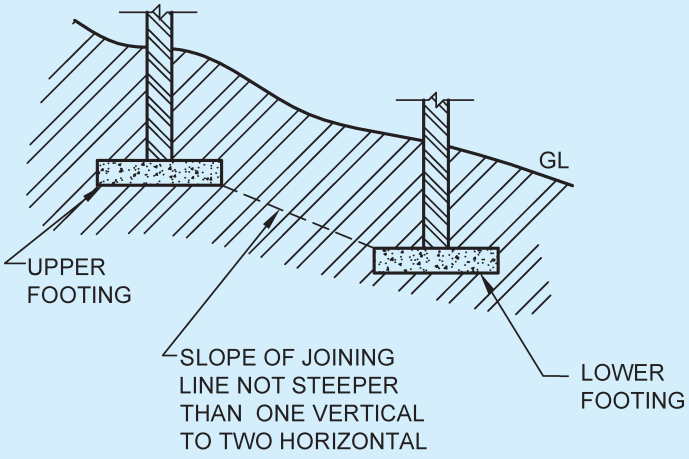


FIG. 4 FOOTING IN CLAYEY SOIL

dry periods may be partially replenished and a subsurface zone or zones deficient in water may persist for many years. Leakage from water mains and underground sewers may also result in large volume changes. Therefore, special care shall be taken to prevent such leakages.

6.5 Effect of Mass Movements of Ground in Unstable Areas

In certain areas mass movements of the ground are liable to occur from causes independent of the loads applied by the foundations of structures. These include mining subsidence, landslides on unstable slopes and creep on clay slopes.

6.5.1 *Mining Subsidence*

In mining areas, subsidence of the ground beneath a building or any other structure is liable to occur. The magnitude of the movement and its distribution over the area are likely to be uncertain and attention shall, therefore, be directed to make the foundations and structures sufficiently rigid and strong to withstand the probable worst loading condition and probable ground movements. Long continuous buildings should be avoided in such areas and large building in such area should be divided into independent sections of suitable size, each with its own foundations. Expert advice from appropriate mining authority should be sought.

NOTE — For prediction of subsidence in coal mines, guidelines as given in the good practice [6-2(8)] may be referred.

6.5.2 *Landslide Prone Areas*

The construction of structures on slopes which are suspected of being unstable and are subject to landslip shall be avoided.

On sloping ground on clay soils, there is always a tendency for the upper layers of soil to move downhill, depending on type of soil, the angle of slope, climatic

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conditions, etc. In some cases, the uneven surface of the slope on a virgin ground will indicate that the area is subject to small land slips and, therefore, if used for foundation, will obviously necessitate special design consideration.

Where there may be creep of the surface layer of the soil, protection against creep may be obtained by following special design considerations.

On sloping sites, spread foundations shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or twice the height of the step, whichever is greater. The steps shall not be of greater height than the thickness of the foundation, unless special precautions are taken.

Cuttings, excavations or sloping ground near and below foundation level may increase the possibility of shear failure of the soil. The foundation shall be well beyond the zone of such shear failure.

If the probable failure surface intersects a retaining wall or other revetment, the latter shall be made strong enough to resist any unbalanced thrust. In case of doubt as to the suitability of the natural slopes or cuttings, the structure shall be kept well away from the top of the slopes, or the slopes shall be stabilized.

Cuttings and excavations adjoining foundations reduce stability and increase the likelihood of differential settlement. Their effect should be investigated not only when they exist but also when there is possibility that they are made subsequently.

Where a structure is to be placed on sloping ground, additional complications are introduced. The ground itself, particularly if of clay, may be subject to creep or other forms of instability, which may be enhanced if the strata dip in the same direction as the ground surface. If the slope of the ground is large, the overall stability of the slope and substructure may be affected. These aspects should be carefully investigated.

6.6 Precautions for Foundations on Inclined Strata

In the case of inclined strata, if they dip towards a cutting of basement, it may be necessary to carry foundation below the possible slip planes, land drainage also requires special consideration, particularly on the uphill side of a structure to divert the natural flow of water away from the foundations.

6.7 Strata of Varying Thickness

Strata of varying thickness, even at appreciable depth, may increase differential settlement. Where necessary, calculations should be made of the estimated settlement from different thickness of strata and the structure should be designed accordingly. When there is large change of thickness of soft strata, the stability of foundation may be affected. Site investigations should, therefore, ensure detection of significant variations in strata thickness.

6.8 Layers of Softer Material

Some soils and rocks have thin layers of softer material between layers of harder material, which may not be detected unless thorough investigation is carried out. The softer layers may undergo marked changes in properties if the loading on them is increased or decreased by the proposed construction or affected by related changes in ground water conditions. These should be taken into account.

6.9 Spacing Between Existing and New Foundation

The deeper the new foundation and the nearer to the existing it is located, the greater the damage is likely to be. The minimum horizontal spacing between existing and new footings shall be equal to the width of the wider one. While the adoption of such provision shall help minimizing damage to adjacent foundation, an analysis of bearing capacity and settlement shall be carried out to have an appreciation of the effect on the adjacent existing foundation.

6.10 Preliminary Work for Construction

6.10.1 The construction of access roads, main sewers and drains should preferably be completed before commencing the work of foundations; alternatively, sufficient precautions shall be taken to protect the already constructed foundations during subsequent work.

6.10.2 *Clearance of Site*

Any obstacles, including the stump of trees, likely to interfere with the work shall be removed. Holes left by digging, such as those due to removal of old foundation, uprooted trees, burrowing by animals, etc, shall be back-filled with soil and well compacted.

6.10.3 *Drainage*

If the site of a structure is such that surface water shall drain towards it, land may be dressed or drains laid to divert the water away from the site.

6.10.4 *Setting Out*

Generally the site shall be levelled before the layout of foundations are set out. In case of sloping terrain, care shall be taken to ensure that the dimensions on plans are set out correctly in one or more horizontal planes.

6.10.5 The layout of foundations shall be set out with steel tapes. Angles should be set out with theodolites

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in the case of important and intricate structures where the length of area exceeds 16 m. In other cases these shall be set out by measurement of sides. In rectangular or square setting out, diagonals shall be checked to ensure accuracy. The setting out of walls shall be facilitated by permanent row of pillars, parallel to and at a suitable distance beyond the periphery of the building. The pillars shall be located at junctions of cross walls with the peripheral line of pillars. The centre lines of the cross walls shall be extended to and permanently erected on the plastered tops of the corresponding sets of pillars. The datum lines parallel to and at the known fixed distance from the centre lines of the external walls also be permanently worked on the corresponding rows of pillars to pillars to serve as checks on the accuracy of the work as it proceeds. The tops of these pillars shall be at the same level and preferably at the plinth or floor level. The pillars shall be of sizes not less than 250 mm wide and shall be bedded sufficiently deep into ground, so that they are not disturbed.

6.11 Protection of Excavation

6.11.1 The protection of excavastion during construction of timbering and dewatering operations, where necessary, shall be done in accordance with [6-2(9)].

6.11.2 After excavation, the bottom of the excavation shall be cleared of all loose soil and rubbish and shall be levelled, where necessary. The bed shall be wetted and compacted by heavy rammers to an even surface.

6.11.3 Excavation in clay or other soils that are liable to be effected by exposure to atmosphere shall, wherever possible, be concreted as soon as they are dug. Alternatively, the bottom of the excavation shall be protected immediately by 8 cm thick layer of cement concrete not leaner than mix 1: 5 : 10 over which shall come the foundation concrete; or in order to obtain a dry hard bottom, the last excavation of about 10 cm shall be removed only before concreting.

6.11.4 The refilling of the excavation shall he done with care so as not to disturb the constructed foundation, and shall be compacted in layers not exceeding 15 cm thick with sprinkling of minimum quantity of water necessary for proper compaction.

6.12 Alterations During Construction

a) Where during construction the soil or rock to which foundation is to transfer loads is found not to be the type or in the condition assumed, the foundation shall be redesigned and constructed for the existing type or conditions and the Authority notified.

b) Where a foundation bears on gravel, sand or silt and where the highest level of the ground water is or likely to be higher than an elevation defined by bearing surface minus the width of the footing, the bearing pressure shall be suitably altered.

c) Where the foundation has not been placed or located as indicated earlier or is damaged or bears on a soil whose properties may be adversely changed by climatic and construction conditions, the error shall be corrected, the damaged portion repaired or the design capacity of the affected foundation recalculated to the satisfaction of the Authority.

d) Where a foundation is placed, and if the results of a load test so indicate, the design of the foundation shall be modified to ensure structural stability of the same.

7 SHALLOW FOUNDATIONS

7.1 Design Information

For the satisfactory design of foundations, the following information is necessary:

a) Type and condition of the soil or rock to which the foundation transfers the loads;

b) General layout of the columns and load-bearing walls showing the estimated loads, including moments and torques due to various loads (dead load, imposed load, wind load, seismic load) coming on the foundation units;

c) Allowable bearing pressure of the soils;

d) Changes in ground water level, drainage and flooding conditions and also the chemical conditions of the subsoil water, particularly with respect to its sulphate content;

e) Behaviour of the buildings, topography and environment/surroundings adjacent to the site, the type and depths of foundations and the bearing pressure assumed; and

f) Seismic zone of the region.

7.2 Design Considerations

7.2.1 *Design Loads*

The foundation shall be proportioned for the following combination of loads:

a) Dead load + Imposed load; and

b) Dead load + Imposed load + Wind load or seismic loads, whichever is critical.

For details, reference shall be made to Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

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NOTE — For shallow foundations on coarse grained soils, settlements shall be estimated corresponding to **7.2.1** (b) and for foundations on fine grained soils, the settlement shall be estimated corresponding to permanent loads only. Permanent loads shall be in accordance with good practice [6-2(10)].

7.2.2 *Allowable Bearing Pressure*

The allowable bearing pressure shall be taken as either of the following, whichever is less:

a) The safe bearing capacity on the basis of shear strength characteristics of soil, or

b) The bearing pressure that the soil can take without exceeding the permissible settlement (*see* **7.2.3**).

7.2.2.1 *Bearing capacity by calculation*

Where the engineering properties of the soil are available, that is, cohesion, angle of internal friction, density, etc, the bearing capacity shall be calculated from stability considerations of shear; factor of safety of 2.5 shall be adopted for safe bearing capacity. The effect of interference of different foundations should be taken into account. The procedure for determining the ultimate bearing capacity and bearing pressure of shallow foundations based on shear and allowable settlement criteria shall be in accordance with good practice [6-2(11)]. Depth factor correction is to be applied only when backfilling is done with proper compaction.

7.2.2.2 *Field method for determining allowable bearing pressure*

Where appropriate, plate load tests can be performed and allowable pressure determined as per accepted standard [6-2(12)]. The allowable bearing pressure for sandy soils may also be obtained by loading tests. When such tests cannot be done, the allowable bearing pressure for sands may be determined using penetration test.

7.2.2.3 Where the bearing materials directly under a foundation overlie a stratum having smaller safe bearing capacity, these smaller values shall not be exceeded at the level of such stratum.

7.2.2.4 *Effect of wind and seismic force*

7.2.2.4.1 Where the bearing pressure due to wind is less than 25 percent of that due to dead and imposed loads, it may be neglected in design. Where this exceeds 25 percent, foundations may be so proportioned that the pressure due to combined dead, imposed and wind loads does not exceed the allowable bearing pressure by more than 25 percent.

7.2.2.4.2 When earthquake forces are considered for the computation of design loads, the permissible increase in bearing pressure of pertaining soil shall be as given in **5.3.3.5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code, depending upon the type of foundation of the structure and the type of soil.

7.2.2.5 *Bearing capacity of buried strata*

If the base of a foundation is close enough to a strata of lower bearing capacity, the latter may fail due to excess pressure transmitted to it from above. Care should be taken to see that the pressure transmitted to the lower strata is within the prescribed safe limits. When the footings are closely spaced, the pressure transmitted to the underlying soil will overlap. In such cases, the pressure in the overlapped zones will have to be considered. With normal foundations, it is sufficiently accurate to estimate the bearing pressure on the underlying layers by assuming the load to be spread at a slope of 2 (vertical) to 1 (horizontal).

7.2.3 *Settlement*

The permissible values of total and differential settlement for a given type of structure may be taken as given in Table 3. Total settlements of foundation due to net imposed loads shall be estimated in accordance with good practice [6-2(13)]. The following causes responsible for producing the settlement shall be investigated and taken into account.

a) *Causes of settlement*

1) Elastic compression of the foundation and the underlying soil,
2) Consolidation including secondary compression,
3) *Ground water lowering* — Specially repeated lowering and raising of water level in loose granular soils tend to compact the soil and cause settlement of the footings. Prolonged lowering of the water table in fine grained soils may introduce settlement because of the extrusion of water from the voids. Pumping water or draining water by tiles or pipes from granular soils without an adequate mat of filter material as protection may, in a period of time, carry a sufficient amount of fine particles away from the soil and cause settlement.
4) Seasonal swelling and shrinkage of expansive clays.
5) Ground movement on earth slope, for example, surface erosion, slow creep or landslides.
6) Other causes, such as adjacent excavation, mining, subsidence and underground erosion.

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Table 3 Permissible Differential Settlements and Tilt (Angular Distortion) for Shallow Foundations in Soils
(*Clause* 7.2.3)

Sl No.	Type of Structure	Isolated Foundations						Raft Foundations					
		Sand and Hard Clay			Plastic Clay			Sand and Hard Clay			Plastic Clay		
		Maximum Settlement	Differential Settlement	Angular Distortion	Maximum Settlement	Differential Settlement	Angular Distortion	Maximum Settlement	Differential Settlement	Angular Distortion	Maximum Settlement	Differential Settlement	Angular Distortion
		mm	mm		mm	mm		mm	mm		mm	mm	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	For steel structure	50	.003 3*L*	1/300	50	.003 3*L*	1/300	75	.003 3*L*	1/300	100	.003 3*L*	1/300
ii)	For reinforced concrete structures	75	.001 5*L*	1/500	75	.002*L*	1/500	75	.003 3*L*	1/300	125	.003 3*L*	1/300
iii)	For multistoreyed buildings:												
	a) RC or steel framed buildings with panel walls	60	.002*L*	1/500	75	.003L	1/300	75	.002 5*L*	1/300	125	.003 3*L*	1/300
	b) For load bearing walls												
	1) *L*/H=2[1)]	60	.000 2*L*	1/5 000	60	.000 2*L*	1/5 000	← Not likely to be encountered →					
	2) *L*/H=7[1)]	60	.000 4*L*	1/2 500	60	.000 4*L*	1/2 500						
iv)	For water towers and silos	50	.001 5*L*	1/666	75	.001 5*L*	1/666	100	.002 5*L*	1/400	125	.002 5*L*	1/400

[1)] For intermediate ratios of *L*/*H*, the values can be interpolated.

NOTES

1 The values given in the table may be taken only as a guide and the permissible total settlement/different settlement and tilt (angular distortion) in each case should be decided as per requirements of the designer.
2 *L* denotes the length of deflected part of wall/raft or centre-to-centre distance between columns.
3 *H* denotes the height of wall from foundation footing.

b) *Causes of differential settlements*

1) Geological and physical non-uniformity or anomalies in type, structure, thickness, and density of the soil medium (pockets of sand in clay, clay lenses in sand, wedge like soil strata, that is, lenses in soil), an admixture of organic matter, peat, mud;
2) Non-uniform pressure distribution from foundation to the soil due to non-uniform loading and incomplete loading of the foundations;
3) Water regime at the construction site,
4) Overstressing of soil at adjacent site by heavy structures built next to light ones;
5) Overlap of stress distribution in soil from adjoining structures;
6) Unequal expansion of the soil due to excavation for footing;
7) Non-uniform development of extrusion settlements; and
8) Non-uniform structural disruptions or disturbance of soil due to freezing and thawing, swelling and softening and drying of soils.

7.2.4 *Shallow Foundations on Rocks*

Estimation of the safe bearing pressures of rocks for shallow foundations based on strength, allowable settlement and classification criteria; and also design and construction of shallow foundations on rocks shall be carried out in accordance with the good practice [6-2(14)].

7.3 Pad or Spread and Strip Foundations

7.3.1 In such type of foundations, wherever the resultant of the load deviates from the centre line by more than 1/6 of its least dimension at the base of footing, it should be suitably reinforced.

7.3.2 For continuous wall foundations (plain or reinforced) adequate reinforcement should be provided particularly at places where there is abrupt change in magnitude of load or variation in ground support.

7.3.3 On sloping sites the foundation should have a horizontal bearing and stepped and lapped at changes

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of levels for a distance at least equal to the thickness of foundation or twice the height of step, whichever is greater. The steps should not be of greater height than thickness of the foundations.

7.3.4 *Ground Beams*

The foundation can also have the ground beam for transmitting the load. The ground beam carrying a load bearing wall should be designed to act with the wall forming a composite beam, when both are of reinforced concrete and structurally connected by reinforcement. The ground beam of reinforced concrete structurally connected to reinforced brick work can also be used.

7.3.5 *Dimensions of Foundation*

The dimensions of the foundation in plan should be such as to support loads as given in good practice [6-2(10)]. The width of the footings shall be such that maximum stress in the concrete or masonry is within the permissible limits. The width of wall foundation (in mm) shall not be less than that given by:

$$B = W + 300$$

where

B = width at base, in mm; and

W = width of supported wall, in mm.

7.3.6 In the base of foundations for masonry foundation it is preferable to have the steps in multiples of thickness of masonry unit.

7.3.7 The plan dimensions of excavation for foundations should be wide enough to ensure safe and efficient working in accordance with good practice [6-2(9)].

7.3.8 Unreinforced foundation may be of concrete or masonry (stone or brick) provided that angular spread of load from the base of column/wall or bed plate to the outer edge of the ground bearing is not more than 1 vertical to 1/2 horizontal for masonry or 1 vertical to 1 horizontal for cement concrete and 1 vertical to 2/3 horizontal for lime concrete. The minimum thickness of the foundation of the edge should not be less than 150 mm. In case the depth to transfer the load to the ground bearing is less than the permissible angle of spread, the foundations should be reinforced.

7.3.9 If the bottom of a pier is to be belled so as to increase its load carrying capacity such bell should be at least 300 mm thick at its edge. The sides should be sloped at an angle of not less than 45° with the horizontal. The least dimension should be 600 mm (circular, square or rectangular). The design should allow for the vertical tilt of the pier by 1 percent of its height.

7.3.10 If the allowable bearing capacity is available only at a greater depth, the foundation can be rested at a higher level for economic considerations and the difference in level between the base of foundation and the depth at which the allowable bearing capacity occurs can be filled up with either: (a) concrete of allowable compressive strength not less than the allowable bearing pressure, (b) incompressible fill material, for example, sand, gravel, etc, in which case the width of the fill should be more than the width of the foundation by an extent of dispersion of load from the base of the foundation on either side at the rate of 2 vertical to 1 horizontal.

7.3.11 The cement concrete foundation (plain or reinforced) should be designed in accordance with Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code and masonry foundation in accordance with Part 6 'Structural Design, Section 4 Masonry' of the Code.

7.3.12 *Thickness of Footing*

The thickness of different types of footings, if not designed according to **7.2**, should be as given in Table 4.

7.3.13 *Land Slip Area*

On a sloping site, spread foundation shall be on a horizontal bearing and stepped. At all changes of levels, they shall be lapped at the steps for a distance at least equal to the thickness of the foundation or twice the

Table 4 Thickness of Footings
(*Clause* 7.3.12)

Sl No. (1)	Type of Footings (2)	Thickness of Footings, *Min* (3)	Remarks (4)
i)	Masonry	a) 250 mm b) Twice the maximum projection from the face of the wall	Select the greater of the two values
ii)	Plain concrete:		
	a) For normal structures	a) 200 mm	—
		b) Twice the maximum offset in a stepped footing	For footings resting on soil
		c) 300 mm	For footings resting on top of the pile
	b) For lightly loaded structures	a) 150 mm	Resting on soil
		b) 200 mm	Resting on pile
iii)	Reinforced concrete	a) 150 mm	Resting on soil
		b) 300 mm	Resting on pile

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height of the step, whichever is greater. The steps shall not be of greater height than the thickness of the foundation unless special precautions are taken. On sloping ground on clay soils, there is always a tendency for the upper layers of soil to move downhill, depending on type of soil, the angle of slope, climatic conditions, etc. Special precautions are necessary to avoid such a failure.

7.3.14 In the foundations, the cover to the reinforcement shall be as prescribed in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code for the applicable environment exposure condition.

7.3.15 For detailed information regarding preparation of ground work, reference shall be made to good practice [6-2(15)].

7.4 Raft Foundations

7.4.1 *Design Considerations*

Design provisions given in **7.2** shall generally apply.

7.4.1.1 The structural design of reinforced concrete rafts shall conform to Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

7.4.1.2 In the case of raft, whether resting on soil directly or on lean concrete, the cover to the reinforcement shall be as prescribed in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code for the applicable environment exposure condition.

7.4.1.3 In case the structure supported by the raft consists of several parts with varying loads and heights, it is advisable to provide separation joints between these parts. Joints shall also be provided, wherever there is a change in the direction of the raft.

7.4.1.4 Foundations subject to heavy vibratory loads should preferably be isolated.

7.4.1.5 The minimum depth of foundation shall generally be not less than 1 m.

7.4.1.6 *Dimensional parameters*

The size and shape of the foundation adopted affect the magnitude of subgrade modulus and long term deformation of the supporting soil and this, in turn, influences the distribution of contact pressure. This aspect needs to be taken into consideration in the analysis.

7.4.1.7 *Eccentricity of loading*

A raft generally occupies the entire area of the building and often it is not feasible and rather uneconomical to proportion it coinciding the centroid of the raft with the line of action of the resultant force. In such cases, the effect of the eccentricity on contact pressure distribution shall be taken into consideration.

7.4.1.8 *Properties of supporting soil*

Distribution of contact pressure underneath a raft is affected by the physical characteristics of the soil supporting it. Consideration shall be given to the increased contact pressure developed along the edges of foundation on cohesive soils and the opposite effect on granular soils. Long term consolidation of deep soil layers shall be taken into account in the analysis. This may necessitate evaluation of contact pressure distribution both immediately after construction and after completion of the consolidation process. The design shall be based on the worst conditions.

7.4.1.9 *Rigidity of foundations*

Rigidity of the foundation tends to iron out uneven deformation and thereby modifies the contact pressure distribution. High order of rigidity is characterized by long moments and relatively small, uniform settlements. A rigid foundation may also generate high secondary stresses in structural members. The effect of rigidity shall be taken into account in analysis.

7.4.1.10 *Rigidity of the super structure*

Free response of the foundations to soil deformation is restricted by the rigidity of the superstructure. In the extreme case, a stiff structure may force a flexible foundation to behave as rigid. This aspect shall be considered to evaluate the validity of the contact pressure distribution.

7.4.1.11 *Modulus of elasticity and modulus of subgrade reaction*

Annex A enumerates the methods of determination of modulus of elasticity (E_s). The modulus of subgrade reaction (k) may be determined in accordance with Annex B .

7.4.2 *Necessary Information*

The following information is necessary for a satisfactory design and construction of a raft foundation:

a) Site plan showing the location of the proposed as well as the neighbouring structures;
b) Plan and cross-sections of building showing different floor levels, shafts and openings, etc, layout of loading bearing walls, columns, shear walls, etc;
c) Loading conditions, preferably shown on a schematic plan indicating combination of design loads transmitted to the foundation;
d) Information relating to geological history of the area, seismicity of their area, hydrological information indicating ground water conditions and its seasonal variations, etc;
e) Geotechnical information giving subsurface profile with stratification details, engineering

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properties of the founding strata (namely, index properties, effective shear parameters determined under appropriate drainage conditions, compressibility characteristics, swelling properties, results of field tests like static and dynamic penetration tests, pressure meter tests, etc); and

f) A review of the performance of similar structure, if any, in the locality.

7.4.3 *Choice of Raft Type*

7.4.3.1 For fairly small and uniform column spacing and when the supporting soil is not too compressible a flat concrete slab having uniform thickness throughout (a true mat) is most suitable (*see* Fig. 5A).

7.4.3.2 A slab may be thickened under heavy loaded columns to provide adequate strength for shear and negative moment. Pedestals may also be provided in such cases (*see* Fig. 5B).

7.4.3.3 A slab and beam type of raft is likely to be more economical for large column spacing and unequal column loads particularly when the supporting soil is very compressive (*see* Fig. 5C and Fig. 5D).

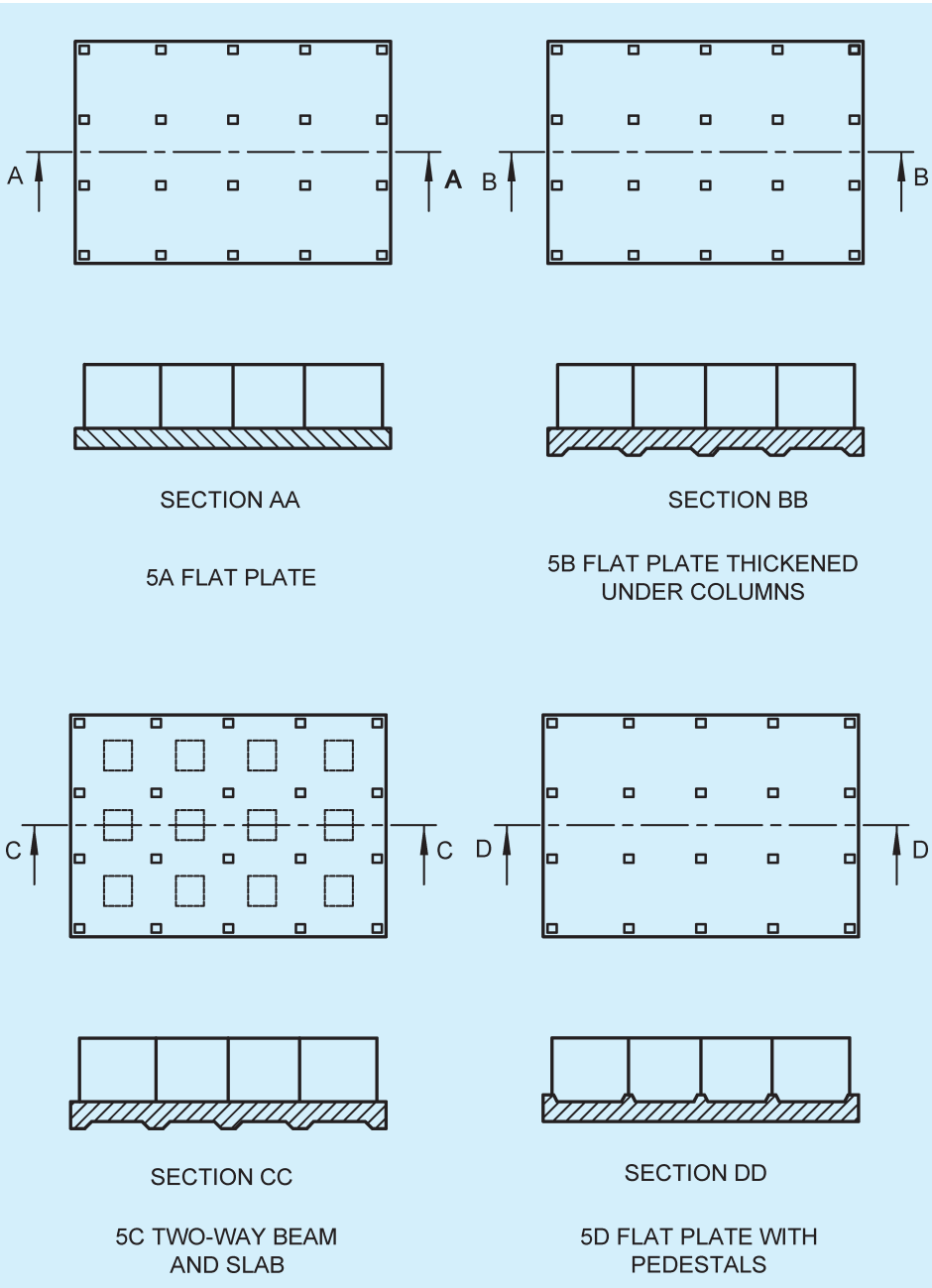


FIG. 5 COMMON TYPES OF RAFT FOUNDATION

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7.4.3.4 For very heavy structures, provision of cellular raft or rigid frames consisting of slabs and basement walls may be considered.

7.4.4 *Methods of Analysis*

The essential task in the analysis of a raft foundation is the determination of the distribution of contact pressure underneath the raft which is a complex function of the rigidity of the superstructure, the supporting soil and the raft itself, and cannot be determined with exactitude, except in very simple cases. This necessitates a number of simplifying assumptions to make the problem amenable to analysis. Once the distribution of contact pressure is determined, design bending moments and shears can be computed based on statics. The methods of analysis suggested are distinguished by the assumptions involved. Choice of a particular method should be governed by the validity of the assumptions in the particular case.

7.4.4.1 *Rigid foundation (conventional method)*

This method is based on the assumption of linear distribution of contact pressure. The basic assumptions of this method are,

a) the foundations rigid relative to the supporting soil and the compressible soil layer is relatively shallow; and

b) the contact pressure variation is assumed as planar, such that the centroid of the contact pressure coincides with the line of action of the resultant force of all loads acting on the foundation.

This method may be used when either of the following conditions is satisfied:

1) The structure behaves as rigid (due to the combined action of the superstructure and the foundation) with relative stiffness factor $K>0.5$ (for evaluation of K, *see* Annex C); and

2) The column spacing is less than $1.75/\lambda$ (*see* Annex C).

The raft is analyzed as a whole in each of the two perpendicular directions. The contact pressure distribution is determined by the procedure outlined in Annex D. Further analysis is also based on statics.

In the case of uniform conditions when the variations in adjacent column loads and column spacings do not exceed 20 percent of the higher value, the raft may be divided into perpendicular strips of widths equal to the distance between mid-spans and each strip may be analyzed as an independent beam with known column loads and known contact pressures. Such beams will not normally satisfy statics due to shear transfer between adjacent strips and design may be based on suitable moment coefficients, or by moment distribution.

NOTE — On soft soils, for example, normally consolidated clays, peat, muck, organic silts, etc, the assumptions involved in the conventional method are commonly justified.

7.4.4.2 *Flexible foundations*

a) *Simplified method* — In this method, it is assumed that the subgrade consists of an infinite array of individual elastic springs each of which is not affected by others. The spring constant is equal to the modulus of subgrade reaction (k). The contact pressure at any point under the raft is, therefore, linearly proportional to the settlement at the point. Contact pressure may be determined as given in Annex E. This method may be used when all the following conditions are satisfied:

1) The structure (combined action of superstructure and raft) may be considered as flexible (relative stiffness factor $K< 0.5$, *see* Annex C).

2) Variation in adjacent column load does not exceed 20 percent of the higher value.

b) *General method* — For the general case of a flexible foundation not satisfying the requirements of (a), the method based on closed form solution of elastic plate theory may be used. This method is based on the theory of plates on winkler foundation which takes into account the restraint on deflection of a point provided by continuity of the foundation in orthogonal foundation. The distribution of deflection and contact pressure on the raft due to a column load is determined by the plate theory. Since the effect of a column load on an elastic foundation is damped out rapidly, it is possible to determine the total effect at a point of all column loads within the zone of influence by the method of superimposition. The computation of effect at any point may be restricted to columns of two adjoining bays in all directions. The procedure is outlined in Annex F.

7.5 Ring Foundations

For provisions regarding ring foundations, good practice [6-2(16)] shall be referred to.

7.6 Shell Foundations

For provisions regarding shell foundations, good practice [6-2(17)] shall be referred to.

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8 DRIVEN/BORED CAST *IN-SITU* CONCRETE PILES

8.1 General

Piles find application in foundations to transfer loads from a structure to competent subsurface strata having adequate load-bearing capacity. The load transfer mechanism from a pile to the surrounding ground is complicated and is not yet fully understood, although application of piled foundations is in practice over many decades. Broadly, piles transfer axial loads either substantially by friction along its shaft and/or by end bearing. Piles are used where either of the above load transfer mechanism is possible depending upon the subsoil stratification at a particular site. Construction of pile foundations require a careful choice of piling system depending upon the subsoil conditions, the load characteristics of a structure and the limitations of total settlement, differential settlement and any other special requirement of a project.

8.2 Materials and Stresses

8.2.1 *Concrete*

Consistency of concrete to be used shall be consistent with the method of installation of piles. Concrete shall be so designed or chosen as to have a homogeneous mix having a slump/workability consistent with the method of concreting under the given conditions of pile installation.

The slump should be 150 to 180 mm at the time of pouring.

The minimum grade of concrete to be used for bored piling shall be M 25. For sub-aqueous concrete, the requirements specified in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall be followed. The minimum cement content shall be 400 kg/m^3. However, with proper mix design and use of proper admixture the cement content may be reduced but in no case the cement content shall be less than 350 kg/m^3 [*see also* Table 5 (and Notes thereunder) of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code].

For the concrete, water and aggregates, specifications laid down in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall be followed in general.

The average compressive stress under working load should not exceed 25 percent of the specified works cube strength at 28 days calculated on the total cross-sectional area of the pile. Where the casing of the pile is permanent, of adequate thickness and of suitable shape, the allowable compressive stress may be increased.

8.2.2 *Steel Reinforcement*

Steel reinforcement shall conform to any one of the types of steel specified in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

8.3 Design Considerations

8.3.1 *General*

Pile foundations shall be designed in such a way that the load from the structure can be transmitted to the subsurface with adequate factor of safety against shear failure of subsurface and without causing such settlement (differential or total), which may result in structural damage and/or functional distress under permanent/transient loading. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil and shall be designed according to Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

8.3.2 *Adjacent Structures*

8.3.2.1 When working near existing structures, care shall be taken to avoid damage to such structures. The good practice [6-2(18)] may be used as a guide for studying qualitatively the effect of vibration on persons and structures.

8.3.2.2 In case of deep excavations adjacent to piles, proper shoring or other suitable arrangement shall be made to guard against undesired lateral movement of soil.

8.3.3 *Pile Capacity*

The load carrying capacity of a pile depends on the properties of the soil in which it is embedded. Axial load from a pile is normally transmitted to the soil through skin friction along the shaft and end bearing at its tip. A horizontal load on a vertical pile is transmitted to the subsoil primarily by horizontal subgrade reaction generated in the upper part of the shaft. Lateral load capacity of a single pile depends on the soil reaction developed and the structural capacity of the shaft under bending. It would be essential to investigate the lateral load capacity of the pile using appropriate values of horizontal subgrade modulus of the soil. Alternatively, piles may be installed in rake.

8.3.3.1 The ultimate load capacity of a pile may be estimated by means of static formula on the basis of soil test results, or by using a dynamic pile formula using data obtained during driving the pile. However, dynamic pile driving formula should be generally used as a measure to control the pile driving at site. Pile capacity should preferably be confirmed by initial load

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tests {*see* good practice [6-2(19)]}. For rock-socketed piles, reference shall also be made to good practice [6-2(20)] for estimating the load capacity of piles.

The settlement of pile obtained at safe load/working load from load-test results on a single pile shall not be directly used for estimating the settlement of a structure. The settlement may be determined on the basis of subsoil data and loading details of the structure as a whole using the principles of soil mechanics.

8.3.3.1.1 *Static formula*

The ultimate load capacity of a single pile may be obtained by using static analysis, the accuracy being dependent on the reliability of the soil properties for various strata. When computing capacity by static formula, the shear strength parameters obtained from a limited number of borehole data and laboratory tests should be supplemented, wherever possible by *in-situ* shear strength obtained from field tests. The two separate static formulae, commonly applicable for cohesive and non-cohesive soil respectively, are indicated in Annex G. Other formula based on static cone penetration test {*see* the accepted standards [6-2(21)]} and standard penetration test {*see* the accepted standard [6-2(22)]} are given in **G-3** and **G-4**.

8.3.3.1.2 *Dynamic formula*

For driven piles, any established dynamic formula may be used to control the pile driving at site giving due consideration to limitations of various formulae.

Whenever, double acting diesel hammers or hydraulic hammers are used for driving of piles, manufacturer's guidelines about energy and set criteria may be referred to. Dynamic formulae are not directly applicable to cohesive soil deposits such as saturated silts and clays as the resistance to impact of the tip of the casing will be exaggerated by their low permeability while the frictional resistance on the sides is reduced by lubrication.

8.3.3.1.3 *Load test results*

The ultimate load capacity of a single pile is determined with reasonable accuracy from test loading as per good practice [6-2(19)]. The load test on a pile shall not be carried out earlier than four weeks from the time of casting the pile.

8.3.3.2 *Uplift capacity*

The uplift capacity of a pile is given by sum of the frictional resistance and the weight of the pile (buoyant or total as relevant). The recommended factor of safety is 3.0 in the absence of any pullout test results and 2.0 with pullout test results. Uplift capacity can be obtained from static formula (*see* Annex G) by ignoring end bearing but adding weight of the pile (buoyant or total as relevant).

8.3.4 *Negative Skin Friction or Dragdown Force*

When a soil stratum, through which a pile shaft has penetrated into a underlying hard stratum, compresses as a result of either it being unconsolidated or it being under a newly placed fill or as a result of remoulding during driving of the pile, a dragdown force is generated along the pile shaft up to a point in depth where the surrounding soil does not move downward relative to the pile shaft. Existence of such a phenomenon shall be assessed and suitable correction shall be made to the allowable load where appropriate.

8.3.5 *Structural Capacity*

The piles shall have necessary structural strength to transmit the loads imposed on it, ultimately to the soil. In case of uplift, the structural capacity of the pile, that is, under tension should also be considered.

8.3.5.1 *Axial capacity*

Where a pile is wholely embedded in the soil (having an undrained shear strength not less than 0.01 N/mm^2), its axial load carrying capacity is not necessarily limited by its strength as a long column. Where piles are installed through very weak soils (having an undrained shear strength less than 0.01 N/mm^2), special considerations shall be made to determine whether the shaft would behave as a long column or not. If necessary, suitable reductions shall be made for its structural strength following the normal structural principles covering the buckling phenomenon.

When the finished pile projects above ground level and is not secured against buckling by adequate bracing, the effective length will be governed by the fixity imposed on it by the structure it supports and by the nature of the soil into which it is installed. The depth below the ground surface to the lower point of contraflexure varies with the type of the soil. In good soil the lower point of contraflexure may be taken at a depth of 1 m below ground surface subject to a minimum of 3 times the diameter of the shaft. In weak soil (undrained shear strength less than 0.01 N/mm^2) such as soft clay or soft silt, this point may be taken at about half the depth of penetration into such stratum but not more than 3 m or 10 times the diameter of the shaft, whichever is more. The degree of fixity of the position and inclination of the pile top and the restraint provided by any bracing shall be estimated following accepted structural principles.

The permissible stress shall be reduced in accordance with similar provision for reinforced concrete columns as laid down in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

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8.3.5.2 *Lateral load capacity*

A pile may be subjected to lateral force for a number of causes, such as wind, earthquake, water current, earth pressure, effect of moving vehicles or ships, plant and equipment, etc. The lateral load capacity of a single pile depends not only on the horizontal subgrade modulus of the surrounding soil but also on the structural strength of the pile shaft against bending, consequent upon application of a lateral load. While considering lateral load on piles, effect of other co-existent loads, including the axial load on the pile, should be taken into consideration for checking the structural capacity of the shaft. A recommended method for the pile analysis under lateral load in given in Annex H.

Because of limited information on horizontal subgrade modulus of soil and pending refinements in the theoretical analysis, it is suggested that the adequacy of a design should be checked by an actual field load test. In the zone of soil susceptible to liquefaction, the lateral resistance of the soil shall not be considered.

8.3.5.2.1 *Fixed and free head conditions*

A group of three or more pile connected by a rigid pile cap shall be considered to have fixed head condition. Caps for single piles shall be interconnected by grade beams in two directions and for twin piles by grade beams in a line transverse to the common axis of the pair so that the pile head is fixed. In all other conditions the pile shall be taken as free headed.

8.3.5.3 *Raker piles*

Raker piles are normally provided where vertical piles cannot resist the applied horizontal forces. Generally the rake will be limited to 1 horizontal to 6 vertical. In the preliminary design, the load on a raker pile is generally considered to be axial. The distribution of load between raker and vertical piles in a group may be determined by graphical or analytical methods. Where necessary, due consideration should be made for secondary bending induced as a result of the pile cap movement, particularly when the cap is rigid. Free-standing raker piles are subjected to bending moments due to their own weight or external forces from other causes. Raker piles, embedded in fill or consolidating deposits, may become laterally loaded owing to the settlement of the surrounding soil. In consolidating clay, special precautions, like provision of permanent casing should be taken for raker piles.

8.3.6 *Spacing of Piles*

The minimum centre-to-centre spacing of pile is considered from three aspects, namely,

a) practical aspects of installing the piles;
b) diameter of the pile; and
c) nature of the load transfer to the soil and possible reduction in the load capacity of piles group.

NOTE — In the case of piles of non-circular cross-section, diameter of the circumscribing circle shall be adopted.

8.3.6.1 In case of piles founded on hard stratum and deriving their capacity mainly from end bearing the minimum spacing shall be 2.5 times the diameter of the circumscribing circle corresponding to the cross-section of the pile shaft. In case of piles resting on rock, the spacing of two times the said diameter may be adopted.

8.3.6.2 Piles deriving their load carrying capacity mainly from friction shall be spaced sufficiently apart to ensure that the zones of soils from which the piles derive their support do not overlap to such an extent that their bearing values are reduced. Generally the spacing in such cases shall not be less than 3 times the diameter of the pile shaft.

8.3.7 *Pile Groups*

8.3.7.1 In order to determine the load carrying capacity of a group of piles a number of efficiency equations are in use. However, it is difficult to establish the accuracy of these efficiency equations as the behaviour of pile group is dependent on many complex factors. It is desirable to consider each case separately on its own merits.

8.3.7.2 The load carrying capacity of a pile group may be equal to or less than the load carrying capacity of individual piles multiplied by the number of piles in the group. The former holds true in case of friction piles, driven into progressively stiffer materials or in end-bearing piles. For driven piles in loose sandy soils, the group capacity may even be higher due to the effect of compaction. In such cases a load test may be carried out on a pile in the group after all the piles in the group have been installed.

8.3.7.3 In case of piles deriving their support mainly from friction and connected by a rigid pile cap, the group may be visualized as a block with the piles embedded within the soil. The ultimate load capacity of the group may then be obtained by taking into account the frictional capacity along the perimeter of the block and end bearing at the bottom of the block using the accepted principles of soil mechanics.

8.3.7.3.1 When the cap of the pile group is cast directly on reasonably firm stratum which supports the piles, it may contribute to the load carrying capacity of the group. This additional capacity along with the individual capacity of the piles multiplied by the number of piles in the group shall not be more than the capacity worked out as per **8.3.7.3**.

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8.3.7.4 When a pile group is subjected to moment either from superstructure or as a consequence of inaccuracies of installation, the adequacy of the pile group in resisting the applied moment should be checked. In case of a single pile subjected to moment due to lateral loads or eccentric loading, beams may be provided to restrain the pile cap effectively from lateral or rotational movement.

8.3.7.5 In case of a structure supported on single piles/ group of piles resulting in large variation in the number of piles from column to column it may result in excessive differential settlement. Such differential settlement should be either catered for in the structural design or it may be suitably reduced by judicious choice of variations in the actual pile loading. For example, a single pile cap may be loaded to a level higher than that of the pile in a group in order to achieve reduced differential settlement between two adjacent pile caps supported on different number of piles.

8.3.8 *Factor of Safety*

8.3.8.1 Factor of safety should be chosen after considering,

a) the reliability of the calculated value of ultimate load capacity of a pile;
b) the types of superstructure and the type of loading; and
c) allowable total/differential settlement of the structure.

8.3.8.2 When the ultimate load capacity is determined from either static formula or dynamic formula, the factor of safety would depend on the reliability of the formula and the reliability of the subsoil parameters used in the computation. The minimum factor of safety on static formula shall be 2.5. The final selection of a factor of safety shall take into consideration the load settlement characteristics of the structure as a whole at a given site.

8.3.8.3 Higher value of factor of safety for determining the safe load on piles may be adopted, where,

a) settlement is to be limited or unequal settlement avoided;
b) large impact or vibrating loads are expected; and
c) the properties of the soil may deteriorate with time.

8.3.9 *Transient Loading*

The maximum permissible increase over the safe load of a pile, as arising out of wind loading, is 25 percent. In case of loads and moments arising out of earthquake effects, the increase of safe load shall be as given in **7.2.2.4.2**. For transient loading arising out of superimposed loads, no increase is allowed.

8.3.10 *Overloading*

When a pile in a group, designed for a certain safe load is found, during or after execution, to fall just short of the load required to be carried by it, an overload up to 10 percent of the pile capacity may be allowed on each pile. The total overloading on the group should not, however, be more than 10 percent of the capacity of the group subject to the increase of the load on any pile being not more than 25 percent of the allowable load on a single pile.

8.3.11 *Reinforcement*

8.3.11.1 The design of the reinforcing cage varies depending upon the driving and installation conditions, the nature of the subsoil and the nature of load to be transmitted by the shaft - axial, or otherwise. The minimum area of longitudinal reinforcement of any type or grade within the pile shaft shall be 0.4 percent of the cross-sectional area of the pile shaft. The minimum reinforcement shall be provided throughout the length of the shaft.

8.3.11.2 The curtailment of reinforcement along the depth of the pile, in general, depends on the type of loading and subsoil strata. In case of piles subjected to compressive load only, the designed quantity of reinforcement may be curtailed at appropriate level according to the design requirements. For piles subjected to uplift load, lateral load and moments, separately or with compressive loads, it would be necessary to provide reinforcement for the full depth of pile. In soft clays or loose sands, or where there may be danger to green concrete due to driving of adjacent piles, the reinforcement should be provided to the full pile depth, regardless of whether or not it is required from uplift and lateral load considerations. However, in all cases, the minimum reinforcement specified in **8.3.11.1** shall be provided throughout the length of the shaft.

8.3.11.3 Piles shall always be reinforced with a minimum amount of reinforcement as dowels keeping the minimum bond length into the pile shaft below its cut-off level and with adequate projection into the pile cap, irrespective of design requirements.

8.3.11.4 Clear cover to all main reinforcement in pile shaft shall be not less than 50 mm. The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same is chosen to impart adequate rigidity of the reinforcing cage during its handing and installations. The minimum diameter of the links or spirals shall be 8 mm and the spacing of the links or spirals shall be not less than 150 mm. Stiffner rings preferably of 16 mm diameter at every 1.5 m centre-to-centre should be provided along the length of the cage for providing rigidity to reinforcement cage. Minimum 6 numbers of vertical bars shall be used for a

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circular pile and minimum diameter of vertical bar shall be 12 mm. The clear horizontal spacing between the adjacent vertical bars shall be four times the maximum aggregate size in concrete. If required, the bars can be bundled to maintain such spacing.

8.3.12 *Design of Pile Cap*

8.3.12.1 The pile caps may be designed by assuming that the load from column is dispersed at 45° from the top of the cap to the mid-depth of the pile cap from the base of the column or pedestal. The reaction from piles may also be taken to be distributed at 45° from the edge of the pile, up to the mid-depth of the pile cap. On this basis the maximum bending moment and shear forces should be worked out at critical sections. The method of analysis and allowable stresses should be in accordance with Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

8.3.12.2 Pile cap shall be deep enough to allow for necessary anchorage of the column and pile reinforcement.

8.3.12.3 The pile cap should be rigid enough so that the imposed load could be distributed on the piles in a group equitably.

8.3.12.4 In case of a large cap, where differential settlement may occur between piles under the same cap, due consideration for the consequential moment should be given.

8.3.12.5 The clear overhang of the pile cap beyond the outermost pile in the group shall be a minimum of 150 mm.

8.3.12.6 The cap is generally cast over a 75 mm thick levelling course of concrete. The clear cover for main reinforcement in the cap slab shall not be less than 60 mm.

8.3.12.7 The embedment of pile into cap should be 75 mm.

8.3.13 *Grade Beams*

8.3.13.1 The grade beams supporting the walls shall be designed taking due account of arching effect due to masonry above the beam. The beam with masonry due to composite action behaves as a deep beam.

For the design of beams, a maximum bending moment of $\frac{wl^2}{50}$, where w is uniformly distributed load per metre run (worked out by considering a maximum height of two storeys in structures with load bearing walls and one storey in framed structures) and l is the effective span, in metres, shall be taken, if the beams are supported during construction till the masonry above it gains strength. The value of bending moment shall be increased to $\frac{wl^2}{30}$, if the beams are not supported. For considering composite action, the minimum height of wall shall be 0.6 times the beam span. The brick strength should not be less than 3 N/mm^2. For concentrated and other loads which come directly over the beam, full bending moment should be considered.

8.3.13.2 The minimum overall depth of grade beams shall be 150 mm. The reinforcement at the bottom should be kept continuous and an equal amount may be provided at top to a distance of a quarter span both ways from pile centres. The longitudinal reinforcement both at top and bottom should not be less than three bars of 10 mm diameter mild steel (or equivalent deformed steel) and stirrups of 6 mm diameter bars should be spaced at a minimum of 300 mm spacing.

8.3.13.3 In expansive soils, the grade beams shall be kept a minimum of 80 mm clear off the ground. In other soils, beams may rest on ground over a leveling concrete course of about 80 mm (*see* Fig. 6).

8.3.13.4 In the case of exterior beams over piles in expansive soils, a ledge projection of 75 mm thickness and extending 80 mm into ground (*see* Fig. 6) shall be provided on the outer side of the beam.

8.4 For detailed information on driven/bored cast *in-situ* concrete piles regarding control of piling, installation, defective pile and recording of data, reference shall be made to good practice [6-2(23)].

8.5 Bored Cast *In-Situ* Concrete Piles on Rocks

Design and construction of bored cast *in-situ* piles founded on rocks shall be carried out in accordance with good practice [6-2(20)].

8.6 Non-Destructive Testing

For quality assurance of concrete piles, non-destructive integrity test may be carried out prior to laying of beam/caps, in accordance with good practice [6-2(24)].

9 DRIVEN PRECAST CONCRETE PILES

9.1 Provisions of **8** except **8.3.11** shall generally apply.

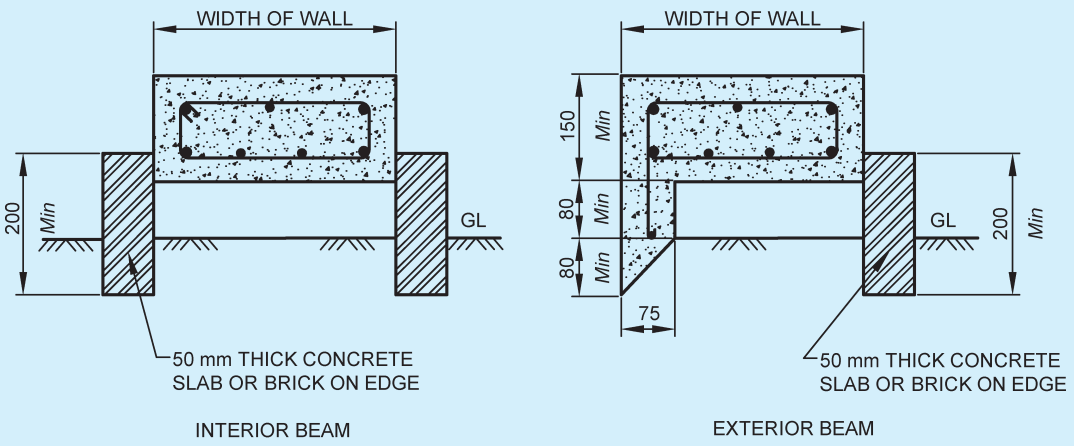
9.2 Design of Pile Section

9.2.1 Design of pile section shall be such as to ensure the strength and soundness of the pile against lifting from the casting bed, transporting, handling and driving stresses without damage.

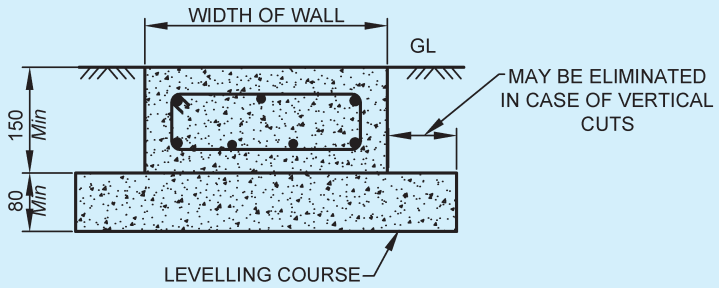
9.2.2 Any shape having radial symmetry will be satisfactory for precast piles. The most commonly used cross-sections are square and octagonal.

9.2.3 Where exceptionally long lengths of piles are required, hollow sections may be used. If the final condition requires larger cross-sectional area, the

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6A BEAMS IN EXPANSIVE SOILS



6B BEAMS IN NON-EXPANSIVE SOILS

All dimensions in millimetres.

FIG. 6 TYPICAL SECTIONS OF GRADE BEAMS

hollow sections may be filled with concrete after driving in position.

9.2.4 Wherever, final pile length is so large that a single length precast pile unit is either uneconomical or impracticable for installation, the segmental precast RCC piles with a number of segments using efficient mechanical jointing could be adopted.

Excessive whipping during handling precast pile may generally be avoided by limiting the length of pile to a maximum of 50 times the least width. As an alternative, segmental precast piling technique could be used.

The design of joints shall take care of corrosion by providing additional sacrificial thickness for the joint, wherever warranted.

9.2.5 Stresses induced by bending in the cross-section of precast pile during lifting and handling may be estimated as for any reinforced concrete section in accordance with relevant provisions of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code. The calculations for bending moment for different support conditions during handling are given in Table 5.

Table 5 Bending Moment for Different Support Conditions
(*Clause* 9.2.5)

Sl No.	Number of Points of Pick Up	Location of Support from End in Terms of Length of Pile for Minimum Moments	Bending Moment to be Allowed for Design kN.m
(1)	(2)	(3)	(4)
i)	One	0.293 *L*	4.3 *WL*
ii)	Two	0.207 *L*	2.2 *WL*
iii)	Three	0.145 *L*, the middle point will be at the centre	1.05 *WL*

NOTE — *W* = weight of pile, in kN.
L = length of pile, in m.

9.2.6 The driving stresses on a pile may be estimated

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by the following formula:

$$\frac{\text{Driving resistance}}{\text{Cross-sectional area of the pile}} \times \left[\frac{2}{\sqrt{n}} - 1\right]$$

where

n = efficiency of the blow (*see* **9.2.6.1** for probable value of n).

NOTE — For the purpose of this formula, cross-sectional area of the pile shall be calculated as the overall sectional area of the pile including the equivalent area for reinforcement.

9.2.6.1 The formula for efficiency of the blow, representing the ratio of energy after impact to striking energy of ram, n, is:

a) where W is greater than $P.e$ and the pile is driven into penetrable ground,

$$n = \frac{W + \left(P \cdot e^2\right)}{W + P}$$

b) where W is less than $P.e$ and the pile is driven into penetrable ground,

$$n = \left[\frac{W + \left(P \cdot e^2\right)}{W + P}\right] - \left[\frac{W - \left(P \cdot e\right)}{W + P}\right]^2$$

The following are the values of n in relation to e and to the ratio of P/W:

Sl No.	*Ratio of P/W*	*e = 0.5*	*e = 0.4*	*e = 0.32*	*e = 0.25*	*e = 0*
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	½	0.75	0.72	0.70	0.69	0.67
ii)	1	0.63	0.58	0.55	0.53	0.50
iii)	1½	0.55	0.50	0.47	0.44	0.40
iv)	2	0.50	0.44	0.40	0.37	0.33
v)	2½	0.45	0.40	0.36	0.33	0.28
vi)	3	0.42	0.36	0.33	0.30	0.25
vii)	3½	0.39	0.33	0.30	0.27	0.22
viii)	4	0.36	0.31	0.28	0.25	0.20
ix)	5	0.31	0.27	0.24	0.21	0.16
x)	6	0.27	0.24	0.21	0.19	0.14
xi)	7	0.24	0.21	0.19	0.17	0.12
xii)	8	0.22	0.20	0.17	0.15	0.11

NOTES

1 W = mass of the ram, in tonne and P = weight of the pile, anvil, helmet, and follower (if any), in tonne.

2 Where the pile finds refusal in rock, $0.5P$ should be substituted for P in the above expressions for n.

3 e is the coefficient of restitution of the materials under impact as tabulated below:

a) For steel ram of double-acting hammer striking on steel anvil and driving reinforced concrete pile, $e = 0.5$.

b) For cast-iron ram of single-acting or drop hammer striking on head of reinforced concrete pile, $e = 0.4$.

c) Single-acting or drop hammer striking a well-conditioned driving cap and helmet with hard wood dolly in driving reinforced concrete piles or directly on head of timber pile, $e = 0.25$.

d) For a deteriorated condition of the head of pile or of dolly, $e = 0$.

9.3 Reinforcement

9.3.1 The longitudinal reinforcement of any type or grade shall be provided in precast reinforced concrete piles for the entire length. All the main longitudinal bars shall be of the same length and should fit tightly into the pile shoe, if there is one. Shorter rods to resist local bending moments may be added but the same should be carefully detailed to avoid any sudden discontinuity of the steel which may lead to cracks during heavy driving. The area of main longitudinal reinforcement shall not be less than the following percentages of the cross-sectional area of the piles:

a) For piles with a length less than 30 times the least width: 1.25 percent,

b) For piles with a length 30 to 40 times the least width: 1.5 percent, and

c) For piles with a length greater than 40 times the least width: 1.5 percent.

9.3.2 Piles shall always be reinforced with a minimum amount of reinforcement as dowels keeping the minimum bond length into the pile shaft below its cut-off level and with adequate projection into the pile cap, irrespective of design requirements.

9.3.3 Clear cover to all main reinforcement in pile shaft shall be not less than 50 mm. The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same is chosen to impart adequate rigidity of the reinforcing cage during its handing and installations. The minimum diameter of the links or spirals shall be 8 mm and the spacing of the links or spirals shall be not less than 150 mm. Stiffner rings preferably of 16 mm diameter at every 1.5 m centre-to-centre to be provided along the length of the cage for providing rigidity to reinforcement cage. Minimum 6 numbers of vertical bars shall be used for a circular pile and minimum diameter of vertical bar shall be 12 mm. The clear horizontal spacing between the adjacent vertical bars shall be four times the maximum aggregate size in concrete. If required, the bars may be bundled to maintain such spacing.

9.4 Additional provision for prestressed concrete piles shall be as per good practice [6-2(25)].

9.5 For detailed information regarding casting and curing, storing and handling, control of pile driving and recording of data, reference shall be made to good practice [6-2(25)].

9.6 Non-Destructive Testing

For quality assurance of concrete piles, non-destructive integrity test may be carried out prior to laying of beam/caps, in accordance with good practice [6-2(24)].

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10 PRECAST CONCRETE PILES IN PREBORED HOLES

10.1 Provisions of **9** except **9.3** shall generally apply.

10.2 Handling Equipment for Lowering and Grouting Plant

Handling equipment such as crane, scotch derricks, movable gantry may be used for handling and lowering the precast piles in the bore. The choice of equipment will depend upon length, mass and other practical requirements.

The mixing of the grout shall be carried out in any suitable high speed colloidal mixer. Normally the colloidal mixer is adequate to fill the annular space with grouts. Where this is not possible, a suitable grout pump shall be used.

10.3 Reinforcement

10.3.1 The design of the reinforcing cage varies depending upon the handling and installation conditions, the nature of the subsoil and the nature of load to be transmitted by the shaft - axial, or otherwise. The minimum area of longitudinal reinforcement of any type or grade within the pile shaft shall be 0.4 percent of the cross-sectional area of the pile shaft or as required to cater for handling stresses (*see* **9.2.5**), whichever is greater. The minimum reinforcement shall be provided throughout the length of the shaft.

10.3.2 Piles shall always be reinforced with a minimum amount of reinforcement as dowels keeping the minimum bond length into the pile shaft below its cut-off level and with adequate projection into the pile cap, irrespective of design requirements.

10.3.3 Clear cover to all main reinforcement in pile shaft shall be not less than 50 mm. The laterals of a reinforcing cage may be in the form of links or spirals. The diameter and spacing of the same is chosen to impart adequate rigidity of the reinforcing cage during its handing and installations. The minimum diameter of the links or spirals shall be 8 mm and the spacing of the links or spirals shall be not less than 150 mm. Stiffner rings preferably of 16 mm diameter at every 1.5 m centre-to-centre to be provided along length of the cage for providing rigidity to reinforcement cage. Minimum 6 numbers of vertical bars shall be used for a circular pile and minimum diameter of vertical bar shall be 12 mm. The clear horizontal spacing between the adjacent vertical bars shall be four times the maximum aggregate size in concrete. If required, the bars may be bundled to maintain such spacing.

10.3.4 A thin gauge sheathing pipe of approximately 40 mm diameter may be attached to the reinforcement cage, in case of solid piles, to form the central duct for pumping grout to the bottom of the bore. The bottom end of the pile shall have proper arrangements for flushing/cleaning for grouting. Air lift technique may be used for cleaning the borehole, however this technique should be used carefully in case of silty and sandy soil.

10.4 For detailed information regarding casting and curing, storing and handling, control of pile installation and recording of data, reference shall be made to good practice [6-2(26)].

10.5 Non-Destructive Testing

For quality assurance of concrete piles, non-destructive integrity test may be carried out prior to laying of beam/caps, in accordance with good practice [6-2(24)].

11 UNDER-REAMED PILES

11.1 General

Under-reamed piles are bored cast *in-situ* and bored compaction concrete types having one or more bulbs formed by enlarging the borehole for the pile stem. These piles are suited for expansive soils which are often subjected to considerable ground movements due to seasonal moisture variations. These also find wide application in other soil strata where economics are favorable. When the ground consists of expansive soil, for example, black cotton soils, the bulb of under-reamed pile provide anchorage against uplift due to swelling pressure, apart from the increased bearing, provided topmost bulb is formed close to or just below the bottom of active zone. Negative slopes may not be stable in certain strata conditions, for example, in pure sands (clean sands with fines less than 5 percent) and very soft clayey strata having N of SPT less than 2 (undrained shear strength of less than 12.5 kN/m^2). Hence formation of bulb(s) in such strata is not advisable. In subsoil strata above water table, the maximum number of bulbs in under-reamed pile should be restricted to four. In the strata such as clay, silty clay and clayey silt with high water table where sides of borehole stand by itself without needing any stabilization by using drilling mud or otherwise, the maximum number of bulbs in under-reamed piles should be restricted to two. In strata for example, clayey sand, silty sand and sandy silt with high water table where borehole needs stabilization by using drilling mud, under-reamed piles with more than one bulb shall not be used. In loose to medium pervious strata such as clayey sand, silty sand and sandy silt strata, compaction under-reamed piles may be used as the process of compaction increases the load carrying capacity of piles. From practical considerations, under-reamed piles of more than 10 m depth shall not be used without ensuring their construction feasibility and load carrying capacity by initial load tests in advance. In view of additional anchorage available with the provision of bulbs, under-reamed piles can be used with advantage to resist uplift loads.

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11.2 Materials

Provisions of **8.2** shall generally apply.

11.3 Design Considerations

11.3.1 *General*

Under-reamed pile foundation shall be designed in such a way that the load from the structure they support can be transmitted to the soil without causing failure of soil or failure of pile material and without causing settlement (differential or total) under permanent transient loading as may result in structural damage and/or functional distress (*see* Fig. 7).

11.3.1.1 In deep deposits of expansive soils the minimum length of piles, irrespective of any other considerations, shall be 3.5 m below ground level. If the expansive soil deposits are of shallow depth and overlying on non-expansive soil strata of good bearing or rock, piles of smaller length can also be provided. In recently filled up grounds or other strata or poor bearing the piles should pass through them and rest in good bearing strata.

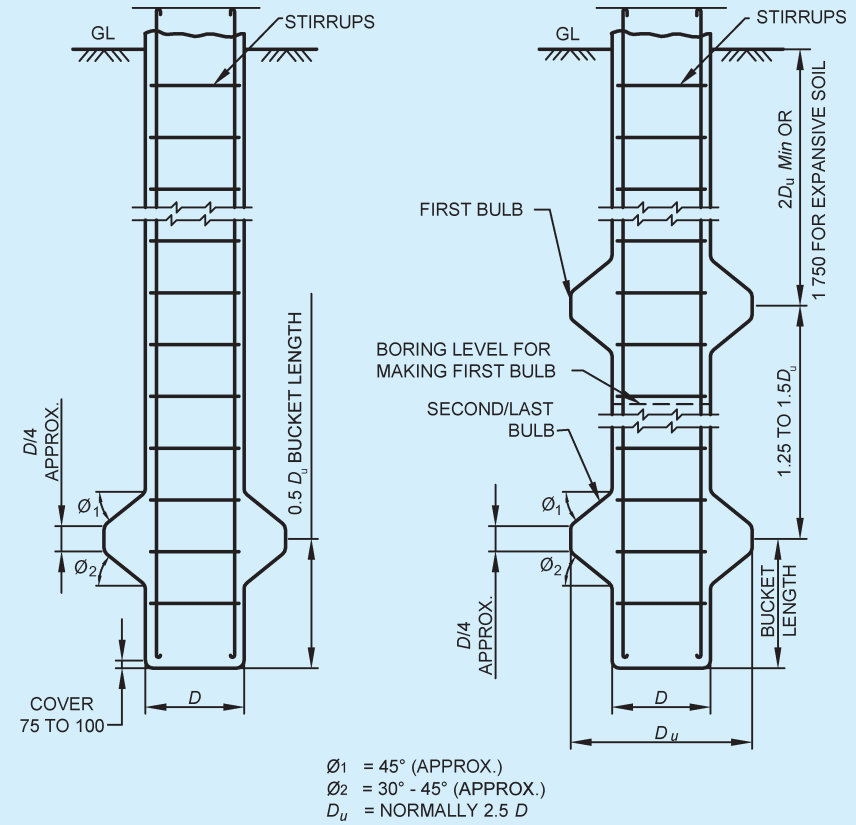
11.3.1.2 The minimum stem diameter of under-reamed pile can be 200 mm up to 5 m depth in dry conditions, that is, strata with low water table. The minimum stem diameter for piles up to 5 m depth in strata with high water table within pile depth, shall be 300 mm for normal under-reamed pile and 250 mm for compaction under-reamed pile. For piles of more than 5 m depth, the minimum diameter in two cases shall be 375 mm and 300 mm, respectively. The minimum diameter of stem for strata consisting of harmful constituents, such as sulphates, should also be 375 mm.

11.3.1.3 The diameter of under-reamed bulbs may vary from 2 to 3 times the stem diameter, depending, upon the feasibility of construction and design requirements. In bored cast *in-situ* under-reamed piles and under-reamed compaction piles, the bulb diameter shall be normally 2.5 and 2 times the stem diameter, respectively.

11.3.1.4 For piles of up to 300 mm diameter, the spacing of the bulbs should not exceed 1.5 times the diameter of the bulb. For piles of diameter greater than 300 mm, spacing can be reduced to 1.25 times the bulb diameter.

11.3.1.5 The topmost bulb should be at a minimum depth of two times the bulb diameter. In expansive soils it should also be not less than 2.75 m below ground level. The minimum clearance below the underside of pile cap embedded in the ground and the bulb should be a minimum of 1.5 times the bulb diameter.

11.3.1.6 Under-reamed piles with more than one bulb



7A SECTION OF SINGLE - UNDER-REAMED PILE

7B SECTION OF MULTI- UNDER-REAMED PILE

All dimensions in millimetres.

FIG. 7 TYPICAL DETAILS OF BORED CAST *IN-SITU* UNDER-REAMED PILE FOUNDATION

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are not advisable without ensuring their feasibility in strata needing stabilization of boreholes by drilling mud. The number of bulbs in the case of bored compaction piles should also not exceed one in such strata.

11.3.1.7 Under-reamed batter piles without lining in dry conditions, that is, strata with low water table can be constructed with batter not exceeding 15°.

11.3.2 *Safe Load*

Safe load on a pile can be determined,

a) by calculating the ultimate load from soil properties and applying a suitable factor of safety as given in Annex J;
b) by load test on pile as good practice [6-2(19)]; and
c) from safe load tables.

11.3.2.1 *Load test*

Provisions of **8.3.3.1.3** shall generally apply.

11.3.2.2 In the absence of detailed subsoil investigations and pile load tests for minor and less important structures, a rough estimate of safe load on piles may be made from the safe load table given in the good practice [6-2(27)].

NOTE — Safe loads as given in the above referred Table are symptomatic. Safe load carrying capacity of pile shall be worked out for the actual geotechnical data using **5.2.3.1** of good practice [6-2(27)], subjected to confirmation by initial pile load test in accordance with good practice [6-2(19)] and other provisions in **5.2.3.2** of good practice [6-2(27)].

11.3.3 *Negative Skin Friction or Dragdown Force*

Provisions of **8.3.4** shall generally apply subject to the condition that the under-reamed bulb is provided below the strata susceptible to negative skin friction.

11.3.4 *Structural Capacity*

Provisions of **8.3.5** shall generally apply except that the under-reamed pile stem is designed for axial capacity as a short column. Under-reamed piles under lateral loads and moments tend to behave more as rigid piles due the presence of bulbs and therefore the analysis can be done on rigid pile basis. Nominally reinforced long single bulb piles which are not rigid may be analyzed as per the method given in Annex G or as per other accepted methods.

11.3.5 *Spacing*

Generally the centre-to-centre spacing for bored cast *in-situ* under-reamed piles in a group should be two times the bulb diameter ($2D_u$). It shall not be less than $1.5D_u$. For under-grade beams, the maximum spacing of piles should generally not exceed 3 m. In under-reamed compaction piles, generally the spacing should not be less than $1.5D_u$. If the adjacent piles are of different diameter, an average value of bulb diameter should be taken for spacing.

11.3.6 *Group Efficiency*

For bored cast *in-situ* under-reamed piles at a usual spacing of $2D_u$, the group efficiency will be equal to the safe load of an individual pile multiplied by the number of piles in the group. For piles at a spacing of $1.5D_u$, the safe load assigned per pile in a group should be reduced by 10 percent.

In under-reamed compaction piles, at the usual spacing of $1.5D_u$, the group capacity will be equal to the safe load on an individual pile multiplied by the number of piles in the group.

11.3.7 *Transient and Overloading*

Provisions of **8.3.9** and **8.3.10** shall generally apply.

11.3.8 *Reinforcement*

11.3.8.1 The minimum area of longitudinal reinforcement (any type or grade) within the pile shaft shall be 0.4 percent of the sectional area calculate on the basis of outside area of the shaft or casing if used. Reinforcement is to be provided in full length and further a minimum of 3 bars of 10 mm diameter mild steel or three 8 mm diameter high strength steel bars shall be provided. Transverse reinforcement shall not be less than 6 mm diameter at a spacing of not more than the stem diameter or 300 mm, whichever is less.

In under-reamed compaction piles, a minimum number of four 12 mm diameter bars shall be provided. For piles of lengths exceeding 5 m and of 375 mm diameter, a minimum number of six 12 mm diameter bars shall be provided. For piles exceeding 400 mm diameter, a minimum number of six 12 mm diameter bars shall be provided. The circular stirrups for piles of lengths exceeding 5 m and diameter exceeding 375 mm shall be minimum 8 mm diameter bars.

For piles in earthquake prone areas, a minimum number of six bars of 10 mm diameter shall be provided. Also transverse reinforcement in the form of stirrups or helical should be at 150 mm centre-to-centre in top few meter depth.

11.3.8.2 The minimum clear cover over the longitudinal reinforcement shall be 40 mm. In aggressive environment of sulphates, etc, it may be increased to 75 mm.

11.3.9 The design of pile cap and grade beams shall conform to the requirements specified in **8.3.12** and **8.3.13** respectively.

11.4 For detailed information on under-reamed piles regarding control of pile, installation, reference shall be made to good practice [6-2(26)].

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11.5 Non-Destructive Testing

For quality assurance of concrete piles, non-destructive integrity test may be carried out prior to laying of beam/caps, in accordance with good practice [6-2(24)].

12 TIMBER PILES

12.1 General

Timber piles find extensive use for compaction of soils and also for supporting as well as protecting water-front structures. The choice for using a timber pile shall be mainly governed by the site conditions, particularly the water-table conditions. Use of treated or untreated piles will depend upon the site conditions and upon whether the work is permanent or of temporary nature. The timber pile installed shall have its entire length embedded under water so that the pile may not get deteriorated. They have the advantages of being comparatively light for their strength and are easily handled. However, they will not withstand as hard driving as steel or concrete piles. Timber has to be selected carefully and treated where necessary for use as piles, as the durability and performance would considerably depend upon the quality of the material and relative freedom from natural defects. In coastal areas such as Kochi, Coconut/Palmyra tree trunks have been used as timber piles.

12.2 Materials

12.2.1 *Timber*

The timber shall have the following characteristics:

a) Only structural timber shall be used for piles (*see* Part 6 'Structural Design, Section 3 Timber and Bamboo, 3A Timber' of the Code);

b) The length of an individual pile shall be,
   1) the specified length ± 300 mm for piles up to and including 12 m in length, and
   2) the specified length ± 600 mm for piles above 12 m in length.

c) The ratio of heartwood diameter to the pile butt diameter shall be not less than 0.8; and

d) Piles to be used untreated shall have as little sapwood as possible.

12.3 Design Considerations

12.3.1 *General*

Timber piles shall be designed in such a way that the load from the structure can be transmitted to the subsurface with adequate factor of safety against shear failure of subsurface and without causing such settlement (differential or total), which may result in structural damage and/or functional distress under permanent/transient loading. The pile shaft should have adequate structural capacity to withstand all loads (vertical, axial or otherwise) and moments which are to be transmitted to the subsoil and shall be designed according to Part 6 'Structural Design, Section 3 Timber and Bamboo, Subsection 3A Timber' of the Code.

12.3.2 *Adjacent Structures*

When working near existing structures, care shall be taken to avoid damage to such structures. In case of deep excavations adjacent to piles, proper shoring or other suitable arrangement shall be made to guard against undesired lateral movement of soil.

12.3.3 *Pile Capacity*

See **8.3.3**.

12.3.4 *Structural Capacity*

The pile shall have the necessary structural strength to transmit the load imposed on it to the soil. Load tests shall be conducted on a single pile or preferably on a group of piles. For compaction piles, test should be done on a group of piles with their caps resting on the ground as good practice [6-2(19)]. If such test data is not available, the load carried by the pile shall be determined by the Engineering News formula (*see* Note).

NOTE — For timber piles, the load carried shall be determined by the Engineering News formula given below. Care shall be taken that while counting the number of blows, the head of the timber pile is not broomed or brushed and in case of interrupted driving, counting shall be done after 300 mm of driving.

For piles driven with drop hammer:

$$P = \frac{160WH}{S + 25}$$

For piles driven with single-acting steam hammer:

$$P = \frac{160WH}{S + 2.5}$$

where

P = safe load on pile, in kN;

W = weight of monkey, in kN;

H = free fall of monkey, in m; and

S = penetration of pile, in mm, to be taken as the average of the last three blows.

12.3.5 For detailed information on timber piles regarding spacing, classification, control of pile driving, storing and handling, reference shall be made to good practice [6-2(28)].

13 OTHER FOUNDATIONS, SUBSTRUCTURES AND FOUNDATIONS FOR SPECIAL STRUCTURES

13.1 Pier Foundations

13.1.1 *Design Considerations*

13.1.1.1 *General*

The design of concrete piers shall conform to the

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requirements for columns specified in Part 6 'Structural Design, Section 5 Concrete' of the Code. If the bottom of the pier is to be belled so as to increase its load carrying capacity, such bell shall be at least 300 mm thick at its edge. The sides shall slope at an angle of not less than 60° with the horizontal. The least permissible dimensions shall be 600 mm, irrespective of the pier being circular, square or rectangular. Piers of smaller dimensions if permitted shall be designed as piles (*see* **8** and **9**).

13.1.1.2 *Plain concrete piers*

The height of the pier shall not exceed 6 times the least lateral dimension. When the height exceeds 6 times the least lateral dimension, buckling effect shall be taken into account, but in no case shall the height exceed 12 times the least lateral dimension.

When the height exceeds 6 times the least lateral dimension, the deduction in allowable stress shall be given by the following formula:

$$f_c' = f_c\left(1.3 - \frac{H}{20D}\right)$$

where

f_c' = reduced allowable stress,

f_c = allowable stress,

H = height of pier, and

D = least lateral dimension.

NOTE – The above provision shall not apply for piers where the least lateral dimension is 1.8 m or greater.

13.1.1.3 *Reinforced concrete piers*

When the height of the pier exceeds 18 times its least dimension, the maximum load shall not exceed:

$$P' = P\left(1.5 - \frac{H}{36D}\right)$$

where

P' = permissible load;

P = permissible load when calculated as axially loaded short column;

H = height of the pier measured from top of bell, if any, to the level of cut-off of pier; and

D = least lateral dimension.

13.2 Design and construction of machine foundations, diaphragm walls, etc, shall be carried out in accordance with good practice [6-2(29)].

14 GROUND IMPROVEMENT

14.1 In poor and weak subsoils, the design of conventional foundation for structures and equipment may present problems with respect to both sizing of foundation as well as control of foundation settlements. A viable alternative in certain situations, is to improve the subsoil to an extent such that the subsoil would develop an adequate bearing capacity and foundations constructed after subsoil improvement would have resultant settlements within acceptance limits. This method/technique is called ground improvement which is used to improve *in-situ* soil characteristics by improving its engineering performance as per the project requirement by altering its natural state, instead of having to alter the design in response to the existing ground limitations. The improvement is in terms of increase in bearing capacity, shear strength, reducing settlement and enhancing drainage facility, mitigating liquefaction potential, etc, of soil, as also in improving lateral capacity in case of deep foundations.

14.2 For provisions with regard to necessary data to be collected to establish the need for ground improvement at a site; considerations for establishing need for ground improvement methods; selection of ground improvement techniques; equipment and accessories for ground improvement; control of ground improvement works and recording of data, reference shall be made to good practice [6-2(30)]. Annex K presents various methods of ground improvement along with principles, applicability to various soil conditions, material requirements, equipment required, results likely to be achieved and limitations. This table may be referred to as guidance for selecting the proper method for a situation {*see also* good practice [6-2(30)] for details}.

14.2.1 For provisions relating to ground improvement by reinforcing the ground using stone columns so as to meet the twin objective of increasing the bearing capacity with simultaneous reduction of settlements, reference shall be made to good practice [6-2(31)].

14.2.2 Whenever soft cohesive soil strata underlying a structure are unable to meet the basic requirements of safe bearing capacity and tolerable settlement, ground improvement is adopted to make it suitable for supporting the proposed structure. Both the design requirements that is shear strength and settlement under loading, can be fulfilled by consolidating the soil by applying a preload, if necessary, before the construction of the foundation. This consolidation of soil is normally accelerated with the use of vertical drains. For provisions relating to ground improvement by preconsolidation using vertical drains, reference shall be made to good practice [6-2(32)].

14.2.3 Use of suitable geo-synthetics/geo-textiles may be made in an approved manner for ground improvement, where applicable. *See also* accepted standards [6-2(33)].

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ANNEX A

(*Clauses* 7.4.1.11 *and* B-3.3)

DETERMINATION OF MODULUS OF ELASTICITY (E_s) AND POISSON'S RATIO (μ)

A-1 DETERMINATION OF MODULUS OF ELASTICITY(E_s)

The modulus of elasticity is a function of composition of the soil, its void ratio, stress history and loading rate. In granular soils it is a function of the depth of the strata, while in cohesive soil it is markedly influenced by the moisture content. Due to its great sensitivity to sampling disturbance, accurate evaluation of the modulus in the laboratory is extremely difficult. For general cases, therefore, determination of the modulus may be based on field tests (*see* **A-2**). Where properly equipped laboratory and sampling facility is available, E_s may be determined in the laboratory (*see* **A-3**).

A-2 FIELD DETERMINATION

A-2.1 The value of E_s shall be determined from plate load test in accordance with good practice [6-2(12)].

$$E_S = qB\frac{\left(1-\mu^2\right)}{s}I_w$$

where

q = intensity of contact pressure,

B = least lateral dimension of test plate,

s = settlement,

μ = Poisson's ratio, and

I_w = influence ratio

= 0.82 for a square plate,

= 1.00 for a circular plate.

NOTE — While this procedure may be adequate for light or less important structures under normal conditions, relevant laboratory tests or field tests are essential in the case of unusual soil types and for all heavy and important structures. Plate load test, though useful in obtaining the necessary information about the soil with particular reference to design of foundation has some limitations. The test results reflect only the character of the soil located within a depth of less than twice the width of the bearing plate. Since the foundations are generally larger than the test plates, the settlement and shear resistance will depend on the properties of a much thicker stratum. Moreover, this method does not give the ultimate settlements particularly in case of cohesive soils. Thus the results of the test are likely to be misleading, if the character of the soil changes at shallow depths, which is not uncommon. A satisfactory load test should, therefore, include adequate soil exploration {*see* good practice [6-2(2)]} with due attention being paid to any weaker stratum below the level of the footing. Another limitation is the concerning of the effect of size of foundation. For clayey soils the bearing capacity (from shear consideration) for a larger foundation is almost the same as that for the smaller test plate. But in dense sandy soils the bearing capacity increases with the size of the foundation. Thus tests with smaller size plate tend to give conservative values in dense sandy soils. It may, therefore, be necessary to test with plates of at least three sizes and the bearing capacity results extrapolated for the size of the actual foundation (minimum dimensions in the case of rectangular footings).

A-2.1.1 The average value of E_s shall be based on a number of plate load tests carried out over the area, the number and location of the tests, depending upon the extent and importance of the structure.

A-2.1.2 *Effect of Size*

In granular soils the value of E_s corresponding to the size of the raft shall be determined as follows:

$$E_s = E_p\frac{B_f}{B_p}\left[\frac{B_f+B_p}{2B_f}\right]^2$$

Where B_f, B_p represent sizes of foundation and plate and E_p is the modulus determined by the plate load test.

A-2.2 For stratified deposits or deposits with lenses of different materials, results of plate load test will be unreliable and static cone penetration tests may be carried out to determine E_s.

A-2.2.1 Static cone penetration tests shall be carried out in accordance with accepted standard [6-2(21)]. Several tests shall be carried out at regular depth intervals up to a depth equal to the width of the raft and the results plotted to obtain an average value of E_s.

A-2.2.2 The value of E_s may be determined from the following relationship:

$$E_s = 2\,C_{kd}$$

where

C_{kd} = cone resistance, in kN/m^2.

A-3 LABORATORY DETERMINATION OF E_S

A-3.1 The value of E_s shall be determined by conducting triaxial test in the laboratory in accordance with accepted standard [6-2(34)] on samples collected with least disturbances.

A-3.2 In the first phase of the triaxial test, the specimen shall be allowed to consolidate fully under an all-round confining pressure equal to the vertical effective overburden stress for the specimen in the field. In the

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second phase, after equilibrium has been reached, further drainage shall be prevented and the deviator stress shall be increased from zero value to the magnitude estimated for the field loading condition. The deviator stress shall then be reduced to zero and the cycle of loading shall be repeated.

A-3.3 The value of E_s shall be taken as the tangent modulus at the stress level equal to one-half the maximum deviator stress applied during the second cycle of loading.

ANNEX B

(*Clause* 7.4.1.11)

DETERMINATION OF MODULUS OF SUBGRADE REACTION

B-1 GENERAL

The modulus of subgrade reaction (k) as applicable to the case of load through a plate of size 300 mm x 300 mm or beams 300 mm wide on the soils is given in Table 6 for cohesionless soils and in Table 7 for cohesive soils. Unless more specific determination of k is done (*see* **B-2** and **B-3**) these value may be used for design of raft foundation in cases where the depth of the soil affected by the width of the footing may be considered isotropic and the extra-polation of plate load test results is valid.

Table 6 Modulus of Subgrade Reaction (k) for Cohesionless Soils
(*Clause* B-1)

Sl No.	Soil Characteristic		Modulus of Subgrade Reaction, k[1] kN/m^3	
	Relative Density	Standard Penetration Test Value, (N) (Blows per 300 mm)	For Dry or Moist State	For Submerged State
(1)	(2)	(3)	(4)	(5)
i)	Loose	< 10	15 000	9 000
ii)	Medium	10 to 30	15 000 to 47 000	9 000 to 29 000
iii)	Dense	30 and over	47 000 to180 000	29 000 to 108 000

[1] The above values apply to a square plate 300 mm x 300 mm or beams 300 mm wide.

B-2 FIELD DETERMINATION

B-2.1 In cases where the depth of the soil affected by the width of the footing may be considered as isotropic, the value of k may be determined in accordance with accepted standard [6-2(35)]. The test shall be carried out with a plate of size not less than 300 mm.

Table 7 Modulus of Subgrade Reaction (k) for Cohesive Soils
(*Clause* B-1)

Sl No.	Soil Characteristic		Modulus of Subgrade Reaction, k[1] kN/m^3
	Consistency	Unconfined Compressive Strength kN/m^2	
(1)	(2)	(3)	(4)
i)	Stiff	100 to 200	27 000
ii)	Very stiff	200 to 400	27 000 to 54 000
iii)	Hard	400 and over	54 000 to 108 000

[1] The values apply to a square plate 300 mm x 300 mm. The above values are based on the assumption that the average loading intensity does not exceed half the ultimate bearing capacity.

B-2.2 The average value of k shall be based on a number of plate load tests carried out over the area, the number and location of the tests depending upon the extent and importance of the structure.

B-3 LABORATORY DETERMINATION

B-3.1 For stratified deposits or deposits with lenses of different materials, evaluation of k from plate load test will be unrealistic and its determination shall be based on laboratory tests {*see* good practice [6-2(4)]}.

B-3.2 In carrying out the test, the continuing cell pressure may be so selected as to be representative of the depth of the average stress influence zone (about 0.5 B to B).

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B-3.3 The value of k shall be determined from the following relationship:

$$k = 0.65 \times \sqrt[12]{\left(\frac{E_s B^4}{EI}\right)} \cdot \frac{E_s}{\left(1-\mu^2\right)} \cdot \frac{1}{B}$$

where

E_s = modulus of elasticity of soil (*see* Annex A),

E = Young's modulus of foundation material,

μ = Poisson's ratio of soil,

I = moment of inertia of the foundation, and

B = width of the footing.

B-4 CALCULATIONS

When the structure is rigid (*see* Annex C), the average modulus of subgrade reaction may also be determined as follows:

$$k_s = \frac{\text{Average contact pressure}}{\text{Average settlement of the raft}}$$

ANNEX C

(*Clauses* 7.4.4.1, 7.4.4.2 *and* B-4)

RIGIDITY OF SUPERSTRUCTURE AND FOUNDATION

C-1 DETERMINATION OF THE RIGIDITY OF THE STRUCTURE

The flexural rigidity EI of the structure of any section may be estimated according to the relation given below (*see also* Fig. 8)

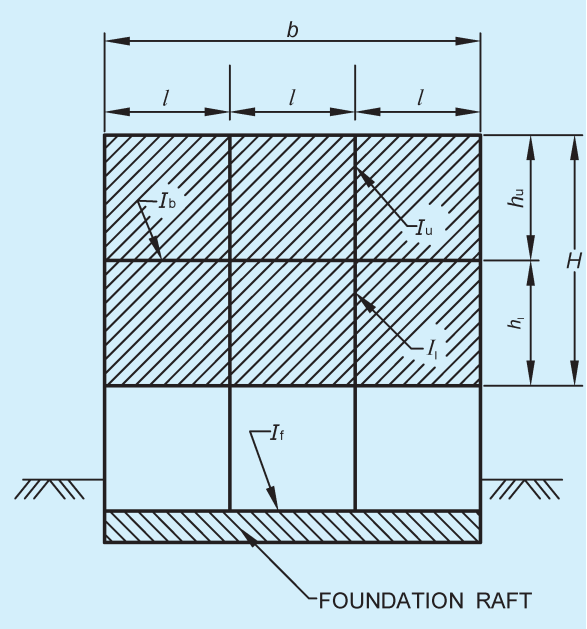


FIG. 8 DETERMINATION OF RIGIDITY OF STRUCTURE

$$EI = \frac{E_1 I_i b^2}{2H^2} + \sum E_2 I_b \left[1 + \frac{\left(I_u' + I_l'\right) b^2}{\left(I_b' + I_u' + I_f'\right) l^2}\right]$$

where

E_1 = modulus of elasticity of the infilling material (wall material), in kN/m^2;

I_i = moment of inertia of the infilling, in m^4;

b = length or breadth of the structure in the direction of bending, in m;

H = total height of the infilling, in m;

E_2 = modulus of elasticity of the frame material, in kN/m^2;

I_b = moment of inertia of the beam, in m^4;

$I_u' = \frac{I_u}{h_u}$;

$I_l' = \frac{I_l}{h_l}$;

$I_b' = \frac{I_b}{l}$;

l = spacing of the columns, in m;

h_u = length of the upper column, in m;

h_l = length of the lower column, in m;

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$I_f' = \frac{I_f}{l}$;

I_u = moment of inertia of the upper column, in m^4;

I_l = moment of inertia of the lower column, in m^4; and

I_f = moment of inertia of the foundation beam or raft, in m^4.

NOTE — The summation is to be done over all the storeys including the foundation beam or raft. In the case of the foundation, I_f' replaces I_b' and I_l becomes zero, whereas for the topmost beam I_u' becomes zero.

C-2 RELATIVE STIFFNESS FACTOR, *K*

C-2.1 Whether a structure behaves as rigid or flexible depends on the relative stiffness of the structure and the foundation soil. This relation is expressed by the relative stiffness factor *K* given below:

a) For the whole structure, $K = \frac{EI}{E_s b^3 a}$

b) For rectangular rafts, $K = \frac{E}{12E_s}\left(\frac{d}{b}\right)^3$

c) For circular rafts, $K = \frac{E}{12E_s}\left(\frac{d}{2R}\right)^3$

where

EI = flexural rigidity of the structure over the length (a), in kN/m^2;

E_s = modulus of compressibility of the foundation soil, in kN/m^2;

b = length of the section in the bending axis, in m;

a = length perpendicular to the section under investigation, in m;

d = thickness of the raft or beam, in m; and

R = radius of the raft, in m.

C-2.1.1 For $K > 0.5$, the foundation may be considered as rigid [*see* **7.4.4.1** (a)].

C-3 DETERMINATION OF CRITICAL COLUMN SPACING

Evaluation of the characteristics λ is made as follows:

$$\lambda = \sqrt[4]{\left(\frac{kB}{4E_c I}\right)}$$

where

k = modulus of subgrade reaction, in kN/m^3, for footing of width B, in m (*see* Annex A);

B = width of raft, in m;

E_c = modulus of elasticity of concrete, in kN/m^2; and

I = moment of inertia of raft, in m^4.

ANNEX D

(*Clause* 7.4.4.1)

CALCULATION OF PRESSURE DISTRIBUTION BY CONVENTIONAL METHOD

D-1 DETERMINATION OF PRESSURE DISTRIBUTION

The pressure distribution (q) under the raft shall be determined by the following formula:

$$q = \frac{Q}{A} \pm \frac{Qe_y'}{I_x'} y \pm \frac{Qe_x'}{I_y'} x$$

where

Q = total vertical load on the raft,

A = total area of the raft,

e_x', e_y', I_x', I_y' = eccentricities and moments of inertia about the principal axes, through the centroid of the section, and

x, y = coordinates of any given point on the raft with respect to the x and y axes passing through the centroid of the area of the raft.

I_x', I_y', e_x', e_y' may be calculated from the following equations:

$$I_x' = I_x - \frac{I_{xy}^2}{I_y}$$

$$I_y' = I_y - \frac{I_{xy}^2}{I_x}$$

$$e_x' = e_x - \frac{I_{xy}}{I_x} e_y$$

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$$e'_y = e_y - \frac{I_{xy}}{I_y} e_x$$

where

I_x, I_y = moment of inertia of the area of the raft respectively about the x and y axes through the centroid,

$I_{xy} = \int xy \cdot dA$ for the whole area about x and y axes through the centroid, and

e_x, e_y = eccentricities in the x and y directions of the load from the centroid.

For a rectangular raft, the equation simplifies to:

$$q = \frac{Q}{A}\left(1 \pm \frac{12e_y y}{b^2} \pm \frac{12e_x x}{a^2}\right)$$

where

a and b = dimensions of the raft in the x and y directions, respectively.

NOTE — If one or more of the values of (q) are negative as calculated by the above formula, it indicates that the whole area of foundation is not subject to pressure and only a part of the area is in contact with the soil, and the above formula will still hold good, provided the appropriate values of I_x, I_y, I_{xy}, e_x and e_y, are used with respect to the area in contact with the soil instead of the whole area.

ANNEX E

(*Clause* 7.4.4.2)

CONTACT PRESSURE DISTRIBUTION AND MOMENTS BELOW FLEXIBLE FOUNDATION

E-1 CONTACT PRESSURE DISTRIBUTION

E-1.1 The distribution of contact pressure is assumed to be linear with the maximum value attained under the columns and the minimum value at mid span.

E-1.2 The contact pressure for the full width of the strip under an interior column load located at a point *i* can be determined as (*see* Fig. 9 A):

$$p_i = \frac{5P_i}{\bar{l}} + \frac{48M_i}{(\bar{l})^2}$$

where

$\bar{l}$ = average length of adjacent span, in m,

P_i = column load, in t at point *i*, and

M_i = moment under an interior columns loaded at *i*.

E-1.3 The minimum contact pressure for the full width of the strip at the middle of the adjacent spans can be determined as (*see* Fig. 9A and 9B):

$$p_{ml} = 2P_i\left(\frac{l_r}{l_l \bar{l}}\right) - p_i\left(\frac{\bar{l}}{l_l}\right)$$

$$p_{mr} = 2P_i\left(\frac{l_l}{l_r \bar{l}}\right) - p_i\left(\frac{\bar{l}}{l_r}\right)$$

$$p_m = \frac{p_{ml} + p_{mr}}{2}$$

where l_r, l_l are as shown in Fig. 9A.

E-1.4 If **E-2.3**(a) governs the moment under the exterior columns, contact pressures under the exterior columns and at end of strip can be determined as (*see* Fig. 9C):

$$p_e = \frac{4P_e + \frac{6M_e}{C} - p_m l_l}{C + l_l}$$

$$p_c = -\frac{3M_e}{C^2} - \frac{p_e}{2}$$

where P_e, p_m, M_e, l_l, C are as shown in Fig. 9C.

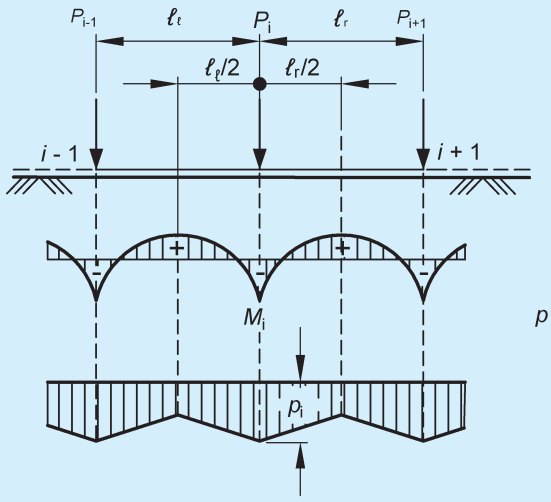
E-1.5 If **E-2.3**(b) governs the moment under the exterior columns, the contact pressures are determined as (*see* Fig. 9C):

$$p_e = p_c \frac{4P_e - p_m l_l}{4C + l_l}$$

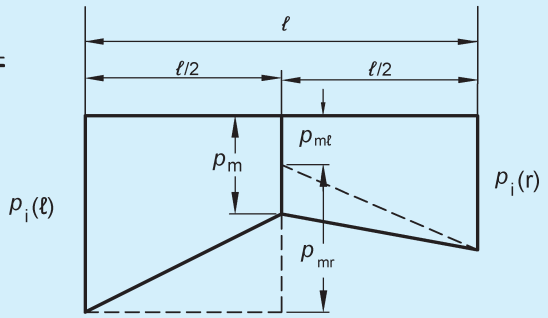
E-2 BENDING MOMENT DIAGRAM

E-2.1 The bending moment under an interior column located at *i* (*see* Fig. 9A) can be determined as:

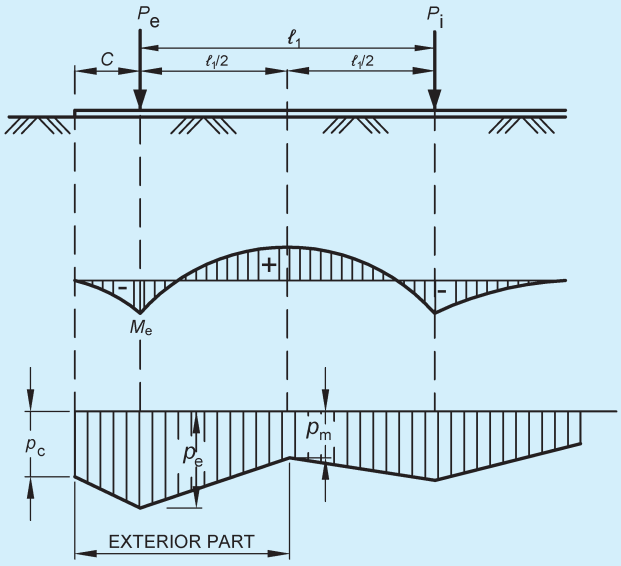
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9A MOMENT AND PRESSURE DISTRIBUTION AT INTERIOR COLUMN



9B PRESSURE DISTRIBUTION OVER AN INTERIOR SPAN



9C MOMENT AND PRESSURE DISTRIBUTION AT EXTERIOR COLUMNS

FIG. 9 MOMENT AND PRESSURE DISTRIBUTION AT COLUMNS

$$M_i = -\frac{P_i}{4\lambda}\left(0.24\lambda\bar{l} + 0.16\right)$$

E-2.2 The bending moment at mid span is obtained as (*see* Fig. 9A):

$$M_m = M_o + M_i$$

where

M_o = moment of simply supported beam

$$= \frac{l^2}{48}\left[p_i(l) + 4p_m + p_i(r)\right]$$

M_i = average of negative moments M_i at each end of the bay.

where $l, p_i(l), p_i(r), p_m$ are as shown in Fig. 9B.

E-2.3 The bending moment M_e under exterior columns can be determined as the least of (*see* Fig. 9C):

a) $$M_{e1} = -\frac{P_e}{4\lambda}\left(0.13\lambda l_1 + 1.06\lambda C - 0.50\right)$$

b) $$M_{e2} = -\frac{\left(4P_e - p_m l_1\right)}{\left(4C + l_1\right)}\frac{C^2}{2}$$

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ANNEX F

[*Clause* 7.4.4.2(b)]

FLEXIBLE FOUNDATION — GENERAL CONDITION

F-1 CLOSED FORM SOLUTION OF ELASTIC PLATE THEORY

F-1.1 For a flexible raft foundation with non-uniform column spacing and load intensity, solution of the differential equation governing the behaviour of plates on elastic foundation (Winkler Type) gives radial moment (M_r) tangential moment (M_t) and deflection (w) at any point by the following expressions:

$$M_r = -\frac{P}{4}\left[Z_4\left(\frac{r}{L}\right) - (1-\mu)\frac{Z_3'\left(\frac{r}{L}\right)}{\left(\frac{r}{L}\right)}\right]$$

$$M_t = -\frac{P}{4}\left[\mu Z_4\left(\frac{r}{L}\right) + (1-\mu)\frac{Z_3'\left(\frac{r}{L}\right)}{\left(\frac{r}{L}\right)}\right]$$

$$w = \frac{PL^2}{4D}\cdot Z_3\left(\frac{r}{l}\right)$$

where

P = column load,

r = distance of the point under investigation from column load along radius, and

L = radius of effective stiffness

$$= \left(\frac{D}{k}\right)^{1/4}$$

where

k = modulus of subgrade reaction for footing of width B,

D = flexural rigidity of the foundation,

$$P = \frac{Et^2}{12(1-\mu)^2},$$

T = raft thickness,

E = modulus of elasticity of the foundation material,

μ = Possion's ratio of the foundation material, and

$Z_3\left(\frac{r}{L}\right)$, $Z_3'\left(\frac{r}{L}\right)$, $Z_4\left(\frac{r}{L}\right)$ = functions of shear, moment and deflection (*see* Fig. 10)

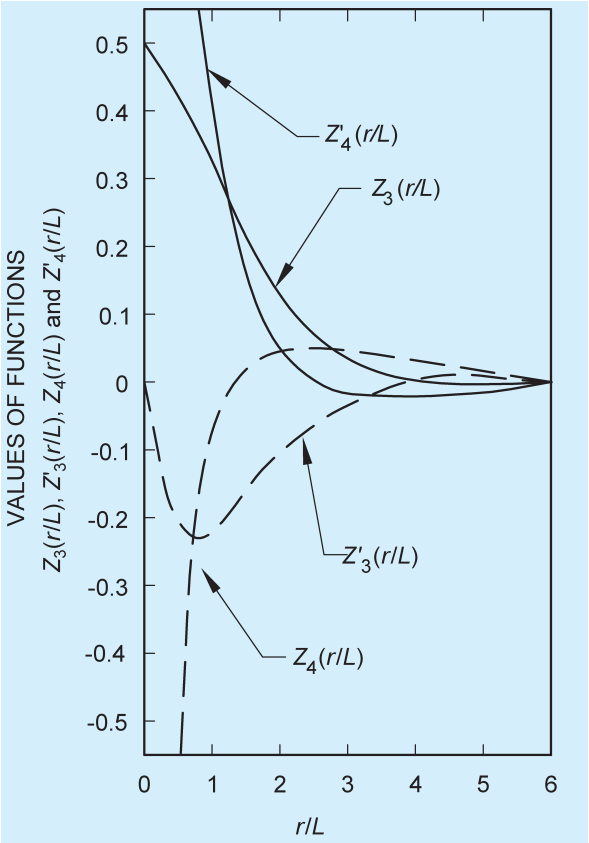


FIG. 10 FUNCTIONS FOR SHEAR, MOMENT AND DEFLECTION

F-1.2 The radial and tangential moments can be converted to rectangular co-ordinates:

$$M_x = M_r \cos^2\phi + M_t \sin^2\phi$$

$$M_y = M_r \sin^2\phi + M_t \cos^2\phi$$

where

ϕ = angle with x-axis to the line joining origin to the point under consideration.

F-1.3 The shear, Q per unit width of raft can be determined by:

$$Q = -\frac{P}{4L}Z_4'\left(\frac{r}{L}\right)$$

where

$Z_4'\left(\frac{r}{L}\right)$ = function for shear (*see* Fig. 10).

F-1.4 When the edge of the raft is located within the radius of influence, the following corrections are to be applied. Calculate moments and shears perpendicular to the edge of the raft within the radius of influence, assuming the raft to be infinitely large. Then apply

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opposite and equal moments and shears on the edge of the mat. The method for beams on elastic foundation may be used.

F-1.5 Finally, all moments and shears calculated for each individual column and wall are superimposed to obtain the total moment and shear values.

ANNEX G

(*Clauses* 8.3.3.1.1, 8.3.3.2 *and* 11.3.4)

LOAD CARRYING CAPACITY OF PILES — STATIC ANALYSIS

G-1 PILES IN GRANULAR SOILS

The ultimate load capacity (Q_u) of piles, in kN, in granular soils is given by the following formula:

$$Q_u = A_p(\tfrac{1}{2} D \gamma N_\gamma + P_D N_q) + \sum_{i=1}^{n} K_i P_{Di} \tan \delta_i A_{si} \quad \ldots(1)$$

The first term gives end bearing resistance and the second term gives skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2;

D = diameter of pile shaft, in m;

γ = effective unit weight of the soil at pile tip, in kN/m^3;

N_γ and N_q = bearing capacity factors depending upon the angle of internal friction, ϕ at pile tip;

P_D = effective overburden pressure at pile tip, in kN/m^2 (*see* Note 5);

$\sum_{i=1}^{n}$ = summation for layers 1 to n in which pile is installed and which contribute to positive skin friction;

K_i = coefficient of earth pressure applicable for the ith layer (*see* Note 3);

P_{Di} = effective overburden pressure for the ith layer, in kN/m^2;

δ_i = angle of wall friction between pile and soil for the ith layer; and

A_{si} = surface area of pile shaft in the ith layer, in m^2.

NOTES

1 N_γ factor can be taken for general shear failure according to good practice [6-2(11)].

2 N_q factor will depend on the nature of soil, type of pile, the L/B ratio and its method of construction. The values applicable for driven and bored piles are given in Fig. 11A and Fig. 11B, respectively.

3 K_i, the earth pressure coefficient depends on the nature of soil strata, type of pile, spacing of piles and its method of construction. For bored piles in loose to dense sand with ϕ varying between 30° and 40°, K_i values in the range of 1 to 2 may be used for driven piles and in case of bored piles, K_i values in the range of 1 to 1.5 may be used.

4 δ, the angle of wall friction may be taken equal to the friction angle of the soil around the pile shaft.

5 In working out pile capacity by static formula, the maximum effective overburden at the pile tip should correspond to the critical depth, which may be taken as 15 times the diameter of the pile shaft for $\phi \leq 30°$ and increasing to 20 times for $\phi \geq 40°$.

6 For piles passing through cohesive strata and terminating in a granular stratum, a penetration of at least twice the diameter of the pile shaft should be given into the granular stratum.

G-2 PILES IN COHESIVE SOILS

The ultimate load capacity (Q_u) of piles, in kN, in cohesive soils is given by the following formula:

$$Q_u = A_p N_c c_p + \sum_{i=1}^{n} \alpha_i c_i A_{si} \quad \ldots (2)$$

The first term gives end bearing resistance and the second term gives the skin friction resistance.

where

A_p = cross-sectional area of pile tip, in m^2;

N_c = bearing capacity factor, may be taken as 9;

c_p = average cohesion at pile tip, in kN/m^2;

$\sum_{i=1}^{n}$ = summation for layers 1 to n in which pile is installed and which contribute to positive skin friction;

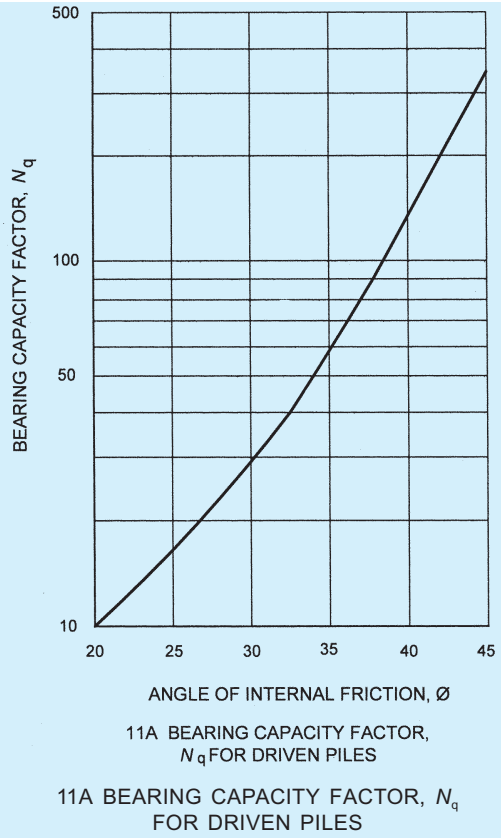
α_i = adhesion factor for the ith layer depending on the consistency of soil (*see* Note);

c_i = average cohesion for the ith layer, in kN/m^2; and

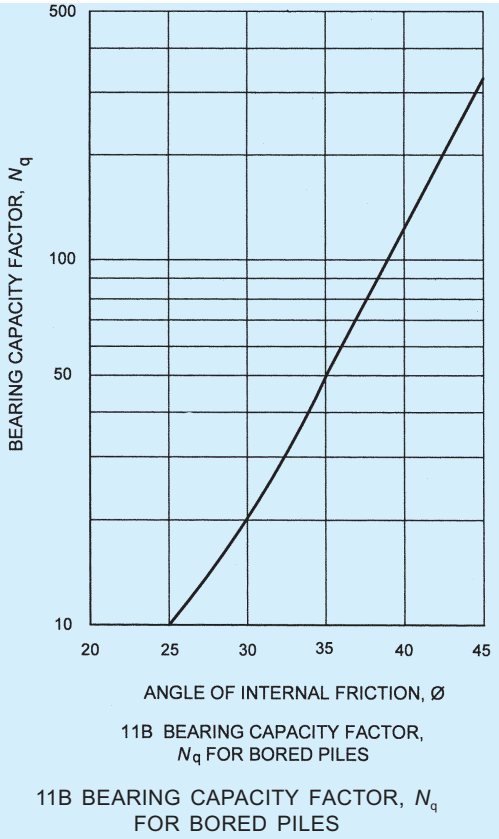
A_{si} = surface area of pile shaft in the ith layer, in m^2.

NOTE — The value of adhesion factor, α_i depends on the undrained shear strength of the clay and may be obtained from Fig. 12.

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11A BEARING CAPACITY FACTOR, N_q FOR DRIVEN PILES



11B BEARING CAPACITY FACTOR, N_q FOR BORED PILES

FIG. 11 BEARING CAPACITY FACTOR, N_q

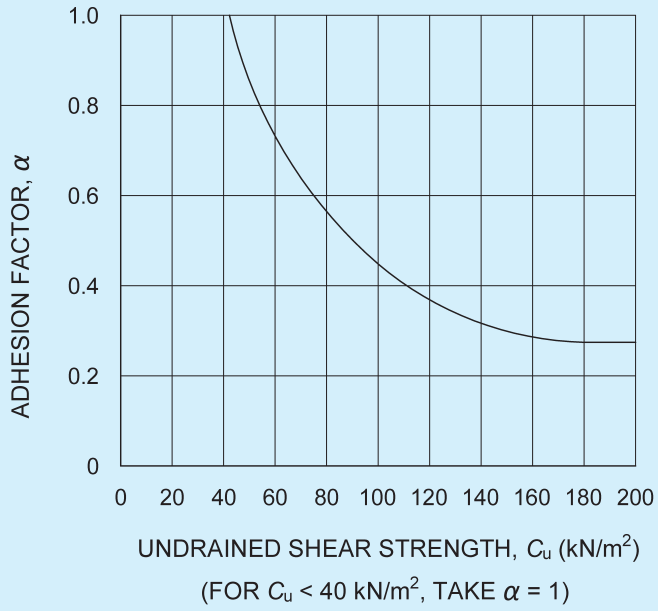


FIG. 12 VARIATION OF α WITH C_u

G-3 USE OF STATIC CONE PENETRATION DATA

G-3.1 When static cone penetration data are available for the entire depth, the following correlation may be used as a guide for the determination of ultimate load capacity of a pile.

G-3.2 Ultimate end bearing resistance (q_u), in kN/m^2, may be obtained as:

$$q_u = \frac{\frac{q_{c0} + q_{c1}}{2} + q_{c2}}{2}$$

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where

q_{c0} = average static cone resistance over a depth of $2D$ below the pile tip, in kN/m^2;

q_{c1} = minimum static cone resistance over the same $2D$ below the pile tip, in kN/m^2;

q_{c2} = average of the envelope of minimum static cone resistance values over the length of pile of $8D$ above the pile tip, in kN/m^2; and

D = diameter of pile shaft.

G-3.3 Ultimate skin friction resistance can be approximated to local side friction (f_s), in kN/m^2, obtained from static cone resistance as given in Table 8.

G-3.4 The correlation between standard penetration resistance, N (blows/30 cm) and static cone resistance, q_c, in kN/m^2, as given in Table 9 may be used for working out the end bearing resistance and skin friction resistance of piles. This correlation should only be taken as a guide and should preferably be established for a given site as they can vary substantially with the grain size, Atterberg limits, water table, etc.

Table 8 Side Friction for Different Soil Types
(*Clause* G-3.3)

Sl No.	Type of Soil	Local Side Friction, f_s kN/m^2
(1)	(2)	(3)
i)	q_c less than 1 000 kN/m^2	$q_c/30 < f_s < q_c/10$
ii)	Clay	$q_c/25 < f_s < 2q_c/25$
iii)	Silty clay and silty sand	$q_c/100 < f_s < q_c/25$
iv)	Sand	$q_c/100 < f_s < q_c/50$
v)	Coarse sand and gravel	$q_c/100 < f_s < q_c/150$

where q_c = cone resistance, in kN/m^2.

Table 9 Corelation Between N and q_c for Different Types of Soil
(*Clause* G-3.4)

Sl No.	Type of Soil	q_c/N
(1)	(2)	(3)
i)	Clay	150-200
ii)	Silts, sandy silts and slightly cohesive silt-sand mixtures	200-250
iii)	Clean fine to medium sand and slightly silty sand	300-400
iv)	Coarse sand and sands with little gravel	500-600
v)	Sandy gravel and gravel	800-1 000

G-4 USE OF STANDARD PENETRATION TEST DATA FOR COHESIONLESS SOIL

G-4.1 The correlation suggested by Meyerhof using standard penetration resistance, N in saturated cohesionless soil to estimate the ultimate load capacity of driven pile is given below. The ultimate load capacity of pile (Q_u), in kN, is given as:

$$Q_u = 40\,N\,\frac{L_b}{D}A_p + \frac{\overline{N}A_s}{0.50} \qquad \ldots (3)$$

The first term gives the end bearing resistance and the second term gives the frictional resistance.

where

N = average N values at pile tip;

L_b = length of penetration of pile in the bearing strata, in m;

D = diameter or minimum width of pile shaft, in m;

A_p = cross-sectional area of pile tip, in m^2;

$\overline{N}$ = average N along the pile shaft; and

A_s = surface area of pile shaft, in m^2.

NOTE — The end bearing resistance should not exceed $400\,NA_p$

G-4.2 For non-plastic silt or very fine sand the equation has been modified as:

$$Q_u = 30\,N\frac{L_b}{D}A_p + \frac{\overline{N}A_s}{0.60} \qquad \ldots (4)$$

The meaning of all terms is same as for equation 3.

G-4.3 The correlation suggested by Meyerhof using standard penetration resistance, N in saturated cohesionless soil to estimate the ultimate load capacity of bored pile is given below. The ultimate capacity of pile (Q_u), in kN, is given as:

$$Q_u = 13\,N\,\frac{L_b}{D}A_p + \frac{\overline{N}A_s}{0.50} \qquad \ldots (5)$$

The first term gives end bearing resistance and the second term gives frictional resistance.

The meaning of all terms is same as for equation 3.

NOTE — The end bearing resistance should not exceed $130\,NA_p$.

G-4.4 For non-plastic silt or very fine sand the equation has been modified as:

$$Q_u = 10\,\frac{L_b}{D}A_p + \frac{\overline{N}A_s}{0.60} \qquad \ldots (6)$$

The meaning of all terms is same as for equation 3.

G-5 FACTOR OF SAFETY

The minimum factor of safety for arriving at the safe pile capacity from the ultimate capacity obtained by using static formulae shall be 2.5.

G-6 PILES IN STRATIFIED SOIL

In stratified soil/C-ϕ soil, the ultimate load capacity of piles should be determined by calculating the skin friction and end bearing in different strata by using appropriate expressions given in **G-1** and **G-2**.

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G-7 PILES IN HARD ROCK

When the crushing strength of the rock is more than characteristic strength of pile concrete, the rock should be deemed as hard rock. Bored piles resting directly on hard rock may be loaded to their safe structural capacity.

G-8 PILES IN WEATHERED/SOFT ROCK

For bored piles founded in weathered/soft rock different empirical approaches are used to arrive at the socket length necessary for utilizing the full structural capacity of the pile.

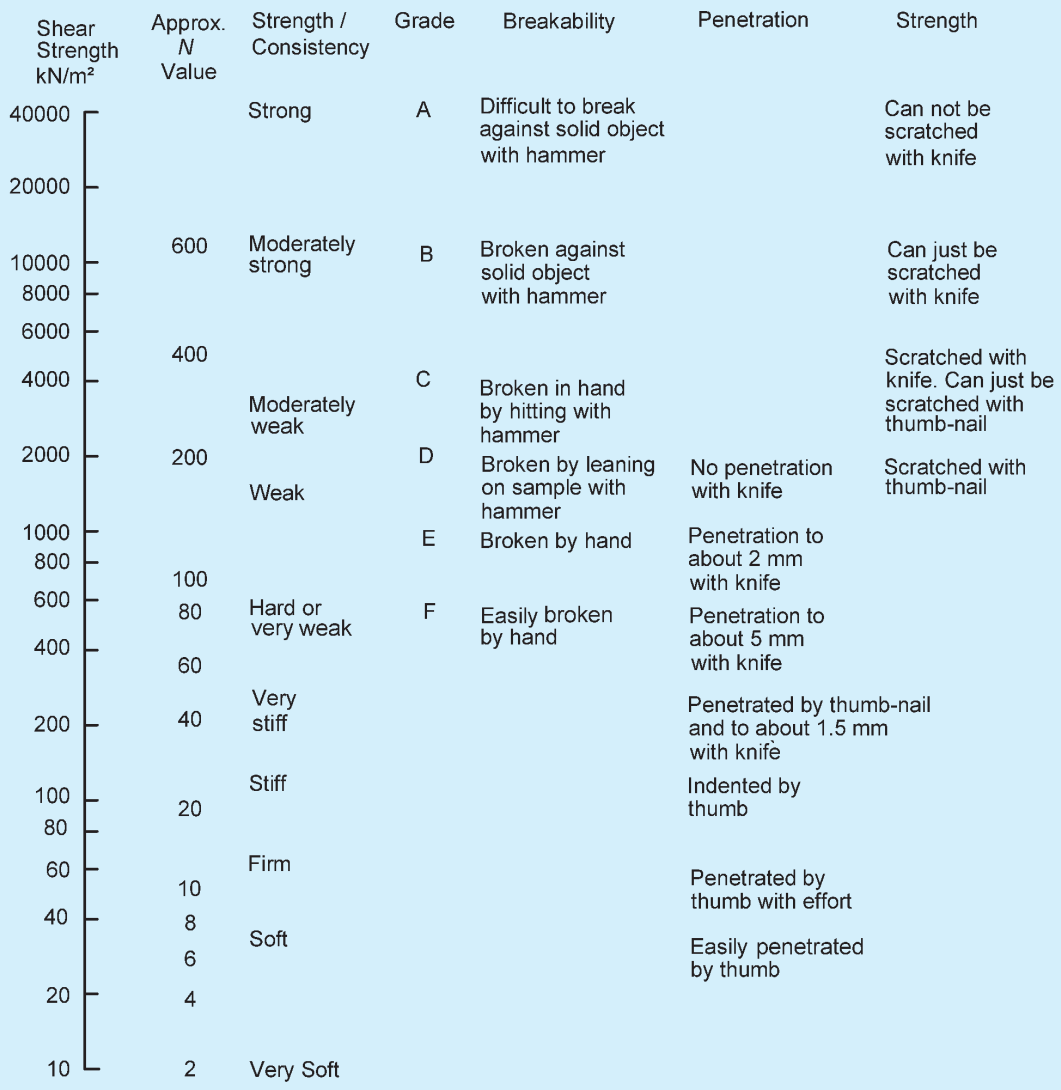
Since it is difficult to collect cores in weathered/soft rocks, the method suggested by Cole and Stroud using '*N*' values is more widely used. The allowable load on the pile, Q_a, in kN, by this approach, is given by:

$$Q_a = c_{u1} N_c \cdot \frac{\pi B^2}{4 F_s} + \alpha \, c_{u2} \cdot \frac{\pi B L}{F_s}$$

where

c_{u1} = shear strength of rock below the base of the pile, in kN/m^2 (*see* Fig. 13);
N_c = bearing capacity factor taken as 9;
F_s = factor of safety usually taken as 3;
α = 0.9 (recommended value);
c_{u2} = average shear strength of rock in the socketed length of pile, in kN/m^2 (*see* Fig. 13);
B = minimum width of pile shaft (diameter in case of circular piles), in m; and
L = socket length of pile, in m.

NOTE — For $N \geq 60$, the stratum is to be treated as weathered rock rather than soil.



NOTE — Standard penetration test may not be practicable for *N* values greater than 200. In such cases, design may be done on the basis of shear strength of rock.

FIG. 13 CONSISTENCY AND SHEAR STRENGTH OF WEATHERED ROCK

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ANNEX H

(*Clause* 8.3.5.2)

ANALYSIS OF LATERALLY LOADED PILES

H-1 GENERAL

H-1.1 The ultimate resistance of a vertical pile to a lateral load and the deflection of the pile as the load builds up to its ultimate value are complex matters involving the interaction between a semi-rigid structural element and soil which deforms partly elastically and partly plastically. The failure mechanisms of an infinitely long pile and that of a short rigid pile are different. The failure mechanisms also differ for a restrained and unrestrained pile head conditions.

Because of the complexity of the problem only a procedure for an approximate solution that is adequate in most of the cases is presented here. Situations that need a rigorous analysis shall be dealt with accordingly.

H-1.2 The first step is to determine, if the pile will behave as a short rigid unit or as an infinitely long flexible member. This is done by calculating the stiffness factor R or T for the particular combination of pile and soil.

Having calculated the stiffness factor, the criteria for behaviour as a short rigid pile or as a long elastic pile are related to the embedded length L_e of the pile. The depth from the ground surface to the point of virtual fixity is then calculated and used in the conventional elastic analysis for estimating the lateral deflection and bending moment.

H-2 STIFFNESS FACTORS

H-2.1 The lateral soil resistance for granular soils and normally consolidated clays which have varying soil modulus is modeled according to the equation:

$$\frac{p}{y} = \eta_h z$$

where

p = lateral soil reaction per unit length of pile at depth z below ground level;

y = lateral pile deflection; and

η_h = modulus of subgrade reaction for which the recommended values are given in Table 10.

H-2.2 The lateral soil resistance for over-consolidated clays with constant soil modulus is modeled according to the equation:

$$\frac{p}{y} = K$$

where

$$K = \frac{k_1}{1.5} \times \frac{0.3}{B}$$

where k_1 is Terzaghi's modulus of subgrade reaction as determined from load deflection measurements on a 30 cm square plate and B is the width of the pile (diameter in case of circular piles). The recommended values of k_1 are given in Table 11.

Table 10 Modulus of Subgrade Reaction for Granular Soils and Normally Consolidated Clays, η_h, kN/m^3
(*Clause* H-2.1)

Sl No.	Soil Type	N (Blows/ 30 cm)	Range of η_h kN/m^3 x 10^3	
			Dry	Submerged
(1)	(2)	(3)	(4)	(5)
i)	Soft organic silt	–	–	0.15
ii)	Soft normally consolidated clay	0 - 4	–	0.35 - 0.7
iii)	Very loose sand	0 - 4	< 0.4	< 0.2
iv)	Loose sand	4 - 10	0.4 - 2.5	0.2 - 1.4
v)	Medium sand	10 - 35	2.5 - 7.5	1.4 - 5.0
vi)	Dense sand	> 35	7.5 - 20.0	5.0 - 12.0

NOTE — The η_h values may be interpolated for intermediate standard penetration values, N.

Table 11 Modulus of Subgrade Reaction for Cohesive Soil, k_1, kN/m^3
(*Clause* H-2.2)

Sl No.	Soil Consistency	Unconfined Compression Strength, q_u kN/m^3 × 10^3	Range of k_1 kN/m^2
(1)	(2)	(3)	(4)
i)	Soft	25-50	4.5-9.0
ii)	Medium stiff	50-100	9.0-18.0
iii)	Stiff	100-200	18.0-36.0
iv)	Very stiff	200-400	36.0-72.0
v)	Hard	> 400	>72.0

NOTE — For q_u less than 25, k_1 may be taken as zero, which implies that there is no lateral resistance.

H-2.3 Stiffness Factors

H-2.3.1 *For Piles in Sand and Normally Consolidated Clays*

Stiffness factor T, in m $= \sqrt[5]{\frac{EI}{\eta_h}}$

where

E = Young's modulus of pile material, in MN/m^2;

I = moment of inertia of the pile cross-section, in m^4; and

η_h = modulus of subgrade reaction variation, in MN/m^3 (*see* Table 10).

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H-2.3.2 *For Piles in Over-Consolidated Clays*

$$\text{Stiffness factor } R, \text{ in m} = \sqrt[4]{\frac{EI}{KB}}$$

where

E = Young's modulus of pile material, in MN/m^2;

I = moment of inertia of the pile cross-section, in m^4;

K = $\frac{k_1}{1.5} \times \frac{0.3}{B}$ (*see* Table 11 for values of k_1, in MN/m^3 (*see also* Note); and

B = width of pile shaft (diameter in case of circular piles), in m.

NOTE – Table 11 shall be referred if the average unconfined compression strength, q_u is greater than or equal to 100 kN/m^2.

H-3 CRITERIA FOR SHORT RIGID PILES AND LONG ELASTIC PILES

Having calculated the stiffness factor T or R, the criteria for behaviour as a short rigid pile or as a long elastic pile are related to the embedded length L_e as given in Table 12.

Table 12 Criteria for Behaviour of Pile Based on its Embedded Length
(*Clause* H-3)

Sl No.	Type of Pile Behaviour	Relation of Embedded Length with Stiffness Factor	
		Linearly Increasing	Constant
(1)	(2)	(3)	(4)
i)	Short (rigid) pile	$L_e \le 2T$	$L_e \le 2R$
ii)	Long (elastic) pile	$L_e \ge 4T$	$L_e \ge 3.5R$

NOTE — The intermediate L_e shall indicate a case between rigid pile behaviour and elastic pile behaviour.

H-4 DEFLECTION AND MOMENTS IN LONG ELASTIC PILES

H-4.1 Equivalent cantilever approach gives a simple procedure for obtaining the deflections and moments due to relatively small lateral loads. This requires the determination of depth of virtual fixity, z_f.

The depth to the point of fixity may be read from the plots given in Fig. 14. 'e' is the effective eccentricity of the point of load application obtained either by converting the moment to an equivalent horizontal load or by actual position of the horizontal load application. R and T are the stiffness factors described earlier.

H-4.2 The pile head deflection, y shall be computed using the following equations:

$$\text{Deflection, } y = \frac{H\left(e + z_f\right)^3}{3EI} \times 10^3 \quad \text{(for free head pile)}$$

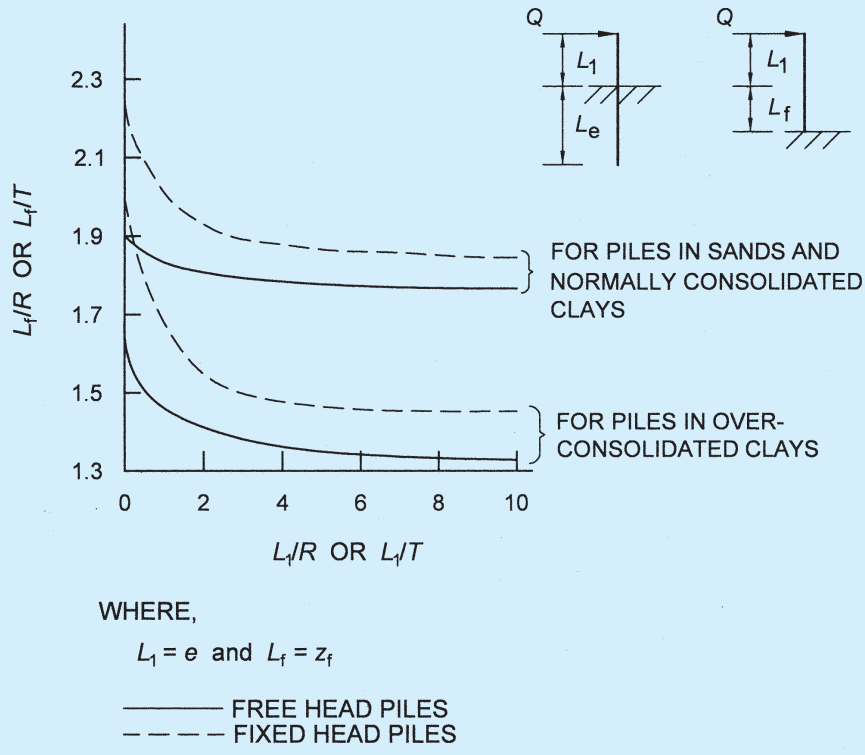


FIG. 14 DEPTH OF FIXITY

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Deflection, $y = \frac{H(e+z_f)^3}{12EI} \times 10^3$ (for fixed head pile)

where

H = lateral load, in kN;

y = deflection of pile head, in mm;

E = Young's modulus of pile material, in kN/m^2;

I = moment of inertia of the pile cross-section, in m^4;

z_f = depth to point of fixity, in m; and

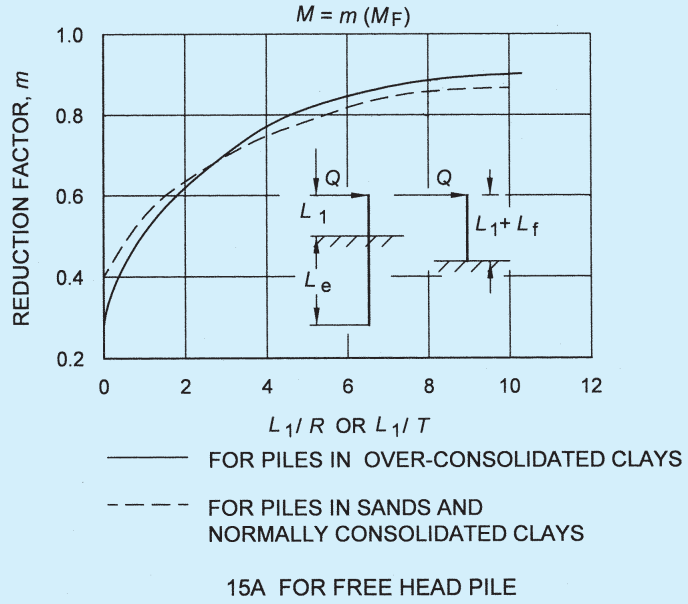
e = cantilever length above ground/bed to the point of load application, in m.

H-4.3 The fixed end moment of the pile for the equivalent cantilever may be determined from the following expressions:

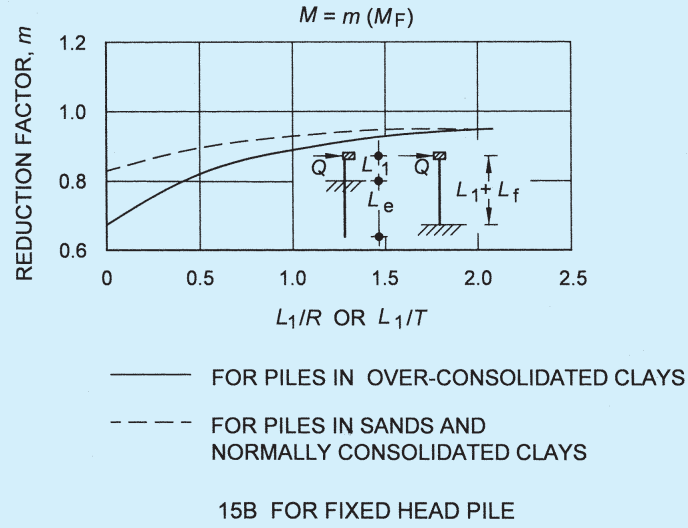
Fixed end moment, $M_F = H(e + z_f)$ (for free head pile)

Fixed end moment, $M_F = \frac{H(e+z_f)}{2}$ (for fixed head pile)

The fixed head moment, M_F of the equivalent cantilever is higher than the actual maximum moment M in the pile. The actual maximum moment may be obtained by multiplying the fixed end moment of the equivalent cantilever by a reduction factor, m, given in Fig. 15.



15A FOR FREE HEAD PILE



15B FOR FIXED HEAD PILE

FIG. 15 DETERMINATION OF REDUCTION FACTORS FOR COMPUTATION OF MAXIMUM MOMENT IN PILE

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ANNEX J

(*Clause* 11.2.2)

LOAD CARRYING CAPACITY OF UNDER-REAMED PILES FROM SOIL PROPERTIES

J-1 ULTIMATE LOAD CAPACITY

The ultimate load capacity of a pile can be calculated from soil properties. The soil properties required are strength parameters, cohesion, angle of internal friction and soil density.

a) *Clayey soils* – For clayey soils, the ultimate load carrying capacity of an under-reamed pile may be worked out from the following expression:

$$Q_u = A_p N_c C_p + A_a N_c C'_a + C'_a A'_s + \alpha C_a A_s$$

where

Q_u = ultimate bearing capacity of pile, in kN;

A_p = cross-sectional area of the pile stem at the pile tip, in m^2;

N_c = bearing capacity factor, usually taken as 9;

C_p = cohesion of the soil around toe, in kN/m^2;

A_a = $(\pi/4)(D_u^2 - D^2)$, where D_u and D are the under-reamed and stem diameter, respectively, in m;

C_a = average cohesion of the soil along the pile stem, in kN/m^2;

A_s = surface area of the stem, in m^2;

A'_s = surface area of the cylinder circumscribing the under-reamed bulbs, in m^2;

C'_a = average cohesion of the soil around the under-reamed bulbs; and

α = reduction factor (usually taken as 0.5 for clays).

NOTES

1 The above expression holds for the usual spacing of under-reamed bulbs spaced at not more than one and a half times their diameter.

2 If the pile is with one bulb only, the third term will not occur. For calculating uplift load, the first term will not occur in the formula.

3 In case of expansive soil, top 2 m strata should be neglected for computing skin friction.

b) *Sandy soils*

$$Q_u = A_p\left(\frac{1}{2}D\cdot\gamma\cdot N_\gamma + \gamma d_f N_q\right) + A_a\left[\frac{1}{2}D_u n\gamma N_\gamma + \gamma N_q\left(\sum_{r=1}^{r=n} d_r\right)\right] + \frac{1}{2}\pi D\gamma K\tan\delta\left(d_1^2 + d_f^2 - d_n^2\right)$$

where

A_p = $\pi D^2/4$, where D is stem diameter, in m;

A_a = $\pi/4\ (D_u^2 - D^2)$ where D_u is the under-reamed bulb diameter, in m;

n = number of under-reamed bulbs;

γ = average unit weight of soil (submerged unit weight in strata below water table), in kN/m^3;

N_γ, N_q = bearing capacity factors, depending upon the angle of internal friction;

d_r = depth of the centre of different under-reamed bulbs below ground level, in m;

d_f = total depth of pile below ground level, in m;

K = earth pressure coefficient (usually taken as 1.75 for sandy soils);

δ = angle of wall friction (may be taken as equal to the angle of internal friction ϕ);

d_1 = depth of the centre of the first under-reamed bulb, in m; and

d_n = depth of the centre of the last under-reamed bulb, in m.

NOTES

1 For uplift bearing on pile tip, A_p will not occur.

2 N_γ will be as specified in good practice [6-2(11)] and N_q will be taken from Fig. 11B.

c) *Soil strata having both cohesion and friction* — In soil strata having both cohesion and friction or in layered strata having two types of soil, the bearing capacity may be estimated using both the formulae. However, in such cases load test will be a better guide.

d) *Compaction piles in sandy strata* — For bored compaction piles in sandy strata, the formula in (b) shall be applied but with the modified value of ϕ_1 as given below:

$$\phi_1 = (\phi + 40)/2$$

where

ϕ = angle of internal friction of virgin soil.

The values of N_γ, N_q and d are taken corresponding to ϕ_1. The value of the earth pressure coefficient K will be 3.

e) *Piles resting on rock* — For piles resting on rock, the bearing component will be obtained by multiplying the safe bearing capacity of rock with bearing area of the pile stem plus the bearing provided by the bulb portion.

NOTE — To obtain safe load in compression and uplift from ultimate load capacity generally the factors of safety will be 2.5 and 3, respectively.

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ANNEX K

(*Clause* 14.2)

SOIL IMPROVEMENT METHODS

Summary of Soil Improvement Methods

	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
In-Situ Deep Compaction of Cohesionless Soils	Blasting	Shock waves and vibrations cause liquefaction and displacement with settlement to higher density	Saturated, clean sands: partly saturated sands and silts (collapsible loess) after flooding	>30 m	Explosives, backfill to plug drill holes, hole casings	Jetting or drilling machine	Can obtain relative densities to 70-80, may get variable density strength gain	Rapid, inexpensive, can treat any size areas: variable properties, no improvement near surface, dangerous	Low
	Vibratory Probe	Densification by vibration; liquefaction induced settlement under overburden	Saturated or dry clean sand	20 m (Ineffective above 3-4m depth)	None	Vibratory pile driver and 750 mm dia open steel pipe	Can obtain relative densities of up to 80. Ineffective in some sands	Rapid, simple, good underwater, soft under layers may damp vibrations, difficult to penetrate, stiff over layers, not good in partly saturated soils	Moderate
	Vibro-compaction	Densification by vibration and compaction of backfill material	Cohesionless soils with less than 20 fines	30 m	Granular backfill, water supply	Vibroflot, crane, pumps	Can obtain high relative densities, good uniformity	Useful in saturated and partly saturated soils, uniformity	Moderate
In-Situ Deep compaction of Cohesionless Soils	Compaction piles	Densification by displacement of pile volume and by vibration during driving	Loose sandy soils: partly saturated clayey soils, loess	>20 m	Pile material (often sand or soil plus cement mixture)	Pile driver, special sand pile equipment	Can obtain high densities, good uniformity	Useful in soils with fines, uniform compaction, easy to check results, slow, limited improvement in upper 1-2 m	Moderate to high
	Heavy tamping (Dynamic compaction/ consolidation)	Repeated application of high intensity impacts at surface	Cohesionless soils, waste fills, partly saturated soils	30 m	None	Tampers of up to 200 tonne, high capacity crane	Can obtain good improvement and reasonable uniformity	Simple, rapid, suitable for some soils with fines; usable above and below water, requires control, shall be away from existing structures	Low

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ANNEX K — (*Continued*)

	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
Injection and Grouting	Particulate grouting	Penetration grouting-fill soil pores with soil, cement, and/or clay	Medium to coarse sand and gravel	Unlimited	Grout, water	Mixers, tanks, pumps, hoses	Impervious, high strength with cement grout, eliminate liquefaction danger	Low cost grouts, high strength; limited to coarse-grained soils, hard to evaluate	Lowest of the grout systems
	Chemical grouting	Solution of two or more chemicals react in soil pores to form a gel or a solid precipitate	Medium silts and coarser	Unlimited	Grout, water	Mixers, tanks, pumps, hoses	Impervious, high strength with cement grout, eliminate liquefaction danger	Low viscosity controllable gel time, good water shut-off; high cost, hard to evaluate	High to very high
	Pressure injected lime	Lime slurry injected to shallow depths under high pressure	Expansive clays	Unlimited, but 2-3 m usual	Lime, water surfactant	Slurry tanks, agitators, pumps, hoses	Lime in capsulated zones formed by channels resulting from cracks, root holes, hydraulic fracture	Only effective in narrow range of soil conditions	Competitive with other solutions to expansive soil problems
	Displacements grout	Highly viscous grout acts as radical hydraulic jack when pumped in under high pressure	Soft, fine-grained soils; foundation soils with large voids or cavities	Unlimited, but a few metre usual	Soil, cement water	Batching equipment, high pressure pumps, hoses	Grout bulbs within compressed soil matrix	Good for correction of differential settlements, filling large voids; careful control required	Low material high injection
	Electro-kinetic injection	Stabilization chemicals moved into soil by electro-osmosis or colloids into pores by electrophoresis	Saturated silts; silty clays (clean sands in case of colloid injection)	Unknown	Chemicals stabilizer colloidal void fillers	d.c. power supply, anodes, cathodes	Increased strength, reduced compressibility reduced liquefaction potential	Existing soil and structures not subjected to high pressures; not good in soils with high conductivity	Expansive
	Jet grouting	High speed jets at depth excavate, inject, and mix stabilizer with soil to form columns or panels	Sands, silts, clays	—	Water, stabilizing chemicals	Special jet nozzle, pumps, pipes and hoses	Solidified columns and walls	Useful in soils that can't be permeation grouted, precision in locating treated zones	—

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ANNEX K — (*Continued*)

	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
Precompression	Preloading with/without drain	Load is applied sufficiently in advance of construction so that compression of soft soils is completed prior to development of the site	Normally consolidated soft clays, silts, organic deposits, completed sanitary landfills	—	Earth fill or other material for loading the site; sand or gravel for drainage blanket	Earth moving equipment, large water tanks or vacuum drainage systems sometimes used; settlement markers, piezo-meters	Reduced water content and void ratio, increased strength	Easy, theory well developed, uniformity; requires long time (vertical drains can be used to reduce consolidation time)	Low (moderate, if vertical drains are required)
	Surcharge fills	Fill in excess of that required permanently is applied to achieve a given amount of settlement in a shorter time; excess fill then removed	Normally consolidated soft clays, silts, organic deposits, completed sanitary landfills	—	Earth fill or other material for loading the site; sand or gravel for drainage blanket	Earth moving equipment; settlement markers, piezometers	Reduced water content, void ratio and compressibility increased strength	Faster than preloading without surcharge, theory well developed, extra material handling; can use vertical drains to reduce consolidation time	Moderate
	Electro-osmosis	d.c. current causes water flow from anode towards cathode where it is removed	Normally consolidated silts and silty clays	—	Anodes (usually rebars or aluminium) cathodes (well points or rebars)	d.c. power supply, wiring, metering systems	Reduced water content and compressibility, increased strength, electrochemical hardening	No fill loading required, can be used in confined area, relatively fast; non-uniform properties between electrodes; not good in highly conductive soils	High

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ANNEX K — (*Continued*)

	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
Admixtures	Remove and replace	Foundation soil excavated, improved by drying or admixture, and re-compacted	Inorganic soils	10 m	Admixture stabilizers	Excavating, mixing and compaction equipment, dewatering system	Increased strength and stiffness, reduced compressibility	Uniform, controlled foundation soil when replaced; may require large area dewatering	High
	Structural fills	Structural fill distributes loads to underlying soft soils	Use over soft clays or organic soils, marsh deposits	—	Sand, gravel fly ash, bottom ash, slag, expanded aggregate, clam shell or oyster shell, incinerator ash	Mixing and compaction equipment	Soft subgrade protected by structural load-bearing fill	High strength, good load distribution to underlying soft soils	Low to high
	Mix-in-place piles and walls	Lime cement or asphalt introduced through rotating auger or special in-place mixer	All soft or loose inorganic soils	>20 m	Cement lime asphalt, or chemical stabilizer	Drill rig, rotary cutting and mixing head, additive proportioning equipment	Solidified soil piles for walls of relatively high strength	Use native soil, reduced lateral support requirements during excavation; difficult quality control	Moderate to high
Thermal	Heating	Drying at low temperatures; alteration of clays at intermediate temperatures (400-600°C); fusion at high temperatures (>1 000°C)	Fine- grained soils, especially partly saturated clays and silts, loess	15 m	Fuel	Fuel tanks, burners, blowers	Reduced water content, plasticity, water sensitivity; increased strength	Can obtain irreversible improvements in properties; can introduce stabilizers with hot gases	High
	Freezing	Freeze soft, wet ground to increase its strength stiffness	All soils	Several metre	Refrigerant	Refrigeration system	Increased strength and stiffness, reduced permeability	No good in flowing ground water, temporary	High

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ANNEX K — (*Concluded*)

	Method	Principle	Most Suitable Soil Conditions/ Types	Maximum Effective Treatment Depth	Special Materials Required	Special Equipment Required	Properties of Treated Material	Special Advantages and Limitation	Relative Cost
Reinforcement	Vibro replacement sand/stone columns	Hole jetted into soft, fine-grained soil and backfilled with densely compacted gravel or sand	Soft clays and alluvial deposits	20 m	Gravel or crushed rock backfill	Vibroflot, crane or vibrocat, water	Increased bearing capacity, reduced settlement	Faster than precompression, avoids dewatering required for remove and replace; limited bearing capacity	Moderate to high
	Root piles, soils nailing	Inclusions used to carry tension, shear, compression	All soils	—	Reinforcing bars, cement grout	Drilling and grouting equipment	Reinforced zone behaves as a coherent mass	*In-situ* reinforcement for soils that can't be grouted or mixed in-place with admixtures	Moderate to high
	Strips and membranes	Horizontal tensile strips, membranes buried in soil under embankments, gravel base courses and footings	All soils	Can construct earth structures to heights of several metres	Metal or plastic strips, geotextiles	Excavating, earth handling, and compaction equipment	Self-supporting earth structures, increased bearing capacity, reduced deformations	Economical, earth structures coherent, can tolerate deformations; increased allowable bearing pressure	Low to moderate

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of reference in this Section.

	IS No.	*Title*
(1)	1892 : 1979	Code of practice for subsurface investigation for foundation (*first revision*)
	2131 : 1981	Method of standard penetration test for soils (*first revision*)
	2132 : 1986	Code of practice for thin walled tube sampling of soils (*second revision*)
	4434 : 1978	Code of practice for *in-situ* vane shear test for soils (*first revision*)
	4968	Method for subsurface sounding for soils
	(Part 1) : 1976	Dynamic method using 50 mm cone without bentonite slurry (*first revision*)
	(Part 2) : 1976	Dynamic method using cone and bentonite slurry (*first revision*)
	(Part 3) : 1976	Static cone penetration test (*first revision*)
	8763 : 1978	Guide for undisturbed sampling of sands and sandy soils
	9214 : 1979	Method for determination of modulus of subgrade reaction (*k*-value) of soils in the field
(2)	1892 : 1979	Code of practice for subsurface investigation for foundation (*first revision*)
(3)	10042 : 1981	Code of practice for site-investigations for foundation in gravel boulder deposits
(4)	13365 (Part 1) : 1998	Guidelines for quantitative classification systems of rock mass: Part 1 RMR for predicting of engineering properties
(5)	2720 (Part 1) : 1983	Methods of tests for soils Preparation of dry soil samples for various tests (*second revision*)
	(Part 2) : 1973	Determination of water content (*second revision*)
	(Part 3/Sec 1) : 1980	Determination of specific gravity, Section 1 Fine grained soils (*first revision*)
	(Part 3/Sec 2) : 1980	Determination of specific gravity, Section 2 Fine, medium and coarse grained soils (*first revision*)
	(Part 4) : 1985	Grain size analysis (*second revision*)
	(Part 5) : 1985	Determination of liquid and plastic limits (*second revision*)
	(Part 10) : 1991	Determination of unconfined compressive strength (*second revision*)
	(Part 11) : 1993	Determination of the shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure(*first revision*)
	(Part 12) : 1981	Determination of shear strength parameters of soil from consolidated undrained triaxial compression test with measurement of pore water pressure (*first revision*)
	(Part 13) : 1986	Direct shear test (*second revision*)
	(Part 15) : 1986	Determination of consolidation properties (*first revision*)
	(Part 28) : 1974	Determination of dry density of soils in place, by the sand replacement method (*first revision*)
	(Part 29) : 1975	Determination of dry density of soils in place, by the core cutter method (*first revision*)
	(Part 33) : 1971	Determination of the density in-place by the ring and water replacement method
	(Part 34) : 1972	Determination of density of soils in-place by rubber-balloon method
	(Part 39/Sec 1): 1977	Direct shear test for soils containing gravel, Section 1 Laboratory test
(6)	1498 : 1970	Classification and identification of soils for general engineering purposes (*first revision*)
(7)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)

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	IS No.	*Title*
(8)	15180 : 2002	Guidelines for use in prediction of subsidence and associated parameters in coal mines having nearly horizontal single seam workings
(9)	3764 : 1992	Code of safety for excavation work (*first revision*)
(10)	1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
(11)	6403 : 1981	Code of practice for determination of bearing capacity of shallow foundations (*first revision*)
(12)	1888 : 1982	Method of load tests on soils (*second revision*)
(13)	8009 (Part 1) : 1976	Code of practice for calculation of settlement of foundations: Part 1 Shallow foundations subjected to symmetrical static vertical loads
(14)	12070 : 1987	Code of practice for design and construction of shallow foundations on rocks
(15)	1080 : 1985	Code of practice for design and construction of shallow foundations in soils (other than raft, ring and shell) (*second revision*)
(16)	11089 : 1984	Code of practice for design and construction of ring foundations
(17)	9456 : 1980	Code of practice for design and construction of conical and hyperbolic paraboloidal types of shell foundations
(18)	2974 (Part 1) : 1982	Code of practice for design and construction of machine foundations: Part 1 Foundations for reciprocating type machines (*second revision*)
(19)	2911 (Part 4) : 2013	Design and construction of pile foundations — Code of practice: Part 4 Load test on piles (*second revision*)
(20)	14593 : 1998	Design and construction of bored cast *in-situ* piles founded on rocks — Guidelines
(21)	4968	Method for subsurface sounding for soils:
	(Part 1) : 1976	Dynamic method using 50 mm cone without bentonite slurry (*first revision*)
	(Part 2) : 1976	Dynamic method using cone and bentonite slurry (*first revision*)
	(Part 3) : 1976	Static cone penetration test (*first revision*)
(22)	2131 : 1981	Method for standard penetration test for soils (*first revision*)
(23)	2911	Code of practice for design and construction of pile foundations
	(Part 1/Sec 1): 2010	Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*second revision*)
	(Part 1/Sec 2): 2010	Concrete piles, Section 2 Bored cast *in-situ* concrete piles (*second revision*)
(24)	14893 : 2001	Guidelines for non-destructive integrity testing of piles
(25)	2911 (Part 1/ Sec 3) : 2010	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 3 Precast driven concrete piles (*second revision*)
(26)	2911 (Part 1/ Sec 4) : 2010	Code of practice for design and construction of pile foundations: Part 1 Concrete piles, Section 4 Precast concrete piles in prebored holes (*first revision*)
(27)	2911 (Part 3): 1980	Code of practice for design and construction of pile foundations: Part 3 Under-reamed pile foundation (*first revision*)
(28)	2911 (Part 2): 1980	Code of practice for design and construction of pile foundations: Part 2 Timber piles (*first revision*)
(29)	2974	Code of practice for design and construction of machine foundation
	(Part 1) : 1982	Foundations for reciprocating type machine (*second revision*)
	(Part 2) : 1980	Foundations for impact type machines (hammer foundations) (*first revision*)
	(Part 3) : 1992	Foundations for rotary type machines (medium and high frequency) (*second revision*)
	(Part 4) : 1979	Foundations for rotary type machines of low frequency (*first revision*)

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	IS No.	*Title*
	(Part 5) : 1987	Foundations for impact machines other than hammers (forging and stamping press; pig breakers, drop crusher and jetter) (*first revision*)
	13301 : 1992	Guidelines for vibration isolation for machine foundations
	9556 : 1980	Code of practice for design and construction of diaphragm walls
(30)	13094 : 1992	Guidelines for selection of ground improvement techniques for foundation in weak soils
(31)	15284 (Part 1) : 2003	Design and construction for ground improvement — Guidelines: Part 1 Stone columns
(32)	15284 (Part 2) : 2004	Design and construction for ground improvement — Guidelines: Part 2 Preconsolidation using vertical drains
(33)	13162 (Part 2) : 1991	Geotextiles – Methods of test: Part 2 Determination of resistance to exposure of ultra-violet light and water (Xenon arc type apparatus)
	13321 (Part 1) : 1992	Glossary of terms for geo-synthetics: Part 1 Terms used in materials and properties
	13325 : 1992	Method of test for the determination of tensile properties of extruded polymer geogrids using the wide strip
	13326 (Part 1) : 1992	Method of test for the evaluation of interface friction between geosynthetics and soil: Part 1 Modified direct shear technique
	14293 : 1995	Geotextiles — Method of test
	14294 : 1995	Geotextiles — Method for determination of apparent opening size by dry sieving technique
	14324 : 1995	Geotextiles – Methods of test for determination of water permeability-permittivity
	14706 : 1999	Geotextiles — Sampling and preparation of test specimens
	14714 : 1999	Geotextiles — Determination of abrasion resistance
	14715 : 2000	Woven jute geotextiles — Specification
	14716 : 1999	Geotextiles — Determination of mass per unit area
	14739 : 1999	Geotextiles — Methods for determination of creep
	14986 : 2001	Guidelines for application of jute geo-grid for rain water erosion control in road and railway embankments and hill slopes
	15060 : 2001	Geotextiles — Tensile test for joints/seams by wide width method
(34)	2720 (Part 11) : 1993	Methods of tests for soils Determination of the shear strength parameters of a specimen tested in unconsolidated undrained triaxial compression without the measurement of pore water pressure (*first revision*)
	(Part 12) : 1981	Determination of shear strength parameters of soil from consolidated undrained triaxial compression test with measurement of pore water pressure (*first revision*)
(35)	9214 : 1979	Method of determination of subgrade reaction (*K* value) of soils in the

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3A Timber

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 3A) deals with the structural design aspect of timber structures. In this Subsection, the various species of Indian timber, classified into three groups depending on the structural properties influencing the design most, are included.

This Section was first published in 1970 which was subsequently revised in 1983 and 2005. In the 1983 version of the Code, timber was covered under Section 3 of Part 6 under the title 'Wood', which did not cover bamboo. In the last version of 2005, the scope of Section 3 was enlarged as Section 3 Timber and Bamboo, which was subdivided into Subsection 3A 'Timber' and Subsection 3B 'Bamboo'. This Subsection pertains to 3A Timber.

In the first revision of 1983, provisions of this Subsection were updated and design of nailed laminated timber beams, were included and information on bolted construction joints was added. In the second revision of 2005, a number of terminologies related to timber for structural purpose were added, strength data of additional species of timber were included, requirements for structural timber and preferred cut sizes thereof were modified, requirements for glued laminated construction and finger joints and also for laminated veneer lumber were introduced. Brief details were included for structural sandwiches, glued laminated beams, lamella roofing, nail and screw holding power of timber, structural use of plywood and trussed rafter. Further, guidelines for protection against termite attack in buildings were also incorporated in the last revision of this Subsection. Also, keeping into consideration the dwindling forest resources, brief details on use of plantation timbers including certain fast growing species and suitable guidelines in terms of their seasoning, sawing, treatment, etc and also use of finger jointing and glued laminated timber was introduced in the last revision so as to effect judicious use of timber.

As a result of experience gained in implementation of 2005 version of this Code and feedback received as well as formulation of new standards in the field and revision/ updation of some of the existing standards, a need to revise this Subsection was felt. This revision has, therefore, been brought out to take care of these aspects.

The significant changes incorporated in this revision include the following:

a) Definitions of various terms have been modified as per the prevailing engineering practice and new terminologies relating to timber for structural use have been added.
b) The permissible lateral strength (in double shear) of mild steel common wire for different new species of timber have been added and also strength values for some of the existing species have been modified based on latest research.
c) Guidance on increase in permissible lateral strength for mild steel nails clenched across the grains over nails with points cut flush, has been included.
d) Design provisions for timber connector joints have been further updated.
e) Data on block shear test results of glued timber joints based on the indigenous work, has been included.
f) Data on strength properties of glued finger joints based on the indigenous work, has been included for information and guidance in design.
g) A new figure has been added for possible orientation of planks in glue laminated beams (Glulam). Also, design outline for horizontally laminated beams has been added.
h) Design provisions for trussed rafters have been further updated and also some design data on the lateral load bearing strength of common wire nails in plywood-to-wood joints have been included for guidance in design.
j) Design provisions for lamella roofing have been updated and detailed.
k) Composite nail and screw holding power of some Indian timbers has been provided for guidance in design.
m) Reference to all the concerned Indian Standards have been updated.

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The information contained in this Subsection is largely based on the following Indian Standards:

IS 399 : 1963	Classification of commercial timbers and their zonal distribution (*revised*)
IS 883 : 2016	Code of practice for design of structural timber in building (*fifth revision*)
IS 1150 : 2000	Trade names and abbreviated symbols for timber species (*third revision*)
IS 2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
IS 4891 : 1988	Specification for preferred cut sizes of structural timber (*first revision*)
IS 4983 : 1968	Code of practice for design and construction of nailed laminated timber beams
IS 11096 : 1984	Code of practice for design and construction of bolt-jointed timber construction
IS 14616 : 1999	Specification for laminated veneer lumber

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3A Timber

1 SCOPE

1.1 This Code (Part 6/Subsection 3A) covers the general principles involved in the design of structural timber in buildings, including elements of structures connected together by fasteners/fastening techniques.

1.2 This shall not be interpreted to prevent the use of material or methods of design or construction not specifically mentioned herein; and the methods of design may be based on analytical and engineering principles, or reliable test data, or both, that demonstrate the safety and serviceability of the resulting structure. The classification of timber into strength groups should not be interpreted as preventing the use of design data desired for a particular timber or grade of timber on the basis of reliable tests.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply, and for other terms those given in the accepted standard [6-3A(1)] shall apply.

2.1 Structural Purpose Definitions

2.1.1 *Beam, Built-Up Laminated* — A beam made by joining layers of timber together with mechanical fastenings, so that the grain of all layers is essentially parallel.

2.1.2 *Beam, Glued-Laminated* — A beam made by bonding layers of veneers or timber with an adhesive, so that grain of all laminations is essentially parallel.

2.1.3 *Bressummer* — A beam, across broad opening, sustaining super structure.

2.1.4 *Diaphragm, Structural* — A structural element of large extent placed in a building as a wall, or roof, and made use of to resist horizontal forces such as wind or earthquakes-acting parallel to its own plane.

2.1.5 *Duration of Load* — Period during which a member or a complete structure is stressed as a consequence of the loads applied.

NOTE — Timber is stronger under loads of brief duration than under permanently applied loads.

2.1.6 *Edge Distance* — The distance measured perpendicular to grain from the centre of the connector to the edge of the member.

2.1.7 *End Distance* — The distance measured parallel to grain of the member from the centre of the connector to the closest end of timber.

2.1.8 *Finger Joint* — End joint formed by machining a number of similar, tapered, symmetrical fingers in the ends of timber member, which are then bonded together.

2.1.9 *Finger Jointed Timber* — Timber containing adhesively bonded finger joints spaced at manufacturers specified minimum spacing.

2.1.10 *Fundamental or Ultimate Stress* — The stress which is determined on small clear specimen of timber, in accordance with accepted standards [6-3A(2)]; and does not take into account the effect of naturally occurring characteristics and other factors.

2.1.11 *Glue* — A substance capable of holding materials together by surface attachment.

2.1.12 *Glued Laminated (Glulam)* — A wood structural element comprising of sawn wood lamination bonded together with adhesives and in which the grains of all laminations are parallel longitudinally.

2.1.12.1 *Glued laminated, horizontally* — Glued laminated timber where gluing planes are perpendicular to the largest dimension of the transverse section, that is, in cross-wise direction.

2.1.12.2 *Glued laminated, vertically* — Glued laminated timber where gluing planes are perpendicular to the smallest dimension of the transverse section.

2.1.13 *Inside Location* — Position in buildings in which timber remains continuously dry or protected from weather.

2.1.14 *Isoptera* — An order of social insects consisting of the termites.

2.1.15 *Lamella Roof* — A roof or frame, made up of relatively short members, called lamellas, forming a network of framing timbers. This network forms a barrel-like structure of mutually braced and stiffened units, arching over the building between supports, and together with the sheathing forms a diaphragm for resistance of vertical and lateral loads.

2.1.16 *Laminations* — Thin elements of wood of appreciable width and length which, when superimposed on each other and fastened together with their grains essentially parallel make up cross section of considerable depth or width.

2.1.17 *Laminated Veneer Lumber* — A structural composite made by laminating veneers, 1.5 to 4.2 mm thick, with suitable adhesive and with the grain of

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veneers in successive layers aligned along the longitudinal (length) dimension of the composite.

2.1.18 *Latewood* — The portion of the wood that is formed in the later part of growth season and consists of thicker walled cells.

2.1.19 *Loaded Edge Distance* — The distance measured from the centre to the edge towards which the load induced by the connector acts, and the unloaded edge distance is the one opposite to the loaded edge.

2.1.20 *Location* — A term generally referred to as exact place where a timber is used in building.

2.1.21 *Mechanically Laminated* — A wood structural element comprising of laminations which are not glued but which are held together with mechanical fastenings such as nails or bolts and in which all laminations have the grains approximately parallel longitudinally.

2.1.22 *Outside Location* — Position in buildings in which timbers are occasionally subjected to wetting and drying as in the case of open sheds and outdoor exposed structures.

2.1.23 *Permissible Stress* — Stress obtained by applying factor of safety to the ultimate stress.

2.1.24 *Sandwich, Structural* — A layered construction comprising a combination or relatively high-strength facing material intimately bonded to and acting integrally with a low density core material.

2.1.25 *Spaced Column* — Two column sections adequately connected together by glue, bolts, screws or otherwise.

2.1.26 *Stressed Skin* — A form of construction in which the outer skin, in addition to its normal functioning of providing a surface covering, acts integrally with the framing members contributing to the strength of the unit as a whole.

2.1.27 *Structure, Permanent* — Structural units in timber which are constructed for a long duration and wherein adequate protection and design measures have initially been incorporated to render the structure serviceable for the required life.

2.1.28 *Structure, Temporary* — Structures which are erected for a short period, such as hutments at project sites, for rehabilitation, temporary defence constructions, exhibition structures, etc.

2.1.29 *Structural Element* — The component timber members and joints which make up a resulting structural assembly.

2.1.30 *Structural Grades* — Grades defining the maximum size of strength reducing natural characteristics (knots, sloping grain, etc) deemed permissible in any piece of structural timber within designated structural grade classification.

2.1.31 *Structural Timber* — Timber in which strength is related to the anticipated in-service use as a controlling factor in grading and selection and/or stiffness.

2.1.32 *Stud* — One of a series of slender wood structural members placed vertically as supporting members in a wall partition, or similar structural unit.

2.1.33 *Termite* — An insect of the order *Isoptera* which may burrow in the wood or wood products of a building for food or shelter.

2.1.34 *Wet Location* — Position in buildings in which timbers are almost continuously damp or wet in contact with the earth or water, such as piles and timber foundations.

2.2 Definitions of Defects in Timber

2.2.1 *Check* — A separation of fibres extending along the grain which is confined to one face of a piece of wood.

2.2.2 *Compression Wood* — Abnormal wood which is formed on the lower sides of branches and inclined stems of coniferous trees. It is darker and harder than normal wood but relatively low in strength for its weight. It can be usually identified by wide eccentric growth rings with abnormally high proportion of growth latewood.

2.2.3 *Dead Knot* — A knot in which the layers of annual growth are not completely intergrown with those of the adjacent wood. It is surrounded by pitch or bark. The encasement may be partial or complete.

2.2.4 *Decay or Rot* — Disintegration of wood tissue caused by fungi (wood destroying) or other micro-organisms.

2.2.5 *Decayed Knot* — A knot softer than the surrounding wood and containing decay.

2.2.6 *Diameter of Knot* — The maximum distance between the two points farthest apart on the periphery of a round knot, on the face on which it becomes visible. In the case of a spike or a splay knot, the maximum width of the knot visible on the face on which it appears shall be taken as its diameter.

2.2.7 *Discolouration* — A change from the normal colour of the wood which does not impair the strength of the wood.

2.2.8 *Knot* — A branch base or limb embedded in the tree or timber by natural growth.

2.2.9 *Knot Hole* — A hole left as a result of the removal of a knot.

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2.2.10 *Live Knot* — A knot free from decay and other defects, in which the fibres are firmly intergrown with those of the surrounding wood. Syn. 'Intergrown Knot'; cf. 'Dead Knot'.

2.2.11 *Loose Grain (Loosened Grain)* — A defect on a flat sawn surface caused by the separation or raising of wood fibres along the growth rings; cf. 'Raised Grain'.

2.2.12 *Loose Knot* — A knot that is not held firmly in place by growth or position, and that cannot be relied upon to remain in place; cf. 'Tight Knot'.

2.2.13 *Mould* — A soft vegetative growth that forms on wood in damp, stagnant atmosphere. It is the least harmful type of fungus, usually confined to the surface of the wood.

2.2.14 *Pitch Pocket* — Accumulation of resin between growth rings of coniferous wood as seen on the cross-section.

2.2.15 *Sap Stain* — Discolouration of the sapwood mainly due to fungi.

2.2.16 *Sapwood* — The outer layer of log, which in the growing tree contain living cells and food material. The sapwood is usually lighter in colour and is readily attacked by insects and fungi.

2.2.17 *Shake* — A partial or complete separation between adjoining layers of tissues as seen in end surfaces.

2.2.18 *Slope of Grain* — The inclination of the fibres to the longitudinal axis of the member.

2.2.19 *Sound Knot* — A tight knot free from decay, which is solid across its face, and at least as hard as the surrounding wood.

2.2.20 *Split* — A crack extending from one face of a piece of wood to another and runs along the grain of the piece.

2.2.21 *Tight Knot* — A knot so held by growth or position as to remain firm in position in the piece of wood; cf. 'Loose Knot'.

2.2.22 *Wane* — The original rounded surface of a tree remaining on a piece of converted timber.

2.2.23 *Warp* — A deviation in sawn timber from a true plane surface or distortion due to stresses causing departure from a true plane.

2.2.24 *Worm Holes* — Cavities caused by worms.

3 SYMBOLS

For the purpose of this Subsection, the following letter symbols shall have the meaning indicated against each:

a = projected area of bolt in main member ($t' \times d_3$), mm^2

B = width of the beam, mm

C = concentrated load, N

D = depth of beam, mm

D_1 = depth of beam at the notch, mm

D_2 = depth of notch, mm

d = dimension of least side of column, mm

d_1 = least overall width of box column, mm

d_2 = least overall dimension of core in box column, mm

d_3 = diameter of bolt, mm

d_f = bolt-diameter factor

e = length of the notch measured along the beam span from the inner edge of the support to the farthest edge of the notch, mm

E = modulus of elasticity in bending, N/mm^2

F = load acting on a bolt at an angle to grain, N

f_{ab} = calculated bending stress in extreme fibre, N/mm^2

f_{ac} = calculated average axial compressive stress, N/mm^2

f_{at} = calculated axial tensile stress, N/mm^2

f_b = permissible bending stress on the extreme fibre, N/mm^2

f_c = permissible stress in axial compression, N/mm^2

f_{cn} = permissible stress in compression normal (perpendicular) to grain, N/mm^2

f_{cp} = permissible stress in compression parallel to grain, N/mm^2

$f_{c\theta}$ = permissible compressive stress in the direction of the line of action of the load, N/mm^2

f_t = permissible stress in tension parallel to grain, N/mm^2 [extreme fibre stress in bending-tension (f_b) is safe practical estimate of tensile strength due to mode of failure in beams]

H = horizontal shear stress, N/mm^2

I = moment of inertia of a section, mm^4

K = Coefficient in deflection depending upon type and criticality of loading on beam

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K_1 = modification factor for change in slope of grain

K_2 = modification factor for change in duration of loadings

K_3, K_4,K_5, K_6 = form factors

K_7 = modification factor for bearing stress

K_8 = constant equal to $0.584\sqrt{\frac{E}{f_{cp}}}$

K_9 = constant equal to $\frac{\pi}{2}\sqrt{\frac{UE}{5q\ f_{cp}}}$

K_{10} = constant equal to $0.584\sqrt{\frac{2.5E}{f_{cp}}}$

ℓ or L = span of a beam or truss, mm

M = maximum bending moment in beam, N-mm

N = total number of bolts in the joint

n = shank diameter of the nail, mm

P = load on bolt parallel to grain, N

p_1 = ratio of the thickness of the compression flange to the depth of the beam

Q = static moment of area above or below the neutral axis about neutral axis, mm^3

q = constant for particular thickness of plank

q_1 = ratio of the total thickness of web or webs to the overall width of the beam

R = load on bolt perpendicular (normal) to grain, N

S = unsupported overall length of column, mm

t = nominal thickness of planks used in forming box type column, mm

t' = thickness of main member, mm

U = constant for a particular thickness of the plank

V = vertical end reaction or shear at a section, N

W = total uniform load, N

x = distance from reaction to load, mm

y = factor determining the value of form factor K_4

δ = deflection at middle of beam, mm

θ = angle of load to grain direction

Z = section modulus of beam, mm^3

λ_1 = percentage factor for t'/d_3 ratio, parallel to grain

λ_2 = percentage factor for t'/d_3 ratio, perpendicular to grain

4 MATERIALS

4.1 Species of Timber

The species of timber recommended for structural purposes are given in Table 1.

4.1.1 *Grouping*

Species of timber recommended for constructional purposes are classified in three groups on the basis of their strength properties, namely, modulus of elasticity (E) and extreme fibre stress in bending-tension (f_b).

The characteristics of these groups are as given below:

a) *Group A* — E above 12.6 kN/mm² and f_b above 18.0 N/mm².

b) *Group B* — E above 9.8 kN/mm² and up to 12.6 kN/mm² and f_b above 12.0 N/mm² and up to 18.0 N/mm².

c) *Group C* — E above 5.6 kN/mm² and up to 9.8 kN/mm² and f_b above 8.5 N/mm² and up to 12.0 N/mm².

NOTE — Modulus of elasticity given above is applicable for all locations and extreme fibre stress in bending is for inside location.

4.1.2 Timber species may be identified in accordance with good practice [6-3A(3)].

4.2 The general characteristics like durability, treatability and seasoning of the species are also given in Table 1. Species of timber other than those recommended in Table 1 may be used, provided the basic strength properties are determined and found in accordance with **4.1.1**.

NOTE — For obtaining basic stress figures of the unlisted species, reference may be made to the Forest Research Institute, Dehra Dun.

4.3 The permissible lateral strength (in double shear) of mild steel common wire nail shall be as given in Table 2 and Table 3 for different species of timber.

4.4 Moisture Content in Timber

The permissible moisture content of timber for various positions in buildings shall be as given in Table 4.

Table 1 Safe Permissible Stresses for the Species of Timber

[*Clauses* 4.1, 4.2, 4.7.1.3(b), 5.4.1, 5.4.2 *and* 6.5.8.3.1(b)]

Species		Locality from where Tested	Average Density at 12 Percent Moisture Content Kg/m^3	Modulus of Elasticity (All Grades and All Locations) × 10^3 N/mm^2	Permissible Stress for Grade I N/mm^2											Preservative Characters		[3)]Refracteriness to Air Seasoning
					Bending-Tension Along Grain, Extreme Fibre Stress			Shear all Locations		Compression Parallel to Grain			Compression Perpendicular to Grain			[1)]Durability Class	[2)]Treatability Grade	
Botanical Name	Trade Name				Inside Location	Outside Location	Wet Location	Horizontal	Along Grain	Inside Location	Outside Location	Wet Location	Inside Location	Outside Location	Wet Location			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
GROUP A																		
Acacia catectou	Khair (KHA)	U.P.	1 009	13.44	20.1	16.8	13.4	1.6	2.2	13.8	12.3	10.1	7.7	6.0	4.9	I	—	A
Acacia chundra	Red kutch	M.P.	1 086	16.79	26.5	22.0	17.6	2.2	3.2	17.9	15.9	13.0	10.9	8.4	6.9	—	—	A
Albizia odoratissima	Kala siris (KSI)	Chennai	737	13.54	18.7	15.6	12.5	1.5	2.2	13.3	11.8	9.6	7.3	5.6	4.6	I	e	B
Bruguiera spp.	Bruguiera (BSV) (Mangrove)	Andmans	897	17.68	21.9	18.3	14.6	1.2	1.7	14.3	12.7	10.4	5.5	4.3	3.5	III	—	—
Grewia tiliifolia	Dhaman (DHA)	Chennai	788	14.82	18.3	15.2	12.2	1.3	1.9	12.0	10.7	8.7	6.0	4.7	3.8	III	d	B
Hopea utilis (Balano carpus utilis)	Karung	Chennai	987	16.91	25.1	20.9	16.7	1.5	2.2	16.4	14.6	11.9	9.3	7.3	5.9	—	—	—
Hopea glabra	Hopea (HOP)	Chennai	1 081	14.79	21.3	17.8	14.2	1.5	2.2	14.5	12.9	10.6	9.9	7.7	6.3	I	—	A
Hopea parviflora	Hopea (HOP)	Chennai	923	13.03	18.6	15.5	12.4	1.3	1.8	13.2	11.8	9.6	9.2	7.3	6.0	I	e	A
Manilota polyandra (Syn. Cynometra polyandra)	Ping (PIG)	Assam	903	13.20	19.1	15.9	12.7	1.3	1.8	1.2	10.4	8.5	5.7	4.4	3.6	III	b	A
Mesua ferrea	Mesua (MES)	Assam	965	16.30	23.3	19.4	15.5	1.2	1.8	15.5	13.8	11.3	5.9	4.6	3.7	I	—	A
Mimusops littoralis	Bullet-wood (BUL)	S.Andaman	1 103	17.39	22.7	18.9	15.1	1.5	2.1	14.2	12.7	10.4	11.3	8.8	7.2	I	—	A
Pesciloneuron indicum	Ballagi (BAL)	Chennai	1 139	16.29	22.4	18.7	15.0	1.5	2.2	14.7	13.1	10.7	8.7	6.8	5.5	I	e	A
Pterocarpus Scantalinus	Red sanders (MA)	Chennai	1 121	12.73	25.0	20.9	16.7	1.7	2.5	18.1	16.1	13.2	11.8	9.2	7.5	—	—	A
Sageraea elliptica	Chooi (COC)	Andmans	869	15.06	21.5	17.9	14.3	1.1	1.5	12.5	11.1	9.1	5.3	4.1	3.4	—	—	A
Stereospermun celonoides	Padri (PAD)	Chennai	731	12.94	19.0	15.8	12.7	1.1	1.6	11.9	10.6	8.7	4.0	3.1	2.6	III	—	B
Vitex altissima	Milla (MIL)	Maharashtra	937	13.01	18.2	15.2	12.1	1.2	1.7	12.6	11.2	9.2	9.5	7.4	6.1	I	e	A
GROUP B																		
Albizzia lebbeck	Kokko (KOK)	Andaman	642	11.17	13.4	11.2	9.0	1.1	1.5	9.0	8.0	6.5	4.4	3.4	2.8	I	e	B
Anogeissus latifolia	Dhaura, Axle wood (AXL) (Bakli)	U.P.	892	10.55	16.1	13.4	10.7	1.1	1.6	9.1	8.1	6.6	4.7	3.7	3.0	I	e	A
Artocarpus hirsulus	Aini (AIH)	Chennai	600	10.45	15.0	12.5	10.0	0.7	1.1	10.4	9.2	7.5	3.3	2.6	2.1	I	—	B
Acacia nilotica	Babul (BAB)	U.P.	797	—	—	—	12.9	10.3	1.4	2.1	8.9	7.9	6.4	5.2	4.0	3.3	I	b	B
Acacia ferruginea	Safed khair	Maharashtra	993	12.28	23.0	19.2	15.3	1.7	2.4	13.9	12.4	10.1	9.9	7.7	6.3	—	—	—
Acrocarpus fraxinifolius	Mundani (MUN)	Chennai	690	12.59	16.1	13.4	10.8	1.2	1.8	10.5	9.4	7.7	4.6	3.6	2.9	III	c	B
Aglaia odulis	Aglaia (AGL)	Assam	815	12.56	18.2	15.2	12.1	1.4	2.0	10.1	8.9	7.3	4.4	3.4	2.8	—	—	A
Anogeissus acuminota	Yon	Orissa	844	11.67	17.6	14.7	11.7	1.3	1.8	10.8	9.6	7.9	5.1	4.0	3.3	—	—	A

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Table 1 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Atalanlia monophylla	Jungli—nimbu (JHI)	Orissa	897	10.31	16.7	13.9	11.1	1.5	2.1	11.3	10.0	8.2	6.3	4.9	4.0	—	—	—
Altingia excelsa	Jutili (JUT)	Assam	795	11.37	17.1	14.3	11.4	1.2	1.8	11.0	9.8	8.0	6.8	5.3	4.4	II	e	A
Amoora spp.	Amari (AMA)	W. Bengal	625	1.05	13.4	1.1	9.2	0.9	1.3	8.4	7.4	6.0	3.7	2.9	2.4	II	d	B
Bucklandia populnea (Syn Exbucklandia populnea)	Pipli (PIP)	W.Bengal	672	9.89	12.8	10.7	8.6	1.1	1.5	7.9	7.0	5.7	3.5	2.7	2.2	III	e	C
Cassia fistula	Amaltas (AMT)	U.P.	865	11.80	19.2	16.0	12.8	1.4	2.0	12.3	10.9	8.9	7.2	5.6	4.6	I	—	A
Carallia lucida	Maniawaga	Assam	748	12.60	18.4	15.3	12.3	1.2	1.7	11.4	10.1	8.3	5.9	4.6	3.8	—	—	—
Canarium strictum	Dhup	Chennai	655	11.86	13.3	11.1	8.9	0.9	1.2	8.1	7.2	5.9	2.8	2.2	1.8	III	—	C
Cassia sienea	Kasod	M.P.	820	10.50	15.4	12.8	10.9	1.0	1.4	10.8	9.6	7.9	5.5	4.3	3.5	—	—	—
Casuerina equisetifolia	Casuarina (CAS)	Orissa	769	11.44	14.6	12.2	9.8	1.3	1.8	8.2	7.3	5.9	4.0	3.1	2.5	III	e	A
Celophyllum temculosum	Poon (POO)	Maharashtra	657	9.77	13.4	11.2	9.0	0.8	1.1	8.6	7.7	6.3	2.8	2.2	1.8	II	—	B
Chloroxylon swielenia	Satin wood (CFI)	M.P.	865	11.69	18.2	15.1	12.1	1.4	2.0	10.9	9.7	8.0	6.3	4.9	4.0	III	—	A
Cullenia resayoana (Syn C. execelsa)	Karani (KAP)	Chennai	625	12.43	14.7	12.3	9.8	0.6	0.9	9.0	8.0	6.6	2.7	2.1	1.7	III	b	C
Diploknema butyracea (Syn Bassia butyrance)	Hill mahua (HMA)	S.Andaman	780	10.64	15.3	12.8	10.2	1.0	1.5	9.9	8.8	7.2	6.6	5.2	4.2	—	—	—
Dyscxylum malebaricum	White ceda (WCE)	Chennai	745	10.92	13.2	11.0	8.8	1.0	1.4	8.0	7.1	5.8	3.1	2.4	1.9	I	—	B
Dipterocarpus grandiflorus	Gurjan (GUR)	N.Andaman	758	11.71	12.5	10.5	8.4	0.8	1.1	7.9	7.1	5.8	2.7	2.1	1.7	I	—	B
Dipterocarpus macrocarpus	Hollong (HOL)	Assam	726	13.34	14.5	12.0	9.6	0.8	1.1	8.8	7.9	6.4	3.5	2.7	2.2	III	a	B
Dichopsis polyantha (Syn Palaquium polyanthum)	Tali (TAL)	Assam	734	11.24	14.9	12.4	10.0	1.1	1.6	9.9	8.8	7.2	4.7	3.7	3.0	—	—	B
Dichopsis elliptica (Syn Palaquium ellipticum)	Pali (PAL)	Chennai	606	11.86	13.9	11.6	9.3	0.7	1.0	8.5	7.5	6.2	2.9	2.2	1.8	I	e	B
Diospyros micropylla	Ebony (EBO)	Maharashtra	776	12.15	14.2	11.9	9.5	0.9	1.3	8.3	7.3	6.0	3.3	2.6	2.1	—	—	A
Diospyros pyrrhocarpus	Ebony (EBO)	N.Andaman	843	9.93	13.5	11.2	9.0	1.0	1.4	7.9	7.0	5.7	4.0	3.1	2.5	III	—	A
Dipterocarpus bourdilloni	Gurjan (GUR)	Kerala	699	12.71	13.6	11.3	9.0	0.7	1.0	7.8	6.9	5.7	2.5	1.9	1.6	—	—	B
Eucalyptus globulus	Eucalyptus (Blue gum) (BLN)	Chennai	912	14.83	15.9	13.2	10.6	10.3	1.5	9.0	8.0	6.5	3.4	2.6	2.1	I	e	A
Eucalyptus ougenioides	Eucalyptus	Chennai	853	11.47	16.4	13.6	10.9	1.2	1.7	11.3	10.0	8.2	7.6	5.9	4.8	—	—	—
Eugenia gardnery	Jaman (JAM)	Chennai	952	11.94	14.8	12.3	9.8	1.1	1.6	9.2	8.2	6.7	5.8	4.5	3.7	III	d	—
Eugenia jambolana	Jaman (JAM)	U.P.	778	10.94	16.0	13.3	10.6	1.2	1.7	9.7	8.6	7.1	4.7	3.7	3.0			
Gluta travancorice	Gluta (GLU)	Chennai	726	12.73	13.5	11.3	9.0	0.9	1.3	9.0	8.0	6.6	4.0	3.1	2.5	I	—	A
Grewia veslita	Dhaman (DHA)	W.Bengal	758	12.00	15.4	12.6	10.3	1.4	2.0	9.1	8.1	6.6	4.1	3.2	2.6	III	d	B
Heritiera spp.	Sundri (SUN)	Assam	872	13.37	17.9	14.9	11.9	1.3	1.8	11.0	9.8	8.0	6.5	5.0	4.1	I	—	A
Kingiodendron pinnatum (Syn Hardwickia pinnata)	Piney (PIN)	Chennai	617	10.62	13.2	11.0	8.8	0.4	1.3	8.2	7.3	6.0	2.9	2.2	1.8	—	—	B
Kayea floribund	Karal	Assam	813	10.88	16.8	14.0	1.1	1.1	1.6	10.1	9.0	7.3	4.4	3.4	2.8	III	—	—
Lagerstromia lanceolata	Benteak (BEN)	Chennai	617	10.76	12.7	10.6	8.5	0.8	1.2	8.2	7.3	5.9	3.4	2.6	2.2	I	e	B
Lagerstromia parviflora	Lendi (LEN)	U.P.	734	10.97	14.3	11.9	9.5	1.1	1.6	8.7	7.7	6.3	3.7	2.9	2.4	I	e	A
Mimusops elengi	Bakul (BKL)	Chennai	885	12.39	17.3	14.4	11.5	1.3	1.8	11.0	9.8	8.0	5.6	4.3	3.6	I	—	A
Machilus macrantha	Machilus (MAC)	W.Bengal	692	10.00	12.4	10.3	8.3	1.0	1.5	8.2	7.3	6.0	3.5	2.7	2.2	III	e	B/C
Miliuse tyomentosa (Syn Saccopapetalum tomentosum)	Hoom (HOO)	Maharashtra	745	11.06	14.8	12.3	9.9	0.9	1.3	9.7	8.6	7.0	3.5	2.7	2.2	III	—	B
Pommetia pinnata	—	Andaman	788	12.90	14.3	11.9	9.5	1.1	1.6	9.1	8.0	6.6	4.0	3.1	2.5	—	—	—
Pterocarpus dolbergioides	Padauk (PAD)	N.Andaman	721	11.24	17.1	14.3	11.4	1.0	1.5	12.0	10.7	8.7	5.5	4.3	3.5	I	c	B
Mesua assamica	Kayea	Assam	842	12.83	17.4	14.5	11.6	1.0	1.4	11.7	10.4	8.5	5.3	4.1	3.3	II	e	—
Pterocarpus marsupium	Bijasal (BIJ)	Maharashtra	803	10.25	14.9	12.4	9.9	0.9	1.3	9.1	8.1	6.6	4.1	3.2	2.6	I	e	B
Fraxlnus macrantha	Ash (ASH)	U.P.	712	10.69	15.0	12.5	10.0	1.2	1.7	8.5	7.6	6.2	4.3	3.3	2.7	III	—	B
Fraxlnus execlsior	Ash (ASH)	Punjab	719	10.41	14.8	12.3	9.8	1.2	1.7	8.1	7.2	5.8	3.3	2.6	2.1	III	—	B
Planchonia valida (Syn P. andamanica)	Red bombwe (RBO)	Andaman	913	13.10	16.1	13.4	10.7	1.0	1.4	10.8	9.6	7.9	4.9	3.8	3.1	III	—	—

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Table 1 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Quercus lamellosa	Oak	W.Bengal	87	12.44	14.5	12.1	9.7	1.2	1.7	8.7	7.8	6.4	3.8	2.9	2.4	II	c	A
Quercus griffithii	Oak	Meghalaya	974	10.06	13.1	10.9	8.8	1.1	1.6	8.0	7.1	5.8	4.6	3.6	2.9	—	—	A
Quercus incane	Oak	Punjab	1008	10.82	15.8	13.1	10.5	1.2	1.8	8.7	7.8	6.3	5.0	3.9	3.2	—	—	A
Quercus lineate	Oak	W.Bengal	874	12.63	15.2	12.7	10.1	1.2	1.7	9.6	8.6	7.0	5.3	4.1	3.4	II	c	A
Quercus semecarpifolia	—	Punjab	834	11.58	15.8	13.1	10.5	1.3	1.8	8.3	7.3	6.0	3.8	2.9	2.4	—	—	A
Shorea robusta [4]	Sal (SAL)	M.P.	805	12.67	16.9	14.0	11.2	0.9	1.3	10.6	9.4	7.7	4.6	3.5	2.9	I	e	A
Soymida fabrifuga	Rohini (ROH)	Chennai	1116	12.22	21.5	17.9	14.4	1.6	2.3	15.0	13.3	10.9	12.9	10.0	8.2	I	—	A
Shorea talura	—	Maharashtra	721	12.20	16.8	14.0	11.2	1.1	1.6	12.6	11.2	9.2	6.8	5.3	4.3	—	—	—
Plerygota alata (*Syn. Sterculia alata*)	Narikel (NAR)	Assam	593	10.95	13.4	11.8	8.9	0.8	1.2	8.2	7.3	6.0	2.7	2.1	1.7	III	—	C
Syzygium cumini	Jaman (JAM)	Assam	841	10.55	14.8	12.4	9.9	1.1	1.6	9.0	8.0	6.5	6.9	5.4	4.4	II	e	A
Terminalia bellirica	Bahera (BAH)	U.P.	729	10.19	13.6	11.3	9.0	1.0	1.4	8.4	7.5	6.1	3.7	2.8	2.3	III	b	B
Terminalia chebula	Myrobalan (MYR)	—	918	12.37	17.1	14.2	11.4	1.1	1.6	1.2	10.4	8.5	6.7	5.2	4.3	II	c	A
Terminalia citrina	—	Assam	755	11.89	17.1	14.3	11.4	1.1	1.6	10.8	9.6	7.9	5.0	3.9	3.2	—	—	—
Terminalia manii	Black—chuglam (BCH)	S.Andaman	822	12.66	16.8	14.0	11.2	1.1	1.6	10.3	9.2	7.5	5.1	4.0	3.2	II	a	B
Tectona grandis	Teak (TEA)	U.P.	660	9.97	15.5	12.9	10.3	1.2	1.6	9.4	8.3	6.8	4.5	3.5	2.8	I	e	B
Terminalia paniculate	Kindal (KIN)	Maharashtra	765	10.57	13.1	10.9	8.7	0.9	1.3	8.6	7.7	6.3	3.6	2.8	2.3	I	c	A
Alreminalia alata	Laurel (LAU), Sain	Chennai	906	10.54	15.1	12.5	10.0	1.1	1.6	9.4	8.4	6.8	6.2	4.8	4.0	I	b	A
Terminalia bilata	White-chuglam (WCH)	S.Andaman	690	12.38	15.5	13.0	10.4	0.9	1.2	9.8	8.7	7.1	3.6	2.8	2.3	III	e	B
Thespesia populnea	Bhendi (BHE)	Maharashtra	766	10.36	18.9	15.8	12.6	1.3	1.9	11.3	10.0	8.2	4.4	3.4	2.8	—	—	B
Xylia xylocarpa	Irul (IRU)	Maharashtra	839	11.63	16.2	13.5	10.8	1.3	1.8	10.9	9.7	7.9	7.8	6.0	4.9	I	e	A
Zanthoxylum budranga	Mullilam (MUL)	W.Bengal	587	10.65	14.7	12.2	9.8	0.9	1.2	9.5	8.4	6.9	3.4	2.6	2.1	I	e	B
Adina oligocephala	—	Arunachal	715	11.17	15.2	12.7	10.1	1.2	1.7	10.3	9.2	7.5	4.0	3.1	2.4	—	—	—
Castanopsis indica	Chestnut	Meghalaya	688	12.54	14.8	12.3	9.9	1.0	1.4	9.8	8.7	7.1	3.4	2.7	2.2	—	—	B
Eucalyptus citriodara	Eucalyptus	Nilgiri	831	12.12	17.3	14.4	11.5	1.4	2.0	11.0	9.8	8.0	4.2	3.3	2.7	—	—	—
Eucalyptus citriodata	Eucalyptus	Ooty	725	9.35	15.4	12.9	10.3	1.0	1.4	8.6	7.6	6.3	3.0	2.4	2.0	—	—	—
Eucalytus tereticornis	Eucalyptus	Chennai	777	11.05	16.7	13.9	11.1	1.0	1.4	9.7	8.6	7.1	3.4	2.6	2.2	III	e	—
GROUP C																		
Tbizia procera	White siris	U.P.	643	9.02	13.4	11.2	8.9	1.0	1.4	8.5	7.6	6.2	4.3	3.3	2.7	I	c	B
Artocarpus lakocha	Lakooch (LAK)	U.P.	647	6.14	10.0	8.3	6.7	1.0	1.4	5.3	4.7	3.8	2.8	2.2	1.8	I	—	B
Artocarpus hetarophyllus (*Syn. A. Integrifolia*)	Jack, kathal (KAT)	Chennai	617	9.46	13.9	11.6	9.2	1.0	1.5	9.3	8.3	6.8	4.5	3.5	2.9	I	d	B
Aphanamixis polystachya (*Syn. Amoora rehituka*)	Pitraj (PIT)	W. Bengal	668	8.98	12.3	10.2	8.2	1.1	1.5	8.0	7.1	5.8	4.0	3.1	2.6	I	—	B
Adina cordifolia [4]	Haldu (HAL)	U.P.	663	8.54	13.3	11.1	8.9	1.0	1.4	8.7	7.7	6.3	4.4	3.4	2.8	III	a	B
Anthocephyalus chinensis (*Syn. A. Cadamba*)	Kadam (KAD)	—	485	1.88	9.7	8.1	5.4	0.7	1.0	5.9	5.3	4.3	1.9	1.5	1.2	III	a	—
Arlocarpus chaplasha	Chaplash (CHP)	Assam	515	9.11	13.2	11.0	8.8	0.9	1.2	8.5	7.5	6.2	3.6	2.8	2.3	III	d	B
Acacia leucophloea	Hiwar (HIW)	M.P.	737	7.85	13.4	11.2	9.0	1.0	1.5	7.5	6.7	5.4	4.5	3.5	2.8	—	—	A
Acacia melanoxylone	Black wood	Chennai	630	9.45	13.0	10.8	8.7	1.1	1.5	7.6	6.8	5.5	3.2	2.5	2.0	—	—	—
Acacia mearnsii (*Syn. A. mollissima*)	Black wattle	Chennai	669	6.10	10.4	8.6	6.9	0.8	1.2	6.0	5.4	4.4	2.3	1.8	1.5	—	—	—
Accer. spp.	Maple (MAP)	Punjab, U.P.	551	7.35	9.9	8.2	6.5	0.9	1.3	5.5	4.9	4.0	2.1	1.7	1.4	III	—	B
Aegla marmalos (*Syn. Intsia bijuga*)	Bael (BEL)	U.P.	890	8.81	13.5	11.2	9.0	1.4	2.0	8.8	7.8	6.4	6.8	5.3	4.3	III	—	B
Afzelia bijuga	—	Andaman	705	9.16	13.2	11.0	8.8	1.1	1.5	7.9	7.1	5.8	4.0	3.1	2.6	—	—	—
Ailanthus grandis	Gokul (GOK)	W. Bengal	404	7.94	8.3	6.9	5.5	0.6	0.8	5.3	4.7	3.9	1.1	0.9	0.7	III	—	C
Anogeissus pendula	Kardhai (KAH)	U.P.	929	9.75	17.0	14.2	11.4	1.3	1.8	9.8	8.7	7.1	6.5	5.1	4.2	III	—	A
Areca nut	—	Kerala	833	9.48	15.2	12.7	10.2	1.2	1.6	10.8	9.6	7.8	7.3	5.7	4.7	—	—	—
Albizia lucida	—	Arunachal, A.P.	566	8.51	10.7	8.9	7.1	8.2	1.2	7.3	6.3	5.3	2.3	1.8	1.5	—	—	—

Table 1 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Azadirachta indica	Neem (NEE)	U.P.	836	8.52	14.6	12.1	9.7	1.3	1.8	10.0	8.9	7.3	5.0	3.9	3.2	—	—	—
Boswellia seriata	Salai (SAA)	Bihar	551	7.21	9.4	7.9	6.3	0.7	1.1	5.5	4.9	4.0	2.1	1.6	1.3	I	e	C
Bridelia retusa	Kassi (KAS)	Bihar	584	9.42	11.6	9.7	7.7	0.9	1.3	7.1	6.3	5.1	4.0	3.1	2.6	I	e	B
Betula lnoides	Birch (BIR)	W. Bengal	625	9.23	9.6	8.0	6.4	0.8	1.1	5.7	5.0	4.1	2.2	1.7	1.4	—	—	B
Bischofia javanica	Uriam Bishopwood (URI)	Chennai	769	8.84	9.6	8.2	6.5	0.8	1.1	5.9	5.3	4.3	3.6	2.8	2.3	III	—	A
Burserra serrata (Syn. Protium serratum)	Muntenga (MUR)	A.P.	756	1.17	15.5	13.3	10.5	0.9	1.3	10.1	9.0	7.4	5.3	4.1	3.4	II	c	—
Careya arbersa	Kumbi (KUM)	U.P.	889	8.37	13.1	10.9	8.8	1.0	1.5	7.7	6.8	5.6	5.3	4.1	3.4	I	e	A
Cedrus deodara	Deodar (DEO)	H.P.	557	9.48	10.2	8.7	7.2	0.7	1.0	7.8	6.9	5.7	2.7	2.1	1.7	I	c	C
Cupressus torulosa	Cypress (CYP)	U.P.	506	8.41	8.8	7.6	6.2	0.6	0.8	6.9	6.2	5.0	2.4	1.8	1.5	I	e	C
Castanopsis hystrix	Indian chestnut (ICH)	W. Bengal	624	9.85	10.6	8.8	7.0	0.8	1.2	6.4	5.7	4.6	2.7	2.1	1.7	II	b	B
Chukrasia vclutina (Syn. C. Tabularis)	Chickrassy (CHI)	W. Bengal	666	8.35	11.8	9.8	7.9	1.1	1.5	7.1	6.3	5.2	3.9	3.1	2.5	II	c	B
Calophyllum wightianum	Poon (POO)	Maharashtra	689	8.68	13.5	11.2	9.0	1.0	1.4	8.7	7.8	6.4	4.0	3.1	2.5	II	—	B
Canarium strictum	White dhup	Assam	569	10.54	10.1	8.4	6.7	0.7	1.1	6.2	5.5	4.5	2.1	1.6	1.3	III	—	C
Chlorophora excelsa	—	Chennai	471	6.57	10.2	8.5	6.8	0.5	0.7	6.4	5.6	4.6	2.0	1.6	1.3	—	—	—
Cocosnucifera	Coconut (COC)	Kerala	761	7.34	9.2	7.7	6.1	0.7	1.1	9.5	8.4	6.9	3.9	3.0	2.5	—	—	—
Dalbergia latifolia	Rosewood (ROS)	M.P.	884	8.39	12.9	10.8	8.6	1.1	1.6	8.0	7.1	5.8	4.2	3.3	2.7	I	—	B
Dalbergia sissee	Sisso (SIS)	Punjab	799	7.14	12.8	10.7	8.5	1.3	1.8	8.2	7.3	6.0	4.2	3.3	2.7	I	e	B
Dillemia indica	Dillenia (DIL)	W. Bengal	617	8.61	12.1	10.0	8.0	0.8	1.2	7.3	6.5	5.3	2.7	2.1	1.7	III	a	B
Dillenia pentagyne	Dillenia (DIL)	W. Bengal	622	7.56	11.8	9.9	7.9	0.9	1.3	7.1	6.3	5.2	3.5	2.7	2.2	III	d	B
Diospyres melanoxylon	Ebony (EBO)	Maharashtra	818	7.69	10.9	9.1	7.3	0.9	1.2	7.0	6.2	5.1	3.3	2.6	2.1	II	—	A
Duabanga grandiflora (Syn. D. Sonneratioides)	Lampati (LAP)	W. Bengal	485	8.38	9.8	8.2	6.5	0.6	0.9	6.4	5.7	4.7	1.8	1.4	1.1	III	c	C
Elesocarpus tuberculatus	Rudrak (RUD)	Chennai	466	8.74	9.7	8.1	6.4	0.7	1.0	6.3	5.6	4.6	2.0	1.5	1.3	—	—	C
Eucalyptus hybrid	Mysore gum (MGU)	Chennai	753	6.00	10.2	8.5	6.8	0.9	1.2	7.3	6.5	5.3	4.0	3.1	2.5	III	e	—
Calitres rhomboidea (Syn. Frenela rhomboidea)	—	Chennai	607	6.48	9.2	7.7	6.1	0.7	1.0	6.9	6.1	5.0	4.0	3.1	2.6	—	—	—
Garuga pinnata	Garuga (GAU)	U.P.	571	7.58	11.7	9.7	7.8	1.0	1.5	7.2	6.4	5.3	3.4	2.6	2.1	I	e	B
Gmeline arborea	Gamari (GAM)	U.P.	501	7.02	9.8	8.2	6.6	0.8	1.2	5.7	5.0	4.1	4.2	3.2	2.7	I	e	B
Gardonia latifolia	Gardenia (GAI)	M.P.	705	7.13	14.1	11.7	9.4	1.2	1.7	8.4	7.4	6.1	4.6	3.6	3.0	—	—	—
Hardwickis binata	Anjan (ANJ)	M.P.	852	6.64	14.1	11.8	9.4	1.3	1.8	9.0	8.0	6.5	7.4	5.6	4.7	I	e	—
Heloptelea integrifolia	Kanju (KAN)	U.P.	592	7.46	12.0	10.0	8.0	0.9	1.3	6.7	6.0	4.9	2.8	2.2	1.8	III	b	B
Heterrophragma rexburghii	Palang (PAL)	M.P.	616	8.69	12.3	10.2	8.2	0.7	1.0	7.9	7.0	5.7	3.4	2.6	2.1	—	—	—
Juglans spp.	Walnut (WAL)	U.P.	565	9.00	9.9	8.3	6.6	0.9	1.2	5.8	5.2	4.2	2.2	1.7	1.4	III	—	B
Lagerstrosmia speciosa (Syn. L. flesregihal)	Jarul (JAAR)	N.Andaman	622	8.53	12.1	10.1	8.1	0.8	1.8	7.7	6.8	5.6	3.4	2.6	2.2	II	e	B
Lannea grandis (Syn. L.coromandelica)	Jhingan (JHI)	U.P.	557	5.63	8.5	7.1	5.7	0.6	0.9	4.9	4.4	3.6	2.2	1.7	1.4	III	e	B
Leucanena leucocephala	Subabul (SUB)	U.P.	673	6.32	11.6	9.7	7.8	1.0	1.5	7.4	6.6	5.4	3.8	3.0	2.4	—	—	
Lophopatalum wightianum	Banati (BAN)	Chennai	460	7.33	8.5	7.5	5.6	0.5	0.8	5.3	4.7	3.8	1.8	1.4	1.1	III	—	C
Madhuca longifolia varlatifolia (Syn. Bassia latifolia)	Mahua (MAU)	M.P.	936	8.82	13.0	10.8	8.7	1.0	1.4	7.5	6.7	5.5	6.3	4.9	4.0	I	e	A
Mangifera indica	Mango, Aam (MAN)	Orissa	661	9.12	12.2	10.2	8.2	1.0	1.4	7.3	6.5	5.3	3.1	2.4	2.0	III	a	C
Machilus macrantha	Machilus (MAC)	Chennai	521	7.63	10.2	8.5	6.8	0.7	1.0	6.3	5.6	4.6	2.4	1.9	1.5	III	e	B
Mallotus philippinensis	Raini (RAI)	U.P.	662	7.51	10.8	9.0	7.2	1.0	1.4	6.0	5.4	4.4	2.9	2.3	1.8	III	—	B
Manglietia insignia	—	Assam	449	10.37	10.9	9.1	7.3	0.7	1.0	8.0	7.1	5.8	3.4	2.6	2.1	—	—	—
Michelia montana	Champ (CHM)	W. Bengal	512	8.25	10.9	9.1	7.3	0.7	1.0	6.6	5.9	4.8	2.8	2.2	1.8	I	—	B
Mitragyna pervifolia (Syn. Stephagyne pervifolia)	Kaim (KAI)	U.P.	651	7.82	12.6	10.5	8.4	1.0	1.5	7.9	7.0	5.7	3.7	2.9	2.4	III	b	B

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Table 1 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Michelia excelsa	Champ (CHM)	W. Bengal	513	10.12	9.8	8.2	6.5	0.7	1.0	6.1	5.5	4.5	1.6	1.3	1.0	II	e	B
Miliusa velutnia	Domsal (DOM)	U.P.	747	7.92	11.7	9.7	7.8	1.1	1.6	7.0	6.3	5.1	3.7	2.9	2.4	III	—	—
Morus alba	Mulberry (MUL)	U.P.	743	8.20	11.8	9.8	7.9	1.0	1.4	6.6	5.8	4.8	3.8	2.9	2.4	II	—	B
Morus serrata	Mulberry (MUL)	H.P.	657	7.03	10.2	8.5	6.8	0.9	1.3	5.6	5.0	4.1	2.6	2.0	1.6	III	—	B
Morus laevigata	Bola (BOL)	Andaman	588	8.61	12.3	10.2	8.2	1.0	1.5	7.2	6.4	5.3	3.3	2.5	2.1	—	—	B
Ougeinia eejeinensis (Syn. O. delbergioides)	Sandan (SAD)	M.P.	784	8.54	13.3	11.1	8.9	1.2	1.7	8.5	7.5	6.2	5.1	3.9	3.2	I	—	B
Phoebe hainesiana	Bonsum (BOH)	Assam	566	9.50	13.2	11.0	8.8	0.8	1.2	8.8	7.8	6.4	2.8	2.1	1.8	II	c	B
Pinus roxburghii (Syn. P. longifolia)	Chir (CHR)	U.P.	525	9.82	8.5	7.3	6.0	0.6	0.9	6.0	5.3	4.4	2.0	1.5	1.3	III	b	C
Pinus wallichiana	Kail (KAL)	—	515	6.80	6.6	5.6	5.0	0.6	0.8	5.2	4.6	3.8	1.7	1.3	1.0	II	c	C
Phoebe goalperansis	Bonsum (BOH)	Assam	511	7.65	9.7	8.1	6.5	0.7	1.0	6.6	5.9	4.8	2.2	1.7	1.4	II	c	B
Parretiopsis jacquementiena	Rohu Parrotia	H.P.	761	5.77	12.5	10.4	8.3	1.2	1.7	6.8	6.1	5.0	4.0	3.1	2.5	III	—	B
Pinus kesia (Syn. Pinus insularis)	Khasi pine (KPI)	North East	513	7.38	8.9	7.4	5.9	0.6	0.7	5.8	5.2	4.3	1.5	1.2	1.0	III	a	B
Pistacia integerrima	Kikar singhi	J&K	881	7.32	13.1	10.9	8.7	1.2	1.7	8.0	7.1	5.8	4.3	3.4	2.8	—	—	—
Podocarpus nerrifolius	Thitmin (THT)	S.Andaman	533	9.41	12.5	10.4	8.3	6.1	0.9	8.0	7.1	5.8	2.6	2.0	1.6	II	—	—
Polyalthia fragrances	Debdaru (DEB) (Nedunar)	Maharashtra	752	9.15	11.9	9.9	7.9	0.8	1.2	6.7	6.0	4.9	3.0	2.3	1.9	III	—	B
Polyalthia coreoides		M.P.	700	9.29	13.2	11.0	8.8	1.0	1.4	7.1	6.3	5.2	3.2	2.5	2.0	—	—	—
Prunus napeulensis	Arupati	W. Bengal	548	9.41	104.4	8.7	69.6	0.9	1.2	6.7	6.0	4.9	2.4	1.9	1.6	—	—	—
Pterespermum acerifolium	Hattipaila (HAT)	W. Bengal	607	9.55	13.5	11.3	9.0	0.9	1.2	8.7	7.7	6.3	3.2	2.5	2.0	III	c	B
Qucrcus spp.	Oak	North East	657	11.65	11.4	9.5	7.6	0.8	1.2	6.7	5.9	4.8	2.0	1.6	1.3	II	c	B
Raderomachera xylocarpe (Syn. Sterosperam xylocarpum)	Vedankonnai	Chennai	696	8.52	13.2	11.0	8.8	1.1	1.5	9.0	8.0	6.6	4.3	3.3	2.7	II	a	—
Schleichera oleosa (Syn. S. trijuga)	Kusum (KUS)	Bihar	1032	12.12	15.5	13.0	10.4	1.5	2.1	10.9	9.7	7.9	6.1	4.2	3.9	II	a	A
Schima wallichii	Chilauni (CHL)	W. Bengal	693	9.57	11.1	9.3	7.4	0.9	1.3	6.6	5.9	4.8	2.3	1.8	1.4	III	d	B
Shotea assamica	Makai (MAK)	Assam	548	9.27	11.1	9.2	7.4	0.9	1.3	7.1	6.3	5.2	2.9	2.2	1.8	III	c	B
Sonneralia apetale	Keora (KEO)	W. Bengal	617	8.63	12.8	10.7	8.5	0.9	1.3	7.4	6.6	5.4	4.8	3.7	3.0	II	—	B
Stereospermum suaveolans	Padri (PAD)	U.P.	721	8.86	13.3	11.1	8.9	0.9	1.3	7.3	7.0	5.7	3.5	2.7	2.2	III	—	B
Tactona grandis	Teak (TEA)	M.P.	617	8.49	12.8	10.7	8.5	0.8	1.3	7.9	7.0	5.7	4.0	3.1	2.6	I	e	B
Terminalia arjuna	Arjun (ARJ)	Bihar	794	7.71	12.2	10.2	8.2	1.1	1.6	7.4	6.6	5.4	5.2	4.1	3.3	II	b	B
Terminalia myriocarpa	Hollock (HOC)	Assam	615	9.62	11.9	9.9	8.0	0.9	1.2	7.6	6.7	5.5	2.9	2.2	1.8	III	a	B
Terminalia procera	White bombwae (WBO)	N.Andaman	626	8.99	11.8	9.8	7.9	0.9	1.3	7.2	6.4	5.3	3.0	2.3	1.9	III	b	B
Taxus buccata	Yew (YEW)	W. Bengal	705	7.79	14.3	11.9	9.5	1.2	1.7	8.7	7.8	6.4	4.7	3.7	3.0	—	—	—
Tamarindus indica	Imli (IML)	Chennai	913	5.63	11.4	9.5	7.6	1.2	1.7	7.0	6.2	5.1	5.3	4.1	3.4	—	—	B
Toena ciliata	Toon (TOO)	U.P.	487	6.40	8.7	7.3	5.8	0.7	1.0	5.4	4.8	3.9	2.4	1.8	1.5	II	c	B
Vateria indica	Vellapine (VEL)	Chennai	535	10.95	11.5	9.6	7.6	0.7	1.1	7.5	6.7	5.5	2.3	1.8	1.4	III	e	C
Aeculas indica	Horse chestnut (HCH)	U.P.	484	7.55	8.5	7.1	5.7	0.8	1.1	4.8	4.2	3.5	1.8	1.4	1.1	—	—	B
Borassus flabelsfer	Tad (Palmyra) (TAD)	A.P.	838	8.79	10.5	8.8	7.0	0.7	1.0	10.0	8.8	7.2	4.7	3.6	2.7	—	—	—
Eucalyptus cemaldulensis	Eucalyptus	Karnataka	804	9.53	12.8	10.6	8.5	0.8	1.1	7.2	6.4	5.2	3.5	2.7	2.2	—	—	A
Eucalyptus camaldulenis	Eucalyptus	U.P.	781	7.03	12.4	10.4	8.3	1.1	1.6	7.9	7.0	5.7	3.5	2.8	2.3	—	—	A
Eucalyptus pilularia	Eucalyptus	T.N.	713	9.22	14.8	12.3	11.1	1.0	1.4	8.5	7.6	6.2	2.8	2.2	1.8	—	—	A
Eucalyptus propingus	Eucalyptus	T.N.	584	7.93	12.8	10.7	8.5	0.8	1.2	8.0	5.4	4.4	2.5	1.9	1.6	—	—	A
Eucalyptus saligna	Eucalyptus	U.P.	819	8.24	11.5	9.6	7.6	1.5	2.1	8.2	7.3	6.0	6.2	4.8	4.0	—	—	A

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Table 1 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)

[1] Classification for preservation based on durability tests, etc.
Class:
I — Average life more than 120 months;
II — Average life 60 months and above but less than 120 months; and
III — Average life less than 60 months.

[2] *Treatability Grades:*
a — Heartwood easily treatable;
b — Heartwood treatable, but complete penetration not always obtained; in case where the least dimension is more than 60 mm;
c — Heartwood only partially treatable;
d — Heartwood refractory to treatment; and
e — Heartwood very refractory to treatment, penetration of preservative being practically nil even from the ends.

[3] Classifications based on seasoning behaviour of timber and refractoriness with respect to cracking, splitting and drying rate:
A — Highly refractory (slow and difficulty to season free from surface and end cracking);
B — Moderately refractory (may be seasoned free from surface and end cracking within reasonably short periods, given a little protection against rapid drying conditions); and
C — Non-refractory may be rapidly seasoned free from surface and end-cracking even in the open air and sun. If not rapidly dried, they develop blue stain and mould on the surface.

[4] Species thus marked and tested from other localities show higher strength to enable their categorization in higher group.
For Example:
i) Sal tested from W. Bengal, Bihar, U.P. and Assam can be classified as Group 'A' species;
ii) Haldu tested from Bihar can be classified as Group 'B' species;
iii) Morus laevigate (Bole) of Assam can be classified in Group 'B' species.

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Table 2 Permissible Lateral Strengths (in Double Shear) of Nails 3.55 mm Dia (9 SWG), 80 mm Long

(*Clause* 4.3)

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength per Nail (For Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints $N \times 10^2$	Node Joints $N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Albies pirdrow*	Fir	8	2	12
ii)	*Acacia catecha*	Khair	20	17.5	37.0
iii)	*Acacia nilotica*	Babul	15	11	32.5
iv)	*Acrocarpus fraxinifolius*	Mundani	18	9.5	19.5
v)	*Adina cordifolia*	Haldu	23.5	10	22
vi)	*Albizia lebbeck*	Kokko	20	7	24
vii)	*Albizia odoratissima*	Kala siris	14	5	22
viii)	*Anogeissus latifolia*	Axlewood	20	10	29
ix)	*Aphanamixis polystachya*	Pithraj	19	9	19
x)	*Azadiratchta indica*	Neem	22	11.5	19
xi)	*Balanocarpus utilis*	Karung	17.5	21	32
xii)	*Bischofia javnica*	Uriam	13	6.5	18
xiii)	*Betula alnoides*	Birch	13	12	22.5
xiv)	*Boswellia serrata*	Salai	12	5	14.5
xv)	*Calophyllum spp.*	Poon	16	9	21
xvi)	*Canarium euphyllum*	White dhup	9	8	10.5
xvii)	*Castanopsis hystrix*	Indian chestnut	18	10.5	23.5
xviii)	*Cedrus deodara*	Deodar	9	4	15
xix)	*Chukrasia tabularis*	Chikrassy	24	8	27
xx)	*Cinnamomum spp.*	Cinnomon	12	9	13
xxi)	*Cullenia rosaana (Syn. Cullenia excalsa)*	Karani	11.5	5	19
xxii)	*Cupressus torulosa*	Cypress	6	5	18
xxiii)	*Dalbergia latifohia*	Rosewood	19	8.5	23
xxiv)	*Dalberia sissoo*	Sissoo	14.5	7.5	19
xxv)	*Dipterocarpus macrocarpus*	Hollong	17	7	20
xxvi)	*Dipterocarpus spp.*	Gurjan	19	9	19.5
xxvii)	*Dillenia pertagyna*	Dillenia	16.5	12	16
xxviii)	*Diospyros melanoxylon*	Ebony	26.5	10	30.5
xxix)	*Duabanga grandiflora*	Lampati	15	5	12
xxx)	*Dysoxylum binectariferum*	White Cedar	7.5	5	14.5
xxxi)	*Eucalyptus eugenioides*	Eucalyptus	17	10	30
xxxii)	*Garuga pinnata*	Garuga	11.0	7.5	21.0
xxxiii)	*Gmelina arborea*	Gaman	8	4	9.5
xxxiv)	*Grerillea robusta*	Silver oak	12.0	7.0	10.5
xxxv)	*Grewia tilifolia*	Dhaman	13	5	24
xxxvi)	*Lagerstroemia spp.*	Jarul	24.5	21.5	22.5
xxxvii)	*Holoptelea integrifolia*	Kanju	12.5	9.5	20.5
xxxviii)	*Hopea parviflora*	Hopea	31.5	13	28.5
xxxix)	*Lagerstroemia spp.*	Lendi	19	5	26
xl)	*Madhuka Logifera (Syn. Barfia Latifolia)*	Mahua	23	7.5	26
xli)	*Mangifera indica*	Mango	11	9	16
xlii)	*Maniltoa polyandra*	Ping	26	23.5	32
xliii)	*Mesua ferrea*	Mesua	26	8	41
xliv)	*Michelia spp.*	Champ	13	9	20
xlv)	*Millingtonia spp.*	Phulsopa	10.5	6	17
xlvi)	*Morus alba*	Mulberry	13	10.5	22.5
xlvii)	*Melia azedarach*	Persian lilac (bakain)	10.5	2.5	10.5
xlviii)	*Morus alba*	Mulberry	13	10.5	22.5
xlix)	*Ougeinia oojeinensis*	Sandan	17	11	18
l)	*Phoebe spp.*	Bonsum	12	6	13
li)	*Pinus roxburghii*	Chir	11	10	16
lii)	*Pinus wallichiana*	Kail	7	3	9
liii)	*Planchonia andamanica*	Red bombwe	14	13	29
liv)	*Planchonia valida (Syn. P. andamonica)*	Red bombwe	14.5	13	29.5
lv)	*Poeciloneuron indicum*	Ballagi	16	7	15.5
lvi)	*Populus deltoides*	Poplar	16	11.5	17.5
lvii)	*Protium serratum (Syn. Burserra Serrata) A.P.*	_	25.5	7.0	22.5
lviii)	*Pterocarpus marsupium*	Bijasal	15	12	27
lix)	*Pterocarpus dalbergiodes*	Pauduak	19	14	23
lx)	*Quercus spp.*	Oak (Assam)	21	10	37.5
lxi)	*Quercus spp.*	Oak (U.P.)	11	10.5	26.5
lxii)	*Scheichera cleosa*	Kusum	23	16	39.5
lxiii)	*Schima wallachi*	Chillauni	19.5	9.5	25.5
lxiv)	*Shorea assamica*	Makai	12.5	7.5	15.0
lxv)	*Shorea robusta*	Sal (M.P.)	23	15.5	19.5

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Table 2 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)
lxvi)	*Shorea robusta*	Sal (U.P.)	10	5	19
lxvii)	*Stereospenmum chelonoides*	Padriwood	16	8	19.5
lxviii)	*Syzygium spp.*	Jamum	15	12	25
lxix)	*Tectona grandis*	Teak	14	8	13
lxx)	*Terminalia alata*	Sain	16	16	29
lxxi)	*Terminalia arjuna*	Arjun	8.5	7	16.5
lxxii)	*Terminalia bellirica*	Bahera	10	10	14
lxxiii)	*Terminalia biolata*	White chuglam	18	9	21
lxxiv)	*Terminalia chebula*	Myrobalan	16.5	5.5	22.5
lxxv)	*Terminalia procera*	Badam	18	10.5	20
lxxvi)	*Terminalia manii*	Black chuglam	23	10	33
lxxvii)	*Terminalia myriocarpa*	Hollock	13	10	19.5
lxxviii)	*Toona spp.*	Toona	10	8	21
lxxix)	*Xylia xylacarpa*	Irul	23	6	33
lxxx)	*Toona ciliata*	Toon	16	9	21

NOTES

1 Nails of 3.55 mm (9 SWG) diameter are most commonly used. The above values can also be used for 4 mm (8 SWG) diameter 100 mm long nails.

2 The values in Newton (N) are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

3 Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of good practice [6-3A(7)].

Table 3 Permissible Lateral Strengths (In Double Shear) of Nails 5.00 mm Dia (6 SWG), 125 mm and 150 mm Long

(*Clause* 4.3)

Sl No.	Species of Wood		For Permanent Construction Strength per Nail		For Temporary Structures Strength Per Nail (For Both Lengthening Joints and Node Joints)
	Botanical Name	Trade Name	Lengthening Joints	Node Joints	
			$N \times 10^2$	$N \times 10^2$	$N \times 10^2$
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Abies pindrow*	Fir	16.5	4.5	21
ii)	*Acacia catechu*	Khair	42	25	71.5
iii)	*Acacia nilotica*	Babul	27	13.5	53
iv)	*Alibizia procera*	Safed siris	35	18	-
v)	*Alibizia odoratissima*	Kala siris	27.5	17.5	45
vi)	*Alstonia scholaris*	Chatian	9.5	5.5	27
vii)	*Anogeissus latifolia*	Axlewood	22.5	13	46.5
viii)	*Azadirachata indica*	Neem	23.5	16	47
ix)	*Cupressus torulosa*	Cypress	20	7	27
x)	*Cullenia rosayroana*	Karani	11	9.5	30
xi)	*Dalbergia sissoo*	Sissoo	17	15	43
xii)	*Diptrocarous spp.*	Gurjan	19.5	9.5	33
xiii)	*Eucalyptus Prob. E. Tereticornis*	—	37.5	28.5	47
xiv)	*Hardwickia binata*	Anjan	32	19	59
xv)	*Hopea perviflora*	Hopea	60.5	25	61.5
xvi)	*Holoptelea integrifolia*	kanju	18	12.5	37.5
xvii)	*Mangifera indica*	Mango	22.5	15	32
xviii)	*Mesua ferrea*	Mesua	24	15.5	57.5
xix)	*Michelia champaca*	Champ	26	12.5	39
xx)	*Pterocarpus marsupium*	Bijasal	20.5	15	43
xxi)	*Pinus roxburghii*	Chir	9	6	24
xxii)	*Shorea robusta* (U.P.)	Sal	19.5	17	37
xxiii)	*Shorea robusta*	Sal	30.5	20	41
xxiv)	*Schleichera cleosa*	Kusum	15	14	55
xxv)	*Stereospimum personatum*	Padriwood	22	8	34
xxvi)	*Syzygium cumini*	Jamum	18	14.5	38.5
xxvii)	*Terminalia myriocarpa*	Hollock	27.5	9	41
xxviii)	*Tectona grandis*	Teak	28	13	30
xxix)	*Toona ciliata*	Toon	19	7	32.5
xxx)	*Hopea utilis*	Karung kangoo	31	10	58
xxxi)	*Phoebe spp.*	Bonsum	20	7.5	30
xxxii)	*Pterocarpus dalbergiodes*	Padauk	27.4	13.4	37.7
xxxiii)	*Populus deltoides*	Poplar	21	15	38.5

NOTES

1 Nails of 5.00 mm diameter are most commonly used.

2 The values in Newton (N) are approximate converted values from kgf. For exact conversion the value is 1 kgf = 9.806 65 N.

3 Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of good practice [6-3A(7)].

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Table 4 Permissible Percentage Moisture Content Values

(*Clause* 4.4)

Sl No.	Use	Zones (*see* Note)			
		I	II	III	IV
(1)	(2)	(3)	(4)	(5)	(6)
i)	Structural elements	12	14	17	20
ii)	Doors and windows:				
	a) 50 mm and above in thickness	10	12	14	16
	b) Thinner than 50 mm	8	10	12	14
iii)	Flooring strips for general purposes	8	10	10	12
iv)	Flooring strips for tea gardens	12	12	14	16

NOTE — The country has been broadly divided into the following four zones based on the humidity variations in the country:

Zone I — Average annual relative humidity less than 40 percent

Zone II — Average annual relative humidity 40 to 50 percent

Zone III — Average annual relative humidity 50 to 67 percent

Zone IV — Average annual relative humidity more than 67 percent

For detailed zonal classification in the country, tolerances, etc, reference may be made to good practice [6-3A(4)].

4.5 Sawn Timber

4.5.1 *Sizes*

Preferred cut sizes of timber for use in structural components shall be as given in Table 5, Table 6 and Table 7.

Table 5 Preferred Cut Sizes of Structural Timber for Roof Trusses (Span from 3 m to 20 m)

(*Clause* 4.5.1)

Sl No.	Thickness mm	Width mm							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	20	40	50	60	80	100	—	—	—
ii)	25	40	50	60	80	100	120	140	160
iii)	30	40	50	60	80	100	120	140	160
iv)	35	—	—	60	80	100	120	140	160
v)	40	—	—	60	80	100	120	140	160
vi)	50	—	—	60	80	100	120	140	160
vii)	60	—	—	—	80	100	120	140	160
viii)	80	—	—	—	—	100	120	140	160

NOTES

1 For truss spans marginally above 20 m, preferred cut sizes of structural timber may be allowed.

2 Preferred lengths of timber: 1, 1.5, 2, 2.5 and 3 m.

Table 6 Preferred Cut Sizes of Structural Timber for Roof Purlins, Rafters, Floor Beams, etc

(*Clause* 4.5.1)

Sl No.	Thick-ness mm	Width mm						
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	50	80	100	120	140		—	—
ii)	60	80	100	120	140	160	—	—
iii)	80	—	100	120	140	160	—	—
iv)	100	—	—	—	140	160	180	200

NOTE — Preferred lengths of timber: 1.5, 2, 2.5 and 3 m.

Table 7 Preferred Cut Sizes of Structural Timber for Partition Framing and Covering, and for Centering

(*Clause* 4.5.1)

Sl No.	Thick-ness mm	Width mm								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	10	40	50	60	80	—	—	—	—	—
ii)	15	40	50	60	80	100	—	—	—	—
iii)	20	40	50	60	80	100	120	160	200	—
iv)	25	40	50	60	80	100	120	160	200	240
v)	30	40	50	60	80	100	120	160	200	240
vi)	40	40	—	60	80	100	120	160	200	240
vii)	50	—	50	—	80	100	120	160	200	240
viii)	60	—	—	60	80	100	120	160	200	240
ix)	80	—	—	—	80	100	120	160	200	240

NOTE — Preferred lengths of timber: 0.5, 1, 1.5, 2, 2.5 and 3 m.

4.5.2 *Tolerances*

Permissible tolerances in measurements of cut sizes of structural timber shall be as follows :

a) For width and thickness:

1) Up to and including 100 mm : $^{+3}_{-0}$ mm

2) Above 100 mm : $^{+6}_{-3}$ mm

b) For length : $^{+10}_{-0}$ mm

4.6 Grading of Structural Timber

4.6.1 Cut sizes of structural timber shall be graded, after seasoning, into three grades based on permissible defects given in Table 8:

a) Select Grade,

b) Grade I, and

c) Grade II.

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Table 8 Permissible Defects for Cut Sizes of Timber for Structural Use

(*Clauses* 4.6.1 *and* 4.6.2.2)

All dimensions in millimetres.

Sl No.	Defects	Select Grade	Grade I	Grade II
(1)	(2)	(3)	(4)	(5)
i)	Wane	Shall be permissible at its deepest portion up to a limit of 1/8 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/6 of the width of the surface on which it occurs	Shall be permissible at its deepest portion up to a limit of 1/4 of the width of the surface on which it occurs
ii)	Worm holes	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible	Other than those due to powder post beetles are permissible
iii)	Slope of grain	Shall not be more than 1 in 20	Shall not be more than 1 in 15	Shall not be more than 1 in 12
iv)	Live knots:			

Width of Wide Faces of Cut Sizes of Timber, Max	*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*		*Permissible Maximum Size of Live Knot on*	
	Narrow Faces and ¼ of the Width Face Close to Edges of Cut Size of Timber	Remaining Central Half of the Width of the Wide Faces	Narrow Faces and ¼ of the Width Face Close to Edges of Cut Size of Timber	Remaining Central Half of the Width of the Wide Faces	Narrow Faces and ¼ of the Width Face Close to Edges of Cut Size of Timber	Remaining Central Half of the Width of the Wide Faces
75	10	10	19	19	29	30
100	13	13	25	25	38	39
150	19	19	38	38	57	57
200	22	25	44	50	66	75
250	25	29	50	57	66	87
300	27	38	54	75	81	114
350	29	41	57	81	87	123
400	32	44	63	87	96	132
450	33	47	66	93	99	141
500	35	50	69	100	105	150
550	36	52	72	103	108	156
600	38	53	75	106	114	159

v) Checks and shakes:

Width of the Face of the Timber Max	*Permissible Depth Max*	*Permissible Depth Max*	*Permissible Depth Max*
75	12	25	36
100	18	35	54
150	25	50	75
200	33	65	99
250	40	81	120
300	50	100	150
350	57	115	171
400	66	131	198
450	76	150	225
500	83	165	249
550	90	181	270
600	100	200	300

4.6.2 The prohibited defects given in **4.6.2.1** and permissible defects given in **4.6.2.2** shall apply to structural timber.

4.6.2.1 *Prohibited defects*

Loose grains, splits, compression wood in coniferous species, heartwood rot, sap rot, crookedness, worm holes made by powder post beetles and pitch pockets shall not be permitted in all the three grades.

4.6.2.2 *Permissible Defects*

Defects to the extent specified in Table 8 shall be permissible.

NOTE — Wanes are permitted provided they are not combined with knots and the reduction in strength on account of the wanes is not more than the reduction with maximum allowable knots.

4.6.3 *Location of Defects*

The influence of defects in timber is different for different locations in the structural element. Therefore, these should be placed during construction in such a way so that they do not have any adverse effect on the members, in accordance with the accepted standard [6-3A(5)].

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4.7 Suitability

4.7.1 *Suitability in respect of Durability and Treatability for Permanent Structures*

There are two choices as given in **4.7.1.1** and **4.7.1.2**.

4.7.1.1 *First choice*

The species shall be any one of the following:

a) Untreated heartwood of high durability. Heartwood if containing more than 15 percent sap wood, may need chemical treatment for protection;
b) Treated heartwood of moderate and low durability and Class 'a' and Class 'b' treatability;
c) Heartwood of moderate durability and Class 'c' treatability after pressure impregnation; and
d) Sapwood of all classes of durability after thorough treatment with preservative.

4.7.1.2 *Second choice*

The species of timber shall be heartwood of moderate durability and Class 'd' treatability.

4.7.2 *Choice of Species for Load-Bearing Temporary Structures or Semi-Structural Components at Construction Site*

The species shall be any one of the following:

a) Heartwood of low durability and Class 'e' treatability; or
b) The species whose durability and/or treatability is yet to be established, as listed in Table 1.

4.8 Fastenings

All structural members shall be framed, anchored, tied and braced to develop the strength and rigidity necessary for the purposes for which they are used. Allowable stresses or loads on joints and fasteners shall be determined in accordance with recognized principles. Common mechanical fastenings are of bar type such as nails and spikes, wood screws and bolts, and timber connectors including metallic rings or wooden disc-dowels. Chemical fastenings include synthetic adhesives for structural applications.

NOTE — Synthetic adhesives are able to achieve for timber what welding has achieved for steel.

4.9 Requirements of Structural Timber

The various other requirements of structural timber for use in building shall be in accordance with the accepted standard [6-3A(5)].

5 PERMISSIBLE STRESSES

5.1 Fundamental stress values of different groups of timber are determined on small clear specimen according to accepted standards [6-3A(2)]. These values are then divided by the appropriate factors of safety to obtain the permissible stresses. Values of these factors of safety for different strength characteristics are as per the relevant table of the accepted standard [6-3A(5)].

5.2 The permissible stresses for Groups A, B and C for different locations applicable to Grade I structural timber shall be as given in Table 9 provided that the following conditions are satisfied:

a) The timbers should be of high or moderate durability and be given the suitable treatment where necessary;
b) Timber of low durability shall be used after proper preservative treatment to good practice [6-3A(6)]; and
c) The loads should be continuous and permanent and not of impact type.

5.3 The permissible stresses (excepting *E*) given in Table 9 shall be multiplied by the following factors to obtain the permissible stresses for other grades provided that the conditions laid down in **5.2** are satisfied:

a) For select grade timber : 1.16
b) For Grade II timber : 0.84

Table 9 Minimum Permissible Stress Limits (in N/mm^2) in Three Groups of Structural Timbers (For Grade I Material)

(*Clauses* 5.2 *and* 5.3)

Sl No. (1)	Strength Character (2)	Location of Use (3)	Group A (4)	Group B (5)	Group C (6)
i)	Bending and tension along grain	Inside [1]	18.0	12.0	8.5
ii)	Shear [2]				
	Horizontal	All Locations	1.05	0.64	0.49
	Along grain	All Locations	1.5	0.91	0.70
iii)	Compression parallel to grain	Inside [1]	11.7	7.8	4.9
iv)	Compression perpendicular to grain	Inside [1]	4.0	2.5	1.1
v)	Modulus of elasticity (× 10^3 N/mm^2)	All locations and grade	12.6	9.8	5.6

[1] For working stresses for other locations of use, that is, outside and wet, generally factors of 5/6 and 2/3 are applied.
[2] The values of horizontal shear to be used only for beams. In all other cases shear along grain to be used.

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5.3.1 When low durability timbers are to be used [*see* **5.2**(b)] on outside locations, the permissible stresses for all grades of timber, arrived at by **5.2** and **5.3** shall be multiplied by 0.80.

5.4 Modification Factors for Permissible Stresses

5.4.1 *Due to Change in Slope of Grain*

When the timber has not been graded and has major defects like slope of grain, knots and checks or shakes but not beyond permissible value, the permissible stress given in Table 1 shall be multiplied by modification factor K_1 for different slopes of grain as given in Table 10.

Table 10 Modifications Factor K_1 to Allow for Change in Slope of Grain

(*Clause* 5.4.1)

Sl No.	Slope	Modification Factor (K_1)	
		Strength of Beams, Joists and Ties	Strength of Posts or Columns
(1)	(2)	(3)	(4)
i)	1 in 10	0.80	0.74
ii)	1 in 12	0.90	0.82
iii)	1 in 14	0.98	0.87
iv)	1 in 15 and flatter	1.00	1.00

NOTE — For intermediary slopes of grains, values of modification factor may be obtained by interpolation.

5.4.2 *Due to Duration of Load*

For different durations of design load, the permissible stresses given in Table 1 shall be multiplied by the modification factor K_2 given in Table 11.

NOTE — The strength properties of timber under load are time-dependent.

Table 11 Modification Factor (K_2), for Change in Duration of Loading

(*Clause* 5.4.2)

Sl No.	Duration of Loading	Modification Factor (K_2)
(1)	(2)	(3)
i)	Continuous (Normal)	1.0
ii)	Two months	1.15
iii)	Seven days	1.25
iv)	Wind and earthquake	1.33
v)	Instantaneous or impact	2.00

5.4.2.1 The factor K_2 is applicable to modulus of elasticity when used to design timber columns, otherwise they do not apply thereto.

5.4.2.2 If there are several duration of loads (in addition to the continuous) to be considered, the modification factor shall be based on the shortest duration load in the combination, that is, the one yielding the largest increase in the permissible stresses, provided the designed section is found adequate for a combination of other larger duration loads.

NOTE — In any structural timber design for dead loads, snow loads and wind or earthquake loads, members may be designed on the basis of total of stresses due to dead, snow and wind loads using modification factor K_2 = 1.33 for the permissible stresses (*see* Table 1) to accommodate the wind load, that is, the shortest of duration and giving the largest increase in the permissible stresses. The section thus found is checked to meet the requirements based on dead loads alone with modification factor K_2 = 1.00.

5.4.2.3 Modification factor K_2 shall also be applied to allowable loads for mechanical fasteners in design of joints, when the wood and not the strength of metal determines the load capacity.

6 DESIGN CONSIDERATIONS

6.1 All structural members, assemblies or framework in a building, in combination with the floors, walls and other structural parts of the building shall be capable of sustaining, with due stability and stiffness the whole dead and imposed loadings as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code, without exceeding the limits of relevant stresses specified in this Subsection.

6.2 Buildings shall be designed for all dead and imposed loads or forces assumed to come upon them during construction or use, including uplifts or horizontal forces from wind and forces from earthquakes or other loadings. Structural members and their connections shall be proportioned to provide a sound and stable structure with adequate strength and stiffness. Wooden components in construction generally include panels for sheathing and diaphragms, siding, beams, girder, columns, light framings, masonry wall and joist construction, heavy-frames, glued laminated structural members, structural sandwiches, prefabricated panels, lamella arches, portal frames and other auxiliary constructions.

6.3 Net Section

6.3.1 The net section is obtained by deducting from the gross sectional area of timber the projected area of all material removed by boring, grooving or other means at critical plane. In case of nailing, the area of the prebored hole shall not be taken into account for this purpose.

6.3.2 The net section used in calculating load carrying capacity of a member shall be at least net section determined as above by passing an imaginary plane or a series of connected planes transversely through the members.

6.3.3 Notches shall be in no case remove more than one quarter of the section.

6.3.4 In the design of an intermediate or a long column, gross section shall be used in calculating load carrying capacity of the column.

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6.4 Loads

6.4.1 The loads shall conform to those given in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

6.4.2 The worst combination and location of loads shall be considered for design. Wind and seismic forces shall not be considered to act simultaneously.

6.5 Flexural Members

6.5.1 Such structural members shall be investigated for the following:

a) Bending strength,
b) Maximum horizontal shear,
c) Stress at the bearings, and
d) Deflection.

6.5.2 *Effective Span*

The effective span of beams and other flexural members shall be taken as the distance from face of supports plus one-half of the required length of bearing at each end except that for continuous beams and joists the span may be measured from centre of bearing at those supports over which the beam is continuous.

6.5.3 Usual formula for flexural strength shall apply in design:

$$f_{ab} = \frac{M}{Z} \leq f_b$$

6.5.4 *Form Factors for Flexural Members*

The following form factors shall be applied to the bending stress:

a) *Rectangular section* — For rectangular sections, for different depths of beams, the form factor K_3 shall be taken as:

$$K_3 = 0.81\left(\frac{D^2 + 89\,400}{D^2 + 55\,000}\right)$$

NOTE — Form factor (K_3) shall not be applied for beams having depth less than or equal to 300 mm.

b) *Box beams and I-beams* — For box beams and I-beams the form factor K_4 shall be obtained by using the formula:

$$K_4 = 0.8 + 0.8y\left(\frac{D^2 + 89\ \ 400}{D^2 + 55\ \ 000} - 1\right)$$

where

$$y = p_1^{\,2}\left(6 - 8p_1 + 3p_1^{\,2}\right)\ \ (1 - q_1) + q_1$$

c) *Solid circular cross-sections* — For solid circular cross sections the form factor K_5 shall be taken as 1.18.

d) *Square cross-sections* — For square cross sections where the load is in the direction of diagonal, the form factor K_6 shall be taken as 1.414.

6.5.5 *Width*

The minimum width of the beam or any flexural member shall not be less than 50 mm or 1/50 of the span, whichever is greater.

6.5.6 *Depth*

The depth of beam or any flexural member shall not be taken more than three times of its width without lateral stiffening.

6.5.6.1 *Stiffening*

All flexural members having a depth exceeding three times its width or a span exceeding 50 times its width or both shall be laterally restrained from twisting or buckling and the distance between such restraints shall not exceed 50 times its width.

6.5.7 *Shear*

6.5.7.1 The following formulae shall apply:

a) The maximum horizontal shear, when the load on a beam moves from the support towards the centre of the span, and the load is at a distance of three to four times the depth of the beam from the support, shall be calculated from the following general formula:

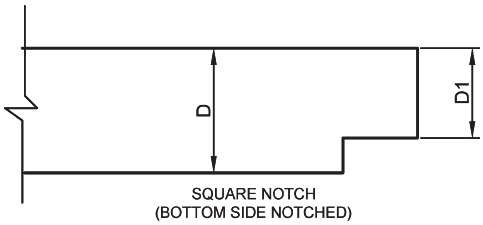
$$H = \frac{VQ}{Ib}$$

b) For rectangular beams:

$$H = \frac{3V}{2bD}$$

c) For notched beams, with tension notch at supports (*see* **6.5.7.3**):

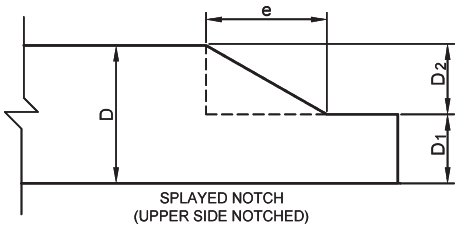
$$H = \frac{3VD}{2bD_1^{\,2}}$$



d) For notched at upper (compression) face, where $e > D$:

$$H = \frac{3VD}{2bD_1}$$

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e) For notched at upper (compression) face, where $e < D$:

$$H = \frac{3V}{2b\left[D - \left(\frac{D_2}{D}\right)e\right]}$$

6.5.7.2 For concentrated loads:

$$V = \frac{10C(l-x)(x/D)^2}{9l\left[2+(x/D)^2\right]} \text{ and}$$

For uniformly distributed loads:

$$V = \frac{W}{2}\left(1 - \frac{2D}{l}\right)$$

After arriving at the value of V, its value shall be substituted in the formula:

$$H = \frac{VQ}{Ib}$$

6.5.7.3 In determining the vertical reaction V, the following deductions in loads may be made:

a) Consideration shall be given to the possible distribution of load to adjacent parallel beams, if any;

b) All uniformly distributed loads within a distance equal to the depth of the beam from the edge of the nearest support may be neglected except in case of beam hanging downwards from a particular support; and

c) All concentrated loads in the vicinity of the supports may be reduced by the reduction factor applicable according to Table 12.

Table 12 Reduction Factor for Concentrated Loads in the Vicinity of Supports

[*Clause* 6.5.7.3 (c)]

Distance of Load from the Nearest Support	1.5 D or Less	2 D	2.5 D	3 D or More
(1)	(2)	(3)	(4)	(5)
Reduction factor	0.60	0.40	0.20	No reduction

NOTE — For intermediate distances, factor may be obtained by linear interpolation.

6.5.7.4 Unless the local stress is calculated and found to be within the permissible stress, flexural member shall not be cut, notched or bored except as follows:

a) Notches may be cut in the top or bottom neither deeper than one-fifth of the depth of the beam nor farther from the edge of the support than one-sixth of the span;

b) Holes not larger in diameter than one quarter of the depth may be bored in the middle third of the depth and length, and

c) If holes or notches occur at a distance greater than three times the depth of the member from the edge of the nearest support, the net remaining depth shall be used in determining the bending strength (*see* Fig. 1)

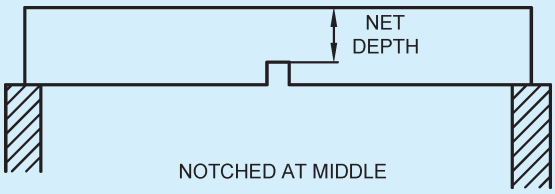


FIG. 1 NOTCHED BEAMS

6.5.8 *Bearing*

6.5.8.1 The ends of flexural members shall be supported in recesses which provide adequate ventilation to prevent dry rot and shall not be enclosed. Flexural members except roof timbers which are supported directly on masonry or concrete shall have a length of bearing of not less than 75 mm. Members supported on corbels, offsets and roof timbers on a wall shall bear immediately on and be fixed to wall-plate not less than 75 mm × 40 mm.

6.5.8.2 Timber joists or floor planks shall not be supported on the top flange of steel beams unless the bearing stress, calculated on the net bearing as shaped to fit the beam, is less than the permissible compressive stress perpendicular to the grain.

6.5.8.3 *Bearing stress*

6.5.8.3.1 *Length and position of bearing*

a) At any bearing on the side grain of timber, the permissible stress in compression perpendicular to the grain, f_{cn}, is dependent on the length and position of the bearing.

b) The permissible stresses given in Table 1 for compression perpendicular to the grain are also the permissible stresses for any length at the ends of a member and for bearings 150 mm or more in length at any other position.

c) For bearings less than 150 mm in length located 75 mm or more from the end of a member as shown in Fig. 2, the permissible stress may be multiplied by the modification factor K_7 given in Table 13.

d) No allowance need be made for the difference in intensity of the bearing stress due to bending of a beam.

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e) The bearing area should be calculated as the net area after allowance for the amount of wane.

f) For bearings stress under a washer or a small plate, the same coefficient specified in Table 13 may be taken for a bearing with a length equal to the diameter of the washer or the width of the small plate.

g) When the direction of stress is at angle to the direction of the grain in any structural member, then the permissible bearing stress in that member shall be calculated by the following formula:

$$f_{c\theta} = \frac{f_{cp} \times f_{cn}}{f_{cp} \sin^2 \theta + f_{cn} \cos^2 \theta}$$

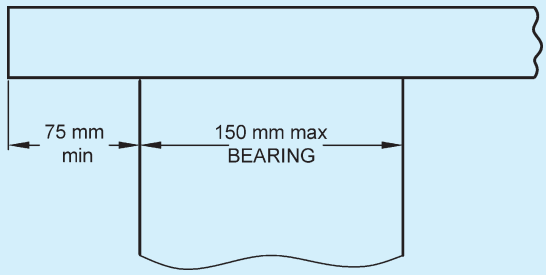


FIG 2. POSITION OF END BEARINGS

Table 13 Modification Factor K_7 for Bearing Stresses

[*Clause* 6.5.8.3.1 (c) *and* (f)]

Length of Bearing mm	15	25	40	50	75	100	150 or more
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Modification factor, K_7	1.67	1.40	1.25	1.20	1.13	1.10	1.00

6.5.9 Purlin is a structural member, essentially a beam subjected to transverse loads and rests on the top chord of roof truss. Being under bi-axial bending, vertical loads are resolved into two components, that is, perpendicular to and parallel to roof slopes (*see* Fig. 3). The effect of normal and tangential components of the vertical load is worked out separately and the in fibre stress in bending, will be the algebraic sum of both.

6.5.10 *Deflection*

The deflection in the case of all flexural members supporting brittle materials like gypsum ceilings, slates, tiles and asbestos sheets shall not exceed 1/360 of the span. The deflection in the case of other flexural members shall not exceed 1/240 of the span and 1/150 of the freely hanging length in the case of cantilevers.

6.5.10.1 Usual formula for deflection shall apply:

$$\delta = \frac{KWL^3}{EI}$$ (ignoring deflection due to shear strain)

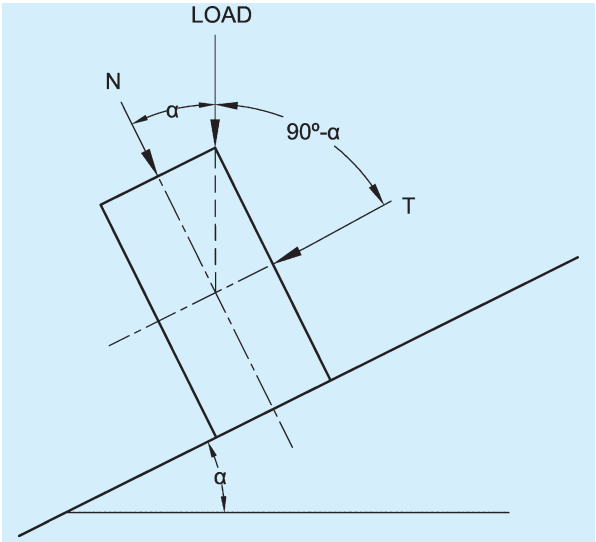


FIG. 3 PURLIN

K-values = 1/3 for cantilevers with load at free end,
= 1/8 for cantilevers with uniformly distributed load,
= 1/48 for beams supported at both ends with point load at centre, and
= 5/384 for beams supported at both ends with uniformly distributed load.

6.5.10.2 In order to allow the effect of long duration loading on *E*, for checking deflection in case of beams and joists the effective loads shall be twice the dead load if timber is initially dry.

NOTE — The tendency of flexural members to acquire larger permanent deflections under long continued loadings has to be taken care of either by considering double the dead load in calculations of deflection or by giving a factor of safety to MOE.

6.5.10.3 Self weight of beam shall be considered in design.

6.6 Columns

NOTE — The formulae given are for columns with pin end conditions and the length shall be modified suitably with other end conditions.

6.6.1 *Solid Columns*

Solid columns shall be classified into short, intermediate and long columns depending upon their slenderness ratio (*S*/*d*) as follows:

a) *Short columns* — Where *S*/*d* does not exceed 11,

b) *Intermediate columns* — Where *S*/*d* is between 11 and K_8, and

c) *Long columns* — Where *S*/*d* is greater than K_8.

6.6.1.1 For short columns, the permissible compressive stress shall be calculated as follows:

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$$f_c = f_{cp}$$

6.6.1.2 For intermediate columns, the permissible compressive stress is calculated by using the following formula:

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_8 d}\right)^4\right]$$

6.6.1.3 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329E}{\left(S/d\right)^2}$$

6.6.1.4 In case of solid columns of timber, *S*/*d* ratio shall not exceed 50.

6.6.1.5 The permissible load on a column of circular cross section shall not exceed that permitted for a square column of an equivalent cross sectional area, where side of square is equal to 0.886 times the diameter

6.6.1.6 For determining *S*/*d* ratio of a tapered column, such as for wooden poles, its least dimension shall be taken as the sum of the corresponding least dimensions at the small end of the column and one-third of the difference between this least dimension at the small end and the corresponding least dimension at the large end, but in no case shall the least dimension for the column be taken as more than one and a half times the least dimension at the small end. The induced stress at the small end of the tapered column shall not exceed the permissible compressive stress in the direction of grain.

6.6.2 *Built-Up Columns*

6.6.2.1 *Box column*

Box columns shall be classified into short, intermediate and long columns as follows:

a) *Short columns* — Where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is less than 8;

b) *Intermediate columns* — Where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is between 8 and K_9; and

c) *Long columns* — Where $\frac{S}{\sqrt{d_1^2+d_2^2}}$ is greater than K_9;

6.6.2.2 For short columns, the permissible compressive stress shall be calculated as follows:

$$f_c = qf_{cp}$$

6.6.2.3 For intermediate columns, the permissible compressive stress shall be obtained using the following formula:

$$f_c = qf_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_9\sqrt{d_1^2+d_2^2}}\right)^4\right]$$

6.6.2.4 For long columns, the permissible compressive stress shall be calculated by using the following formula:

$$f_c = \frac{0.329\,UE}{\left(\frac{S}{\sqrt{d_1^2+d_2^2}}\right)^2}$$

6.6.2.5 The following values of *U* and *q*, depending upon plank thickness (*t*) in **6.6.2.3** and **6.6.2.4**, shall be used for width of plank not greater than 5 times the plank thickness:

t mm	*U*	*q*
25	0.80	1.00
50	0.60	1.00

6.6.3 *Spaced Columns*

6.6.3.1 The formulae for solid columns as specified in **6.6.1** are applicable to spaced columns with a restraint factor of 2.5 or 3, depending upon distances of end connectors in the column.

NOTE — A restrained factor of 2.5 for location of centroid group of fasteners at *S*/20 from end and 3 for location at *S*/10 to *S*/20 from end shall be taken.

6.6.3.2 For intermediate spaced column, the permissible compressive stress shall be:

$$f_c = f_{cp}\left[1-\frac{1}{3}\left(\frac{S}{K_{10}d}\right)^4\right]$$

6.6.3.3 For long spaced columns, the permissible compressive stress shall be:

$$f_c = \frac{0.329E\times 2.5}{(S/d)^2}$$

6.6.3.4 For individual members of spaced columns, *S*/*d* ratio shall not exceed 80.

6.6.4 Compression members shall not be notched. When it is necessary to pass services through such a member, this shall be effected by means of a bored hole provided that the local stress is calculated and found to be within the permissible stress specified. The distance from the edge of the hole to the edge of the member shall not be less than one quarter of width of the face.

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6.7 Tension Member (Ties)

The stress is axial tension parallel to grain of wood shall be calculated on the basis of net-section area which shall not exceed the safe permissible value in tension parallel to grain

$$f_{at} = \frac{\text{Maximum force prevailing}}{\text{Area of cross-section}} \leq f_t$$

6.8 Structural Members Subject to Bending and Axial Stresses

6.8.1 Structural members subjected both to bending and axial compression shall be designed to comply with the following:

$$\frac{f_{ac}}{f_c} + \frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

6.8.2 Structural members subjected both to bending and axial tension shall be designed to comply with the following:

$$\frac{f_{at}}{f_t} + \frac{f_{ab}}{f_b} \text{ is not greater than 1.}$$

6.9 Timber Roof Truss

Trusses are framed structures in which separate straight members are so arranged and connected at their ends that members form triangles. The external loads cause direct stresses in the members. Essentially a plane structure which is very stiff in the plane of the members but very flexible in every other direction. For members subjected to reversal of stresses, design has to be for one stress and tested for the other applied at the panel points. Eccentricity of meeting members at joint may result in the increased stresses in design.

7 DESIGN OF COMMON STEEL WIRE NAIL JOINTS

7.1 General

Nail jointed timber construction is suitable for light and medium timber framings (trusses, etc) up to 15 m spans. With the facilities of readily available materials and simpler workmanship in mono-chord and split-chord constructions, this type of fabrication has a large scope. Preboring of nail-jointed timber construction is desirable and shall be done in accordance with good practice as in, **6.2.2** and Table 3 of good practice [6-3A(7)].

7.2 Dimensions of Members

The dimension of an individual piece of timber (that is any single member) shall be within the range given below:

a) The minimum thickness of the main members in mono-chord construction shall be 30 mm.

b) The minimum thickness of an individual piece of members in split-chord construction shall be 20 mm for web members and 25 mm for chord members.

c) The space between two adjacent pieces of timber shall be restricted to a maximum of 3 times the thickness of the individual piece of timber of the chord member. In case of web members, it may be greater for joining facilities.

7.3 No lengthening joint shall preferably be located at a panel point. Generally not more than two, but preferably one, lengthening joint shall be permitted between the two panel points of the members.

7.4 Specification and Diameter of Nails

7.4.1 The nails used for timber joints shall conform to Part 5 'Building Materials' of the Code. The nails shall be diamond pointed.

7.4.2 The diameter of nail shall be within the limits of one-eleventh to one-sixth of the least thickness of members being connected.

7.4.3 Where the nails are exposed to be saline conditions, common wire nails shall be galvanized.

7.5 Arrangement of Nails in the Joints

The end distances, edge distances and spacings of nails in a nailed joint should be such as to avoid undue splitting of the wood and shall not be less than those given in **7.5.1** and **7.5.2.**

7.5.1 *Lengthening Joints*

The requirement of spacing of nails in a lengthening joint shall be as given in Table 14 (*see also* Fig. 4):

Table 14 Spacing of Nails

(*Clause* 7.5.1)

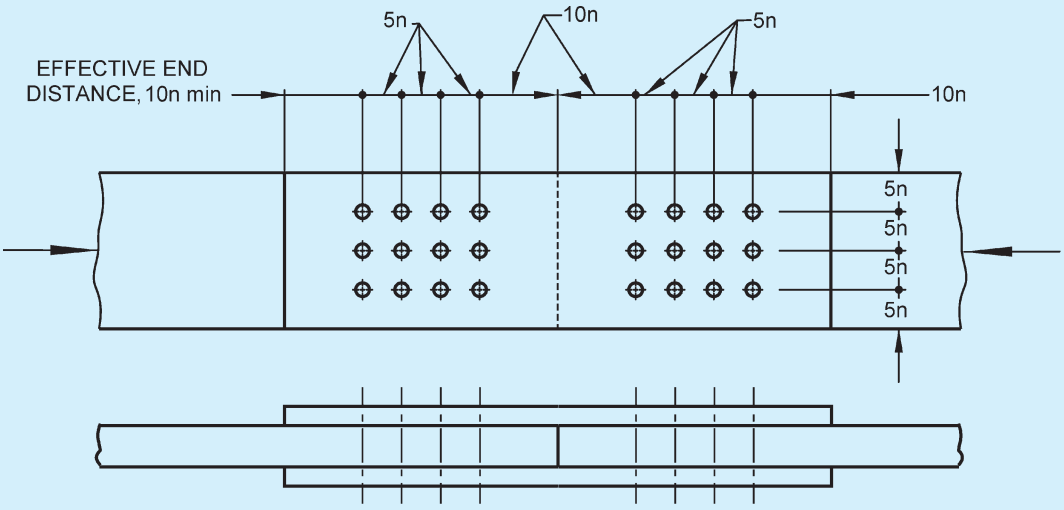
Sl No.	Spacing of Nails	Type of Stress in the Joint	Requirement *Min*
(1)	(2)	(3)	(4)
i)	End distance	Tension	12 *n*
		Compression	10 *n*
ii)	In direction of grain	Tension	10 *n*
		Compression	5 *n*
iii)	Edge distance	—	5 *n*
iv)	Between row of nails perpendicular to the grain	—	5 *n*

NOTES

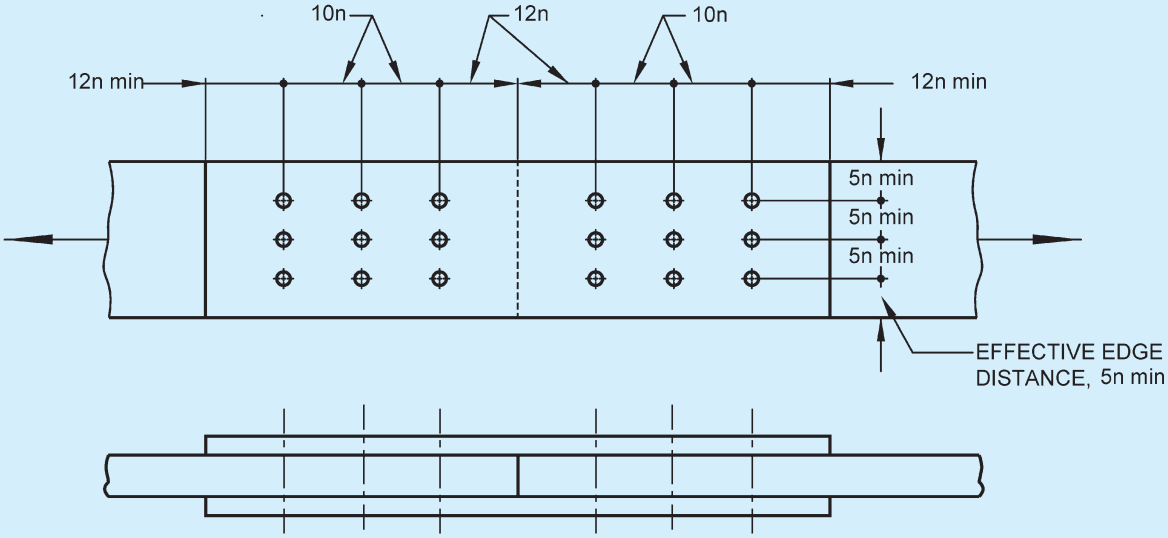
1 *n* is shank diameter of nails.

2 The 5*n* distance between rows perpendicular to the grain may be increased subject to the availability of width of the member keeping edge distance constant.

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4A Monochord Type Butt Joint Subject to Compression

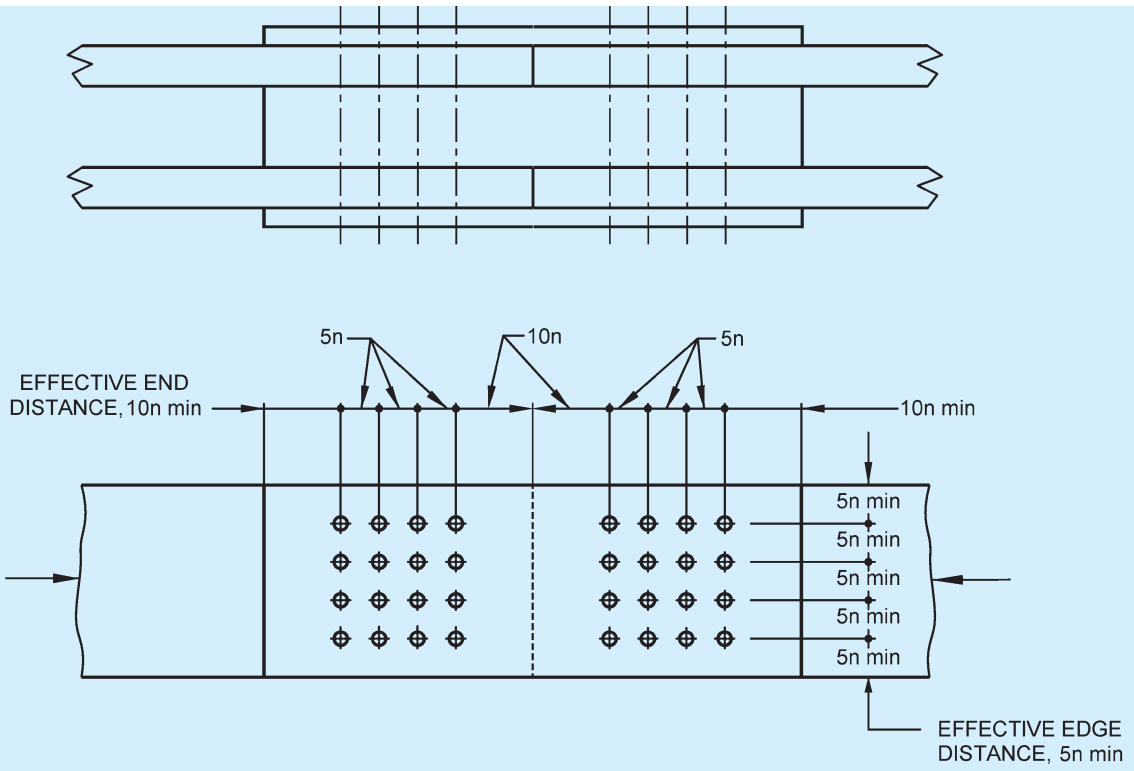


n = SHANK DIAMETER OF NAIL

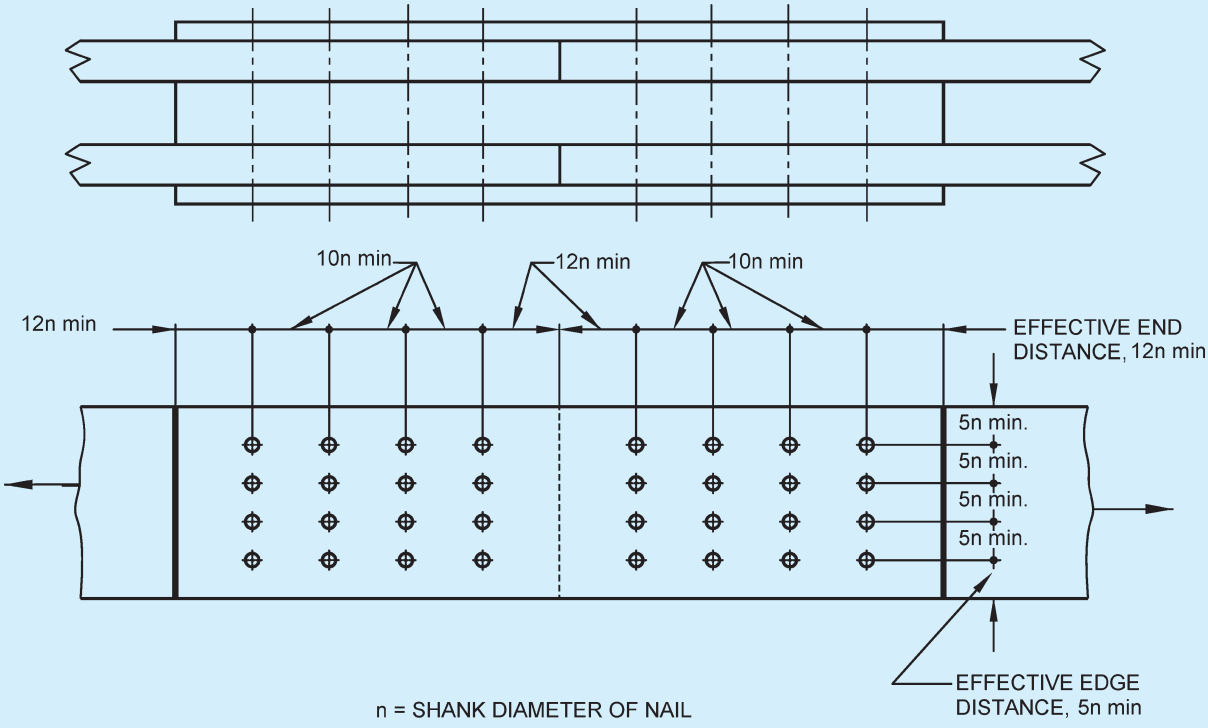
4B Monochord Type Butt Joint Subject to Tension

FIG. 4 SPACING OF NAILS IN A LENGTHENING JOINT — (*Continued*)

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4C Split - Chord Type Butt Joint Subject to Compression



n = SHANK DIAMETER OF NAIL

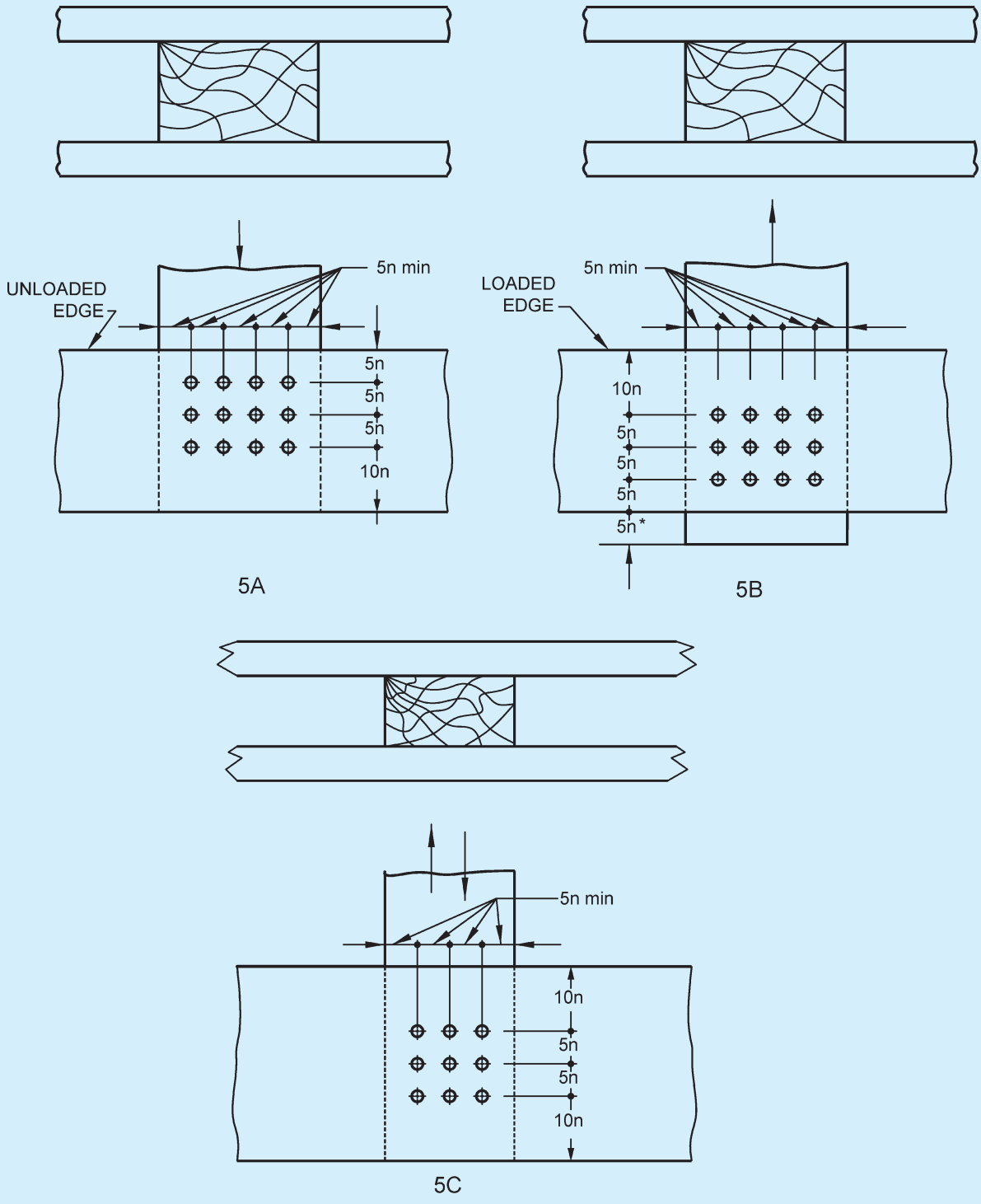
4D Split - Chord Type Butt Joint Subject to Tension

FIG. 4 SPACING OF NAILS IN A LENGTHENING JOINT

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7.5.2 *Node Joints*

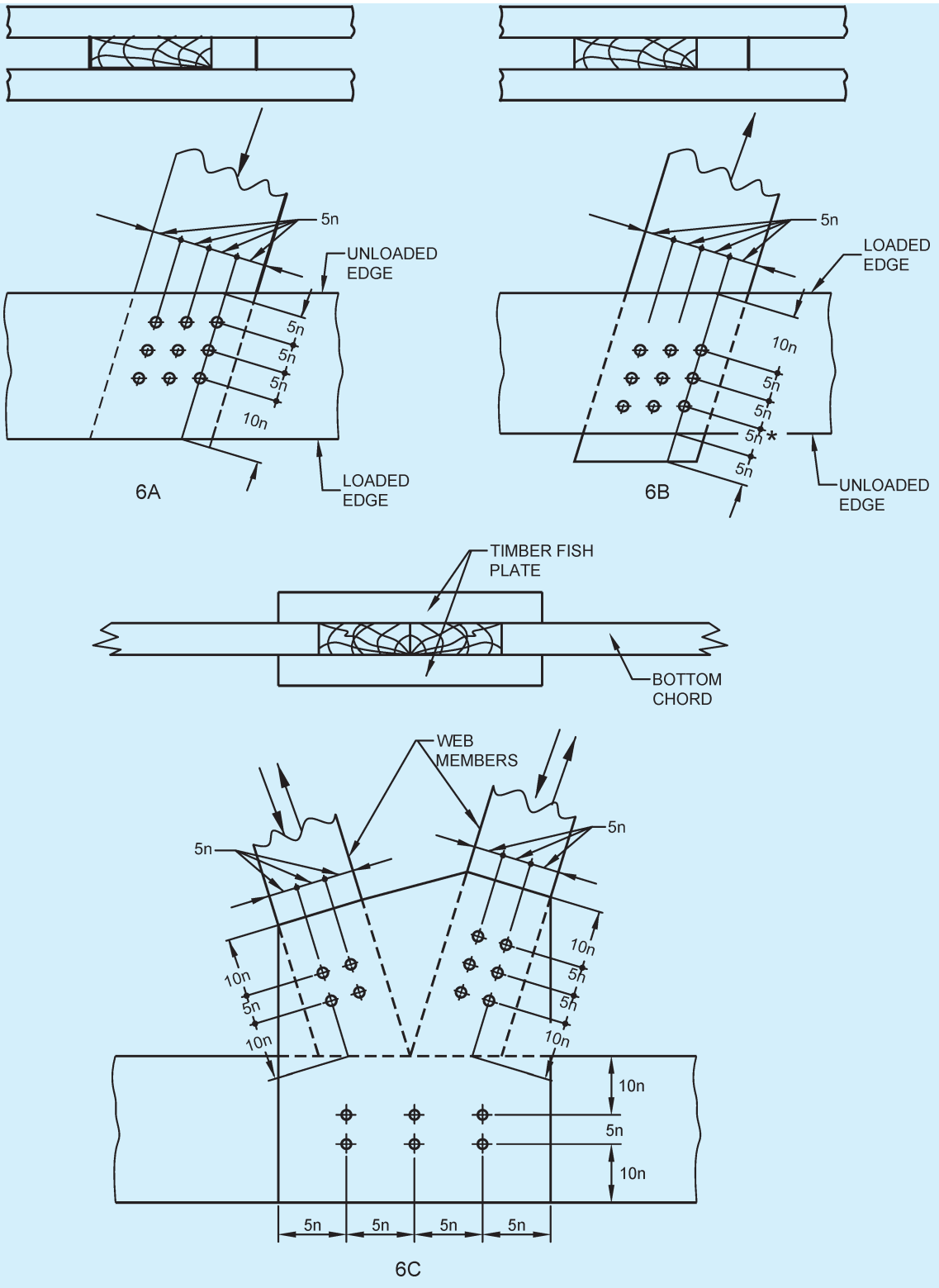
The requirement for spacing of nails in node joints shall be as specified in Fig. 5 where the members are at right angle and as in Fig. 6 where the members are inclined to one another at angles other than 90° and subjected to either pure compression or pure tension.



*5n may be increased to 10n, if the designed width of chord member permits. Otherwise the end of the loaded web member may be extended by 5n minimum.

FIG. 5 SPACING OF NAILS WHERE MEMBERS ARE AT RIGHT ANGLES TO ONE ANOTHER

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n = SHANK DIAMETER OF NAIL

*5n may be increased to 10n, if the designed width of chord member permits. Otherwise the end of the loaded web member may be extended by 5n minimum.

FIG. 6 SPACING OF NAILS AT NODE JOINTS WHERE MEMBERS ARE INCLINED TO ONE ANOTHER

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7.6 Penetration of Nails

7.6.1 For a lap joint when the nails are driven from the side of the thinner member, the length of penetration of nails in the thicker member shall be one and a half times the thickness of the thinner member subject to maximum of the thickness of the thicker member.

7.6.2 For butt joints the nails shall be driven through the entire thickness of the joint.

7.7 Design Considerations

7.7.1 Where a number of nails are used in a joint, the allowable load in lateral resistance shall be the sum of the allowable loads for the individual nails, provided that the centroid of the group of these nails lies on the axis of the member and the spacings conform to **7.5**. Where a large number of nails are to be provided at a joint, they should be so arranged that there are more of rows rather than more number of nails in a row.

7.7.2 Nails shall, as far as practicable, be arranged so that the line of force in a member passes through the centroid of the group of nails. Where this is not practicable, allowance shall be made for any eccentricity in computing the maximum load on the fixing nails as well as the loads and bending moment in the member.

7.7.3 Adjacent nails shall preferably be driven from opposite faces, that is, the nails are driven alternatively from either face of joint.

7.7.4 For a rigid joint, a minimum of 2 nails for nodal joints and 4 nails for lengthening joint shall be driven.

7.7.5 Two nails in a horizontal row are better than using the same number of nails in a vertical row.

7.7.6 The permissible lateral strength (in double shear) of mild steel common wire for different species of timber shall be as per **4.3**.

7.8 Special Consideration in Nail-Jointed Truss Construction

7.8.1 The initial upward camber provided at the centre of the lower chord of nail-jointed timber trusses shall be not less than 1/200 of the effective span for timber structures using seasoned wood and 1/100 for unseasoned or partially seasoned wood.

7.8.2 The total combined thickness of the gusset or splice plates on either side of the joint in a mono-chord type construction shall not be less than one and a half times the thickness of the main members subject to a minimum thickness of 25 mm of individual gusset plate.

NOTES

1 The allowable load or lateral strength values of nails shall be those as given in Table 2 and Table 3.

2 The strength data for joints given in the Subsection apply to gusset or splice or fish plates of solid wood; however, materials other than solid wood may be used for gusset when field tests are made and their strength requirements have been established.

7.8.3 The total combined thickness of all spacer blocks or plates or both including outer splice plates, at any joint in a split-chord type construction shall not be less than one and a half times the total thickness of all the main members at that joint.

7.9 Fabrication

The fabrication of nail-jointed timber construction shall be done in accordance with good practice [6-3A(7)].

8 DESIGN OF NAIL LAMINATED TIMBER BEAMS

8.1 Method of Arrangement

8.1.1 The beam shall be made up of 20 mm to 30 mm thick planks placed vertically with joints staggered in the adjoining planks with a minimum distance of 300 mm. The planks are laminated with the help of wire nails at regular intervals to take up horizontal shear developed in the beam besides keeping the planks in position (*see* Fig. 7).

8.1.2 The advantage in laminations lies in dimensional stability, possible dispersal of defects and better structural performance.

8.2 Sizes of Planks and Beams

8.2.1 The plank thickness for fabrication of nailed laminated beams recommended are 20, 25 and 30 mm.

8.2.2 In case of nailed laminated timber beam the maximum depth and length of planks shall be limited to 250 mm and 2 000 mm, respectively.

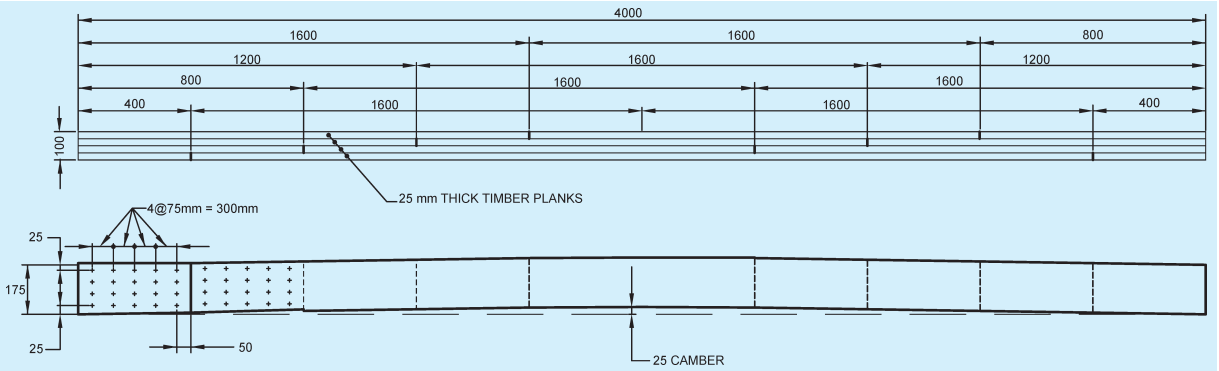
8.2.3 In order to obtain the overall width of the beam, the number and thickness of planks to form vertical nailed laminated beams, and also type and size of wire nail shall be as mentioned in Table 15. The protruding portion of the nail shall be cut off or clenched across the grains.

8.3 Design Considerations

8.3.1 Nail laminated beams shall be designed in accordance with **6** and provisions in the good practice [6-3A(8)].

8.3.1.1 The deflection in the case of nailed laminated timber beams, joists, purlins, battens and other flexural members supporting brittle materials like gypsum, ceiling slates, tiles and asbestos sheets shall not exceed 1/480 of the span. The deflection in case of other flexural members shall not exceed 1/360 of the span in the case of beams and joists, and 1/225 of the freely hanging length in case of cantilevers.

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All dimensions in millimetres.

FIG. 7 PLAN AND ELEVATION OF A TYPICAL NAILED LAMINATED TIMBER BEAM

8.3.2 Permissible lateral strength of diamond pointed mild steel wire nails shall be as given in Table 2 and Table 3 for Indian species of timber, which shall apply to nails that have their points cut flush with the faces. For nails clenched across the grains the strength may be increased by 20 percent over the values for nails with points cut flush.

Table 15 Number and Size of Planks and Nails for Nailed Laminated Beams

(*Clause* 8.2.3)

Sl No.	Overall Width of Beam	No. of Planks	Thickness of Each Plank	Type and Size of Nail to be Used
	mm		mm	mm
(1)	(2)	(3)	(4)	(5)
i)	50	2	25	80 long 3.55 dia
ii)	60	3	20	- do -
iii)	70	3	(2 x 25) (1 x 20)	- do -
iv)	80	4	20	100 long 4.0 dia
v)	90	3	30	- do -
vi)	100	4	25	125 long 5.0 dia
vii)	110	4	(3 x 30) (1 x 20)	- do -
viii)	120	4	30	- do -
ix)	150	5	30	150 long 5.0 dia

NOTE — A number of combinations of the different thickness of planks may be adopted as long as the minimum and maximum thickness of the planks are adhered to.

8.3.3 *Arrangement of Nails*

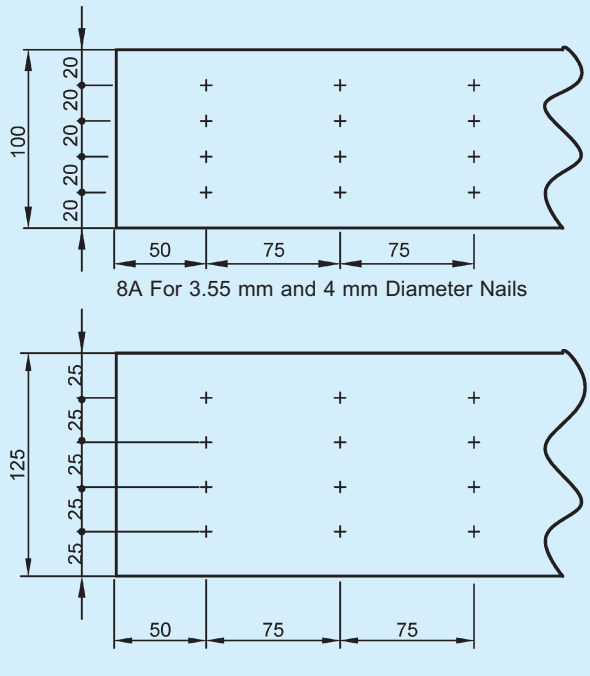
8.3.3.1 A minimum number of four nails in a vertical row at regular interval not exceeding 75 mm to take up horizontal shear as well as to keep the planks in position shall be used. Near the lengthening joints of the planks this distance may, however, be limited to 50 mm instead of 75 mm.

8.3.3.2 Shear shall be calculated at various points of the beam and the number of nails required shall be accommodated within the distance equal to the depth of the beam, with a minimum of 4 nails in a row at a standard spacing as shown in Fig. 8.

8.3.3.3 If the depth of the beam is more, then the vertical intermediate spacing of nails may be increased proportionately.

8.3.3.4 If the nails required at a point are more than that can be accommodated in a row, then these shall be provided lengthwise of the beam within the distance equal to the depth of the beam at standard lengthwise spacing.

8.3.3.5 For nailed laminated beam minimum depth of 100 mm for 3.55 mm and 4 mm diameter nails, and 125 mm for 5 mm diameter nails shall be provided.



8A For 3.55 mm and 4 mm Diameter Nails

8B For 5 mm diameter Nails

All dimensions in millimetres.

FIG. 8 STANDARD LENGTHWISE SPACING IN NAILED LAMINATED BEAM

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8.4 Fabrication

The fabrication of nailed laminated timber beams shall be done in accordance with good practice [6-3A(8)].

9 DESIGN OF BOLTED CONSTRUCTION JOINTS

9.1 General

Bolted joints suit the requirements of prefabrication in small and medium span timber structures for speed and economy in construction. Bolt jointed construction units offer better facilities as regards to workshop ease, mass production of components, transport convenience and re-assembly at site of work particularly in defence sector for high altitudes and far off situations. Designing is mainly influenced by the species, size of bolts, moisture conditions and the inclination of loadings to the grains. In principle, bolted joints follow the pattern of riveted joints in steel structures.

9.2 Design Considerations

9.2.1 Bolted timber construction shall be designed in accordance with **6**. The concept of critical section, that is, the net section obtained by deducting the projected area of bolt-holes from the cross-sectional area of member is very important for the successful design and economy in timber.

9.2.2 *Bolt Bearing Strength of Wood*

The allowable load for a bolt in a joint consisting of two members (single shear) shall be taken as one half the allowable loads calculated for a three member joint (double shear) for the same t'/d_3 ratio. The percentage of safe working compressive stress of timber on bolted joints for different t'/d_3 ratios shall be as given in Table 16.

9.2.2.1 Where a number of bolts are used in a joint, the allowable loads shall be the sum of the allowable loads for the individual bolts.

9.2.2.2 The factors for different bolt diameter used in calculating safe bearing stress perpendicular to grain in the joint shall be as given in Table 17.

9.2.3 *Dimensions of Members*

a) The minimum thickness of the main member in mono-chord construction shall be 40 mm.

b) The minimum thickness of side members shall be 20 mm and shall be half the thickness of main members.

c) The minimum individual thickness of spaced member in split-chord construction shall be 20 mm and 25 mm for webs and chord members, respectively.

Table 16 Percentage of Safe Working Compressive Stress of Timber for Bolted Joints in Double Shear

(*Clause* 9.2.2)

Sl No.	t'/d_3 Ratio	Stress Percentage	
		Parallel to Grain	Perpendicular to Grain
		λ_1	λ_2
(1)	(2)	(3)	(4)
i)	1.0	100	100
ii)	1.5	100	96
iii)	2.0	100	88
iv)	2.5	100	80
v)	3.0	100	72
vi)	3.5	100	66
vii)	4.0	96	60
viii)	4.5	90	56
ix)	5.0	80	52
x)	5.5	72	49
xi)	6.0	65	46
xii)	6.5	58	43
xiii)	7.0	52	40
xiv)	7.5	46	39
xv)	8.0	40	38
xvi)	8.5	36	36
xvii)	9.0	34	34
xviii)	9.5	32	33
xix)	10.0	30	31
xx)	10.5	—	31
xxi)	11.0	—	30
xxii)	11.5	—	30
xxiii	12.0	—	28

Table 17 Bolt Diameter Factor

(*Clause* 9.2.2.2)

Sl No.	Diameter of Bolt mm	Diameter Factor (d_f)
(1)	(2)	(3)
i)	6	5.70
ii)	10	3.60
iii)	12	3.35
iv)	16	3.15
v)	20	3.05
vi)	22	3.00
vii)	25	2.90

9.2.4 *Bolts and Bolting*

a) The diameter of bolt in the main member shall be so chosen to give larger slenderness (t'/d_3) ratio of bolt.

b) There shall be more number of small diameter bolts rather than small number of large diameter bolts in a joint.

c) A minimum of two bolts for nodal joints and four bolts for lengthening joints shall be provided.

d) There shall be more number of rows rather than more bolts in a row.

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e) The bolt holes shall be of such diameter that the bolt can be driven easily.

f) Washers shall be used between the head of bolt and wood surface as also between the nut and wood.

9.3 Arrangement of Bolts

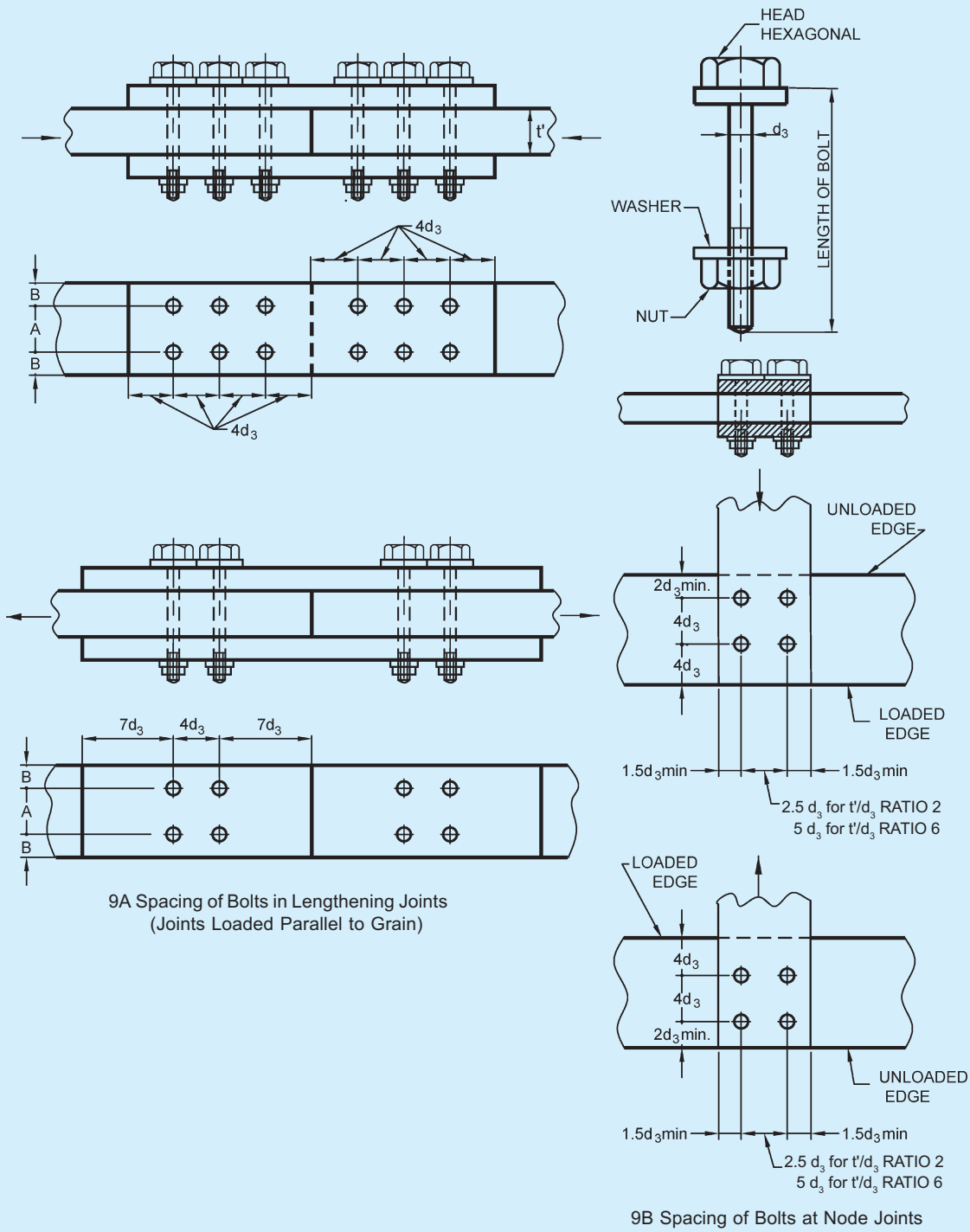
9.3.1 The following spacings in bolted joints shall be followed (*see* Fig. 9):

a) *Spacing of bolts in a row* — For parallel and perpendicular to grain loading = 4 d_3

b) *Spacing between rows of bolts*

1) *For perpendicular to grain loading* — 2.5 d_3 to 5 d_3 (2.5 d_3 for t'/d_3 ratio of 2 and 5 d_3 for t'/d_3 ratio of 6 or more. For ratios between 2 and 6 the spacing shall be obtained by interpolation).

2) *For parallel to grain loading* — At least



9A Spacing of Bolts in Lengthening Joints (Joints Loaded Parallel to Grain)

9B Spacing of Bolts at Node Joints

FIG. 9 TYPICAL SPACING OF BOLTS IN STRUCTURAL JOINTS

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(N - 4) d_3 with a minimum of 2.5 d_3. Also governed by net area at critical section which should be 80 percent of the total area in bearing under all bolts.

c) *End distance* — $7d_3$ for softwoods in tension, $5\,d_3$ for hardwoods in tension and $4\,d_3$ for all species in compression.

d) *Edge distance*

1) For parallel to grain loading $1.5\,d_3$ or half the distance between rows of bolts, whichever is greater.

2) For perpendicular to grain loading, the loaded edge distance shall be at least $4\,d_3$.

9.3.2 For inclined members, the spacing given above for perpendicular and parallel to grain of wood may be used as a guide and bolts arranged at the joint with respect to loading direction.

9.3.3 The bolts shall be arranged in such a manner so as to pass the centre of resistance of bolts through the intersection of the gravity axis of the members.

9.3.4 Staggering of bolts shall be avoided as far as possible in case of members loaded parallel to grain of wood. For loads acting perpendicular to grain of wood, staggering is preferable to avoid splitting due to weather effects.

9.3.5 *Bolting*

The bolt holes shall be bored or drilled perpendicular to the surface involved. Forcible driving of the bolts shall be avoided which may cause cracking or splitting of members. A bolt hole of 1.0 mm oversize may be used as a guide for preboring.

9.3.5.1 Bolts shall be tightened after one year of completion of structure and subsequently at an interval of two to three years.

9.4 Outline for Design of Bolted Joints

Allowable load on one bolt (unit bearing stress) in a joint with wooden splice plates shall not be greater than value of *P, R, F* as determined by one of the following equations:

a) *For loads parallel to grain:*
$P = f_{cp}\, a\, \lambda_1$

b) *For loads perpendicular to grain:*
$R = f_{cn}\, a\, \lambda_2\, d_f$

c) *For loads at an angle to grain:*

$$F = \frac{PR}{P\sin^2\theta + R\cos^2\theta}$$

9.5 Fabrication

The fabrication of bolt jointed construction shall be in accordance with good practice [6-3A(9)].

To meet the specific requirements of 'all-timber construction' for structures where chemical corrosion of steel elements is a problem, and in order to erect anti-magnetic laboratories, sheds, etc, design should be made on the basis of mild steel bolt joints with the following reductions for timber bolts and bamboo pins:

Allowable safe working load per hardwood timber bolt	=	66 percent of the safe working load per mild steel bolt
Safe working load per solid bamboo pin	=	56 percent of the working load per mild steel bolt

10 DESIGN OF TIMBER CONNECTOR JOINTS

10.1 In large span structures, the members have to transmit very heavy stresses requiring stronger jointing techniques with metallic rings or wooden disc-dowels. Improvised metallic ring connector is a split circular band of steel made from mild steel pipes. This is placed in the grooves cut into the contact faces of the timber members to be joined, the assembly being held together by means of a connecting bolt (*see* Fig. 10).

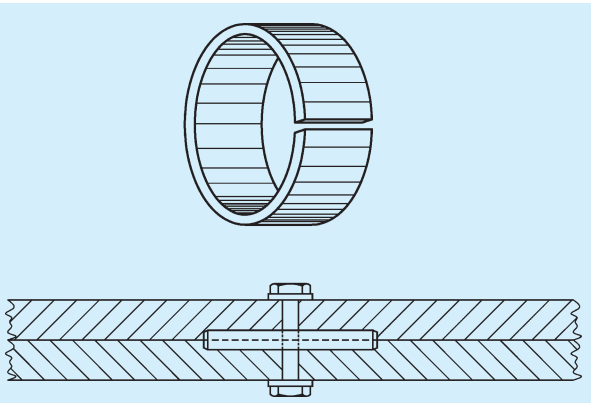


FIG. 10 SPLIT RING CONNECTOR

10.1.1 *Dimensions of Members*

Variation of thickness of central (main) and side members affect the load carrying capacity of the joint. The thickness of main member shall be at least 57 mm and that of side member 38 mm with length and width of members governed by placement of connector at joint.

The metallic connector shall be so placed that the loaded edge distance is not less than the diameter of the connector and the end distance not less than 1.75 times the diameter on the loaded side.

10.1.2 *Design Considerations*

The primary stresses in a split ring connector joint under

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tension are illustrated in Fig. 11. The shaded areas represent the part of wood in shear, compression and tension. Related formulae for the same are given in **10.1.2.1**.

For fabrication of structural members, a hole of the required size of the bolt is drilled into the member and a groove is made on the contact faces of the joint.

Theoretical safe loads in design shall be corroborated with sample tests done in accordance with accepted standard [6-3A(10)].

NOTE — A pilot study on determination of strength of improvised split ring connector joint in a compression test for a specific design problem conducted using *Mesua ferrea* (Mesua), yielded the data which is given below, for guidance:

10.1.2.1 Strength of joint is controlled by one or another or combination of three properties:

a) Tension area (*see* Fig. 11A):

$$t_1 w - \left[2\left(\frac{ad_2}{2}\right) + b(t_1 - a) \right]$$

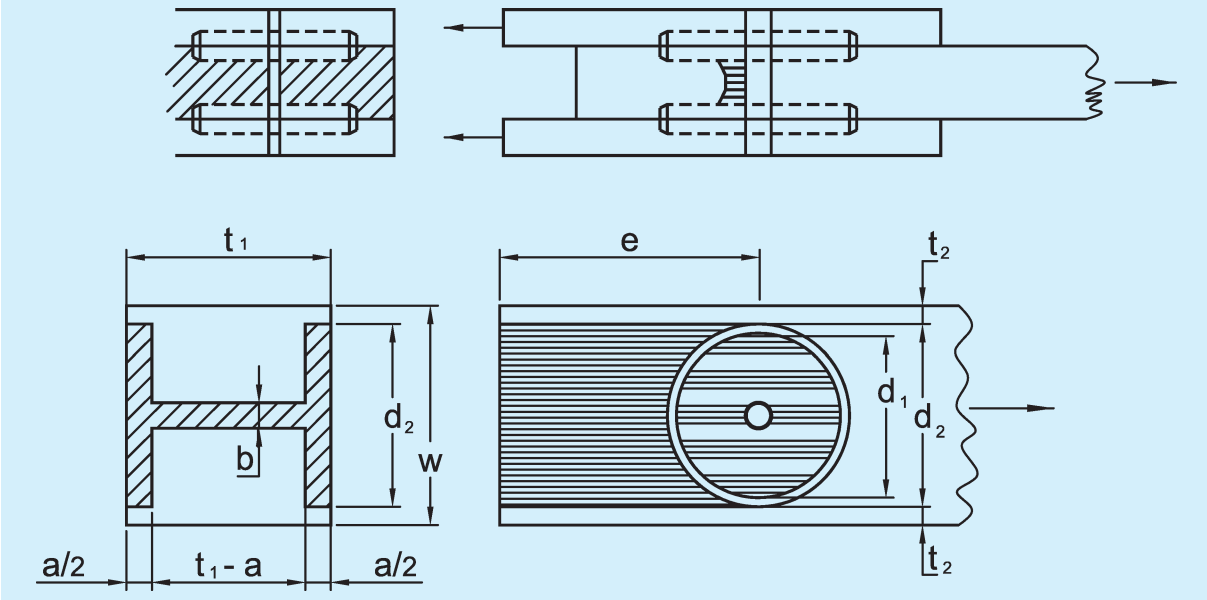
b) Compression area (*see* Fig. 11B and Fig. 11C):

$$2\left(\frac{ad_2}{2}\right) + b(t_1 - a)$$

c) Shear area (*see* Fig. 11D):

1) *Within core*: $2\left(\frac{\pi d_1^2}{4}\right)$

No. and Diameter of Ring Used in a Joint		*No. and Size of Bolt Used in a Joint*		*Side Member*		*Central Member*		*Load Direction with respect to Grains of Wood*	*End Distance*	*Inter-mediate Distance*	*Load Per Pair of Connector*
No.	Size mm	No.	Size mm	Thickness mm	Width mm	Thickness mm	Width mm		mm	mm	kgf
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
2	63	1	12×125	31	92	38	92	Parallel	63	—	3 930
2	63	1	12×125	31	92	38	92	Parallel	75	—	4 185
2	63	1	12×150	38	92	63	92	Parallel	75	—	4 010
2	63	1	12×150	38	117	63	117	Parallel	75	—	4 450
2	63	1	12×125	31	138	38	92	Perpendicular	69	—	2 520
2	63	1	12×125	38	138	38	92	Perpendicular	69	—	3 515
2	100	1	19×175	38	138	66	138	Parallel	100	—	7 075
2	100	1	19×175	38	138	66	138	Parallel	125	—	7 370
2	100	1	19×175	41	138	75	138	Parallel	100	—	7 220
2	100	1	19×175	41	138	75	138	Parallel	125	—	7 645
4	100	2	19×200	38	138	66	138	Parallel	100	150	5 655
4	100	2	19×200	41	138	75	138	Parallel	100	150	5 925
4	100	2	19×200	41	138	75	138	Parallel	125	200	7 135



NOTE — Symbols are exclusive to this figure.

FIG. 11 STRESS DISTRIBUTION IN A SPLIT RING CONNECTOR

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2) *Below core*:

$$2\left[d_2 e - \frac{1}{2}\left(\frac{\pi {d_2}^2}{4}\right) + 2\left(\frac{ae}{2}\right)\right]$$

where

d_1 = inside diameter of connector;
d_2 = outside diameter of connector;
e = end distance from centre of connector to end of member;
a = depth of connector;
b = diameter of bolt;
t_1 = thickness of member;
t_2 = thickness of metal; and
w = width of member;

10.2 Wooden Disc-Dowel

10.2.1 It is a circular hardwood disc generally tapered each way from the middle so as to form a double conical frustum. Such a disc is made to fit into preformed holes (recesses), half in one member and the other half in another, the assembly being held by one mild steel bolt through the centre of the disc to act as a coupling for keeping the jointed wooden members from spreading apart.

As timber always fails by shearing or crushing in front of bolts, the function of disc-dowel incorporated in the joint is to distribute the shearing stresses on a larger area of wood so as to transmit the full amount of stresses.

10.2.2 *Dimensions of Members*

The thickness of dowel may vary from 25 mm to 35 mm and diameter from 50 mm to 150 mm. The diameter of dowel shall be 3.25 to 3.50 times the thickness.

The edge clearance shall range from 12 mm to 20 mm as per the size of the dowel. The end clearance shall be at least equal to the diameter of dowel for joints subjected to tension and three-fourth the diameter for compression joints. Disc dowel shall be turned from radial (quarter sawn) planks of seasoned material.

10.2.3 *Choice of Species*

Wood used for making dowels shall be fairly straight grained, free from excessive liability to shrink and warp, and retain shape well after seasoning and having high shear strength. Species recommended include,

a) Babul,
b) Dhaman,
c) Irul,
d) Sissoo,
e) Rose Wood,
f) Sandal,
g) Axle-Wood,
h) Padauk, and
j) Yon.

NOTE — Data on the above species are as per Table 1.

10.2.4 *Design Considerations*

The forces on dowel in a lap joint and butt joint are illustrated in Fig. 12. Dowel is subjected to shearing at the mid-section, and compression along the grain at the bearing surfaces. For equal strength in both the forces, formula equations are given in the Fig. 12 to determine the size of dowel.

The making of wooden discs may present some problems in the field, but they may be made in small workshop to the specifications of the designer. This is also economically important. Once the wood fittings are shop tailored and made, the construction process in the field is greatly simplified.

Theoretical safe loads in design shall be confirmed through sample tests.

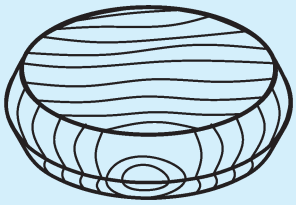
NOTE — Some experimental studies have indicated the following safe loads, in kN, for dowels bearing parallel to the grain, which are given here for guidance only:

Species		*Safe Loads for Dowels Bearing Parallel to the Grain, in* kN *Size of Dowel* (mm)					
Members	Dowels	62 × 25	75 × 25	87 × 25	100 × 31	112 × 37	125 × 37
Sal	Babul	6.671	9.810	13.342	17.805	22.269	27.566
Sal	Sissoo	5.346	7.554	10.251	13.342	16.922	20.895

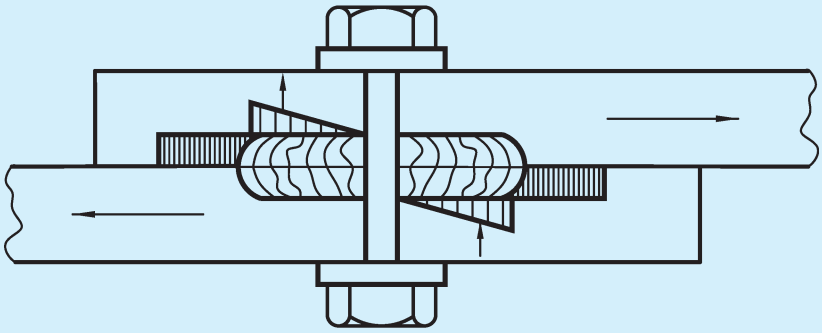
10.2.4.1 Rigid specifications regarding use of particular planks for fabrication of wooden disc-dowels, and the specific alignment of grains to be in line with grains of members forming the joint, can be relaxed. Application of appropriate factors in design of such joints whatever be the angle of load and members etc, would eliminate risks involved by providing 60 percent more number of dowels at a joint. Thus, decrease the calculated load per dowel to 60 percent.

10.2.4.2 Analysis of variance for safe load in case of dowel joints made with MS bolt, timber bolt, bamboo pin as joiners showed no significant difference. Thus the concept of 'all-timber construction' hold good for chemical industries where corrosion due to acid fumes is a recurring problem.

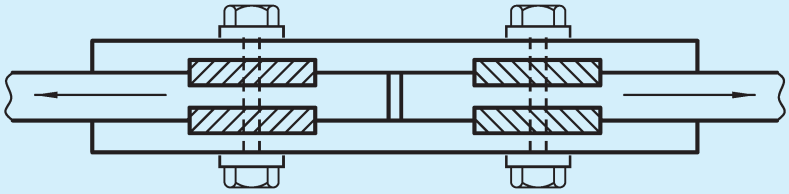
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DOWEL



LAP JOINT



BUTT JOINT

Lap joint : Bolt in simple tension due to clockwise turning moment on dowel.

Butt joint : No tilting moment in dowel due to balancing effect [dowels are in shear (no bending, shearing and tensile stress on bolts)]

Size of dowel for equal strength in both shearing and bearing.

$$\frac{\pi d^2}{4} \times S = d \times \frac{t}{2} \times c$$

where

d = mid diameter of the dowel,

t = thickness of dowel,

s = safe working stress in shear along grain, and

c = safe compressive stress along grain.

NOTE — Symbols are exclusive to this figure.

FIG. 12 DISTRIBUTION OF FORCES IN DOWEL JOINT

11 GLUED LAMINATED CONSTRUCTION

11.1 Developments in the field of synthetic adhesive have brought gluing techniques within the range of engineering practice. Timber members of larger cross-sections and long lengths can be fabricated from small sized planks by the process of glulam. The term glued laminated timber construction as applied to structural members refers to various laminations glued together, either in straight or curved form, having grain of all laminations essentially parallel to the length of the member.

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11.1.1 *Choice of Glue*

The adhesive used for glued laminated assembly are 'gap filling' type. A 'filler' in powder form is introduced in the adhesive. Structural adhesives are supplied either in powder form to which water is added or in resin form to which a hardener or catalyst is added. For choice of glues, reference may be made to accepted standard [6-3A(11)]. However, it is important that only boiling water proof (BWP) grade adhesives shall be used for fabrication of glulam in tropical, high humid climates like India.

11.1.2 *Manufacturing Schedule*

In absence of a systematic flow-line in a factory, provisions of intermediate technology shall be created for manufacturing structural elements. The schedule involves the following steps:

a) Drying of planks;
b) Planing;
c) End-jointing by scarfs or fingers;
d) Machining of laminations;
e) Setting up dry assembly of structural unit;
f) Application of glue;
g) Assembly and pressing the laminations;
h) Curing the glue lines, as specified; and
j) Finishing, protection and storage.

11.1.3 The information with regard to block shear test results on glued timber joints is given in Table 18.

Table 18 Block Shear Test Results on Glued Timber Joints

(*Clause* 11.1.3)

Sl No.	Timber Species	Ultimate Shear Stress (Inside Location) N/mm^2		
		Solid Timber Along the Grain (Un-Jointed)	With Urea Formal-dehyde	With Phenol Formal-dehyde
(1)	(2)	(3)	(4)	(5)
i)	*Abies pindrow* (Fir)	5.984	7.652	9.614
ii)	*Acacia catechu* (Khair)	15.107	7.456	—
iii)	*Acacia milotica* (Babul)	14.126	5.199	3.237
iv)	*Albizia Odoratissima* (Karasiris)	15.009	14.126	5.984
v)	*Azadirachta indica* (Neem)	12.557	7.259	8.240
vi)	*Casteanopsis hystrix* (Chestnut)	8.044	1.668	—
vii)	*Cedrus deodar* (Deodar)	6.867	4.218	3.237
viii)	*Dalbergia sissoo* (Sissoo)	10.595	15.107	9.320
ix)	*Eucalyptus eugenioides* (Eucalyptus)	12.164	10.987	5.101
x)	*Grewia tiliefolia* (Dhawan)	8.927	10.889	6.475
xi)	*Hopea utilis* (Karunkangoo)	14.813	9.320	—
xii)	*Hopea glabra &H. parviflora* (Hopea)	15.009	13.832	0.491
xiii)	*Mangifera Indica* (Mango)	9.418	9.418	3.826
xiv)	*Madhuca longifolia* (Mahua)	9.810	0.883	7.456
xv)	*Mesua ferrea* (Mesua)	12.164	1.079	2.256
xvi)	*Morus alba* (Mulberry)	9.810	13.734	8.142
xvii)	*Pinus wallichiana* (Kail)	5.494	6.377	7.259
xviii)	*Pinus roxburghii* (Chir)	6.082	6.769	7.750
xix)	*Poecilone indicum* (Ballagi)	14.911	5.297	5.984
xx)	*Pterocarpus mersupium* (Bijasal)	9.221	5.003	6.671
xxi)	*Quercus spp.* (Oak)	8.142	10.791	5.396
xxii)	*Ougeinia oojeinensis* (Sanetan)	13.440	5.396	9.516
xxiii)	*Shorea robusta* (Sal) M.P	9.123	5.003	—
xxiv)	*Shorea robusta* (Sal) UP	12.361	5.396	1.472
xxv)	*Sterospermum chelonoides* (Padriwood)	11.674	9.221	8.829
xxvi)	*Syzygium cuzainii* (Jaman)	10.791	9.418	10.301
xxvii)	*Terminalia alata* (Sain)	9.320	13.538	8.142
xxviii)	*Tectona grandis* (Teak)	10.987	5.984	6.377
xxix)	*Terminalia myriocarpa* (Hollock)	8.339	9.221	9.810
xxx)	*Toona ciliata* (Toon)	6.867	4.905	6.180

NOTE — The information given in the above table is based on the block shear test results on glued timber joints conducted on the basis of BS 4169:1970 'Specification for manufacture of glued-laminated timber structural members' (since revised and subsequently superseded by BS EN 392:1995, BS EN 391:1995, BS EN 386:1995), and the failures observed with regard to glue line and the wood. Ultimate shear stresses for 29 species were studied keeping design glue shear strength at least one-third of ultimate. Glue mixing, spreading, pressing and curing was done as per the instructions of adhesive manufacturers under improvised techniques locally developed. Sustainable period before delamination of glue bond (urea formaldehyde) in weathering tests was recorded for over a year. Limited number of species survived with most of them failed within a period of six months

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11.2 Design of Glued Laminated Beams

11.2.1 *General*

Glued laminated structural members shall be fabricated only where there are adequate facilities for accurate sizing and surfacing of planks, uniform application of glue, prompt assembly, and application of adequate pressure and prescribed temperature for setting and curing of the glue. Design and fabrication shall be in accordance with established engineering principles and good practice. A glued laminated beam is a straight member made from a number of laminations assembled both ways either horizontally or vertically (*see* Fig. 13). While vertical laminations have limitations in restricting the cross-section of a beam by width of the plank, horizontally laminated section offers wider scope to the designer in creating even the curved members. Simple straight beams and joists are used for many structures from small domestic rafters or ridges to the light industrial structures.

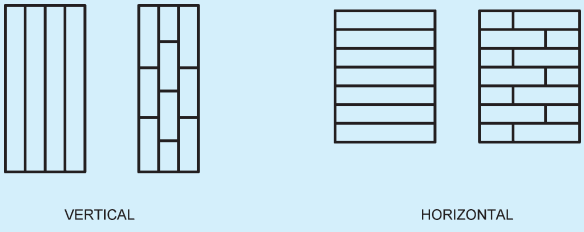


FIG. 13 POSSIBLE ORIENTATION OF PLANKS IN GLULAM

11.2.2 *Design*

The design of glue laminated wood elements shall be in accordance with good engineering practice and shall take into consideration the species and grade of timber used, presence of defects, location of end joints in laminations, depth of beams and moisture contents expected while in service. Beams of large spans shall be designed with a suitable camber to assist in achieving the most cost effective section where deflection governs the design. The strength and stiffness of laminated beams is often governed by the quality of outer laminations. Glued laminated beams can be tapered to follow specific roof slopes across a building and/or to commensurate with the varying bending moments. Glulam allows the engineers to mix grades within a beam. Obviously, the lower tensile portion should be of high grade material. However, it is possible to incorporate a considerable volume of lower grade material near the neutral axis taking care of the horizontal shear stress. Similarly, species can also be mixed depending upon the modulus of elasticity.

Straight beams that will be simply supported should be cambered during fabrication to allow for deflection due to dead loads over a period of time. The usual camber is $\frac{\text{Span}}{400}$, unless otherwise specified.

11.2.2.1 *Design outline for horizontally laminated beams*

A design outline for horizontal laminated beams, specifying data required and a possible solution is given below.

Data required:

a) Span (L), loads including self weight of beam (W), species of timber, thickness of lamination proposed; and

b) Mechanical properties of timber species (permissible extreme fibre stress in bending-tension, permissible compressive stress perpendicular to grain, modulus of elasticity, permissible shear stress parallel to grain).

The permissible shear stress at the glue line is at least the same as the permissible shear stress parallel to grain of the species in design, unless otherwise tested.

Solution:

a) Let, b = width of beam, and d = depth of beam, for lateral stability,

$b : d = 1 : 4$ (*say*).

b) Determine bending moment on the basis of span, loading and support conditions (say, $WL/8$ for beams with both ends fixed).

c) Also, Bending moment (M) = Bending stress (f_b) × Section modulus (Z).

$$\text{Therefore, } M = f_b \times \frac{bd^2}{6} = \frac{WL}{8}$$

$$\text{or } bd^2 = \frac{WL}{8} \times \frac{6}{f_b}$$

d) From bd^2 obtained at (c) and b:d assumed at (a), arrive at appropriate values of b and d.

e) Check for deflection of beam. Since dead load is for long term, double this for deflection check, that is,

$$W = (2 \times \textit{Dead load}) + \textit{Imposed load}$$

Deflection is to be limited to the specified requirement, say 0.003 of span.

Substituting values of b and d from (d) and I ($= bd^3/12$) in the formula for deflection, perform check against the limit for deflection.

f) Decide the number and thickness of laminations for the required depth of section.

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11.2.3 *Material*

Laminating boards shall not contain decay, knots or other strength reducing characteristics in excess of those sizes or amounts permitted by specifications. The moisture content shall approach that expected in service and shall in no case exceed 15 percent at the time of gluing. The moisture content of individual laminations in a structural member shall not differ by more than 3 percent at the time of gluing. Glue shall be of type suitable for the intended service of a structural member.

11.2.4 *Fabrication/Manufacture*

In order to assure a well-bonded and well-finished member of true shape and size, all equipment, end-jointing, glue spread, assembly, pressing, curing or any other operation in connection with the manufacture of glued structural members shall be in accordance with the available good practices and as per glue manufacturers' instructions as applicable.

11.2.4.1 End joints shall be scattered in adjacent laminations, which shall not be located in very highly stressed outer laminations.

11.2.5 *Testing*

Quality control, inspection and testing during production is essential to structural glulam. Special attention needs to be given to members exposed to weather.

For examining the quality of glue and its relative strength *vis-à-vis* species of timber in glued laminated construction, it is necessary to conduct block shear and other related tests in accordance with accepted standard [6-3A(11)]. Structural loading tests on prototype sizes provide information on the strength properties, stiffness or rigidity against deflection of a beam. Information on different strength functions as obtained from such indigenous tests carried out on laminated timber beams are given in Table 19, for guidance in design.

12 LAMINATED VENEER LUMBER

12.1 Certain reconstituted lignocellulosic products with fibre oriented along a specific direction have been developed and are being adopted for load bearing applications. Laminated veneer lumber is one such product developed as a result of researches in plantation grown species of wood. Density of laminated veneer lumber ranges from 600 to 750 kg/m^3 which is manufactured in accordance with accepted standard [6-3A(12)].

12.1.1 *Dimensions*

Sizes of laminated veneer lumber composite shall be inclusive of margin for dressing and finishing unless manufactured to order. The margin for dressing and finishing shall not exceed 3 mm in the width and thickness and 12 mm in the length.

12.1.2 *Permissible Defects*

a) Jointing gaps : Not more than 3 mm wide, provided they are well staggered in their spacing and position between the successive plies.

b) Slope of grain : Not exceeding 1 in 10 in the face layers.

c) Tight knot : Three numbers up to 25 mm diameter in 1m^2 provided they are spaced 300 mm or more apart.

d) Warp : Not exceeding 1.5 mm per metre length.

Table 19 Laminated Timber Beams — Structural Bending Test Under Third Point Loading

(*Clause* 11.2.5)

Species — *Pinus wallichiana* (Kail),
Effective span — 2.3 m, Cross section: 100 × 240 mm, and
Adhesive — Urea formaldehyde

Sl No.	Strength Functions	Nail Laminated Vertical Laminates with Four Full Size Planks Using 8 SWG, 100 mm Long Nails	Glue Laminated		Solid (Control) Specimen
			Vertical Laminates Four Planks, Each 25 mm Thick	Horizontal Laminates Eight Planks, Each 30 mm Thick	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Modulus of rupture, N/mm^2	27.439	31.363	21.568	30.509
ii)	Modulus of elasticity (×10^3 N/mm^2)	8.167	8.903	8.210	7.554
iii)	Fibre stress at limit of proportionality, N/mm^2	18.136	14.166	13.259	18.276
iv)	Maximum horizontal shear stress, N/mm^2	1.723	1.967	1.319	1.906

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12.1.3 *Strength Requirements*

The strength requirements for laminated veneer lumber shall be as per Table 20.

Table 20 Requirements of Laminated Veneer Lumber

(*Clause* 12.1.3)

Sl No.	Properties	Requirement
(1)	(2)	(3)
i)	Modulus of rupture, N/mm^2, *Min*	50
ii)	Modulus of elasticity, N/mm^2, *Min*	7 500
iii)	Compressive strength parallel to grain, N/mm^2, *Min*	35
iv)	Horizontal shear :	
	a) Parallel to laminae, N/mm^2, *Min*	6
	b) Perpendicular to laminae, N/mm^2, *Min*	8
v)	Tensile strength parallel to grain, N/mm^2, *Min*	55
vi)	Screw holding power :	
	a) Edge (N), *Min*	2 300
	b) Face (N), *Min*	2 700
vii)	Thickness swelling in 2 h water soaking (percent), *Max*	3

13 GLUED FINGER JOINTS

13.1 Finger joints are glued joints connecting timber members end-to-end (*see* Fig. 14). Such joints shall be produced by cutting profiles (tapered projections) in the form of v-shaped grooves to the ends of timber planks or scantling to be joined, gluing the interfaces and then mating the two ends together under pressure. Finger joints provide long lengths of timber, ideal for upgrading timber by permitting removal of defects, minimising warping and reducing wastage by avoiding short off-cuts.

13.1.1 In finger joints the glued surfaces are on the side grain rather than on the end grain and the glue line is stressed in shear rather in tension.

13.1.1.1 The fingers can be cut from edge-to-edge or from face-to-face. The difference is mainly in appearance, although bending strength increases if several fingers share the load. Thus a joist is slightly stronger with edge-to-edge finger joints and a plank is stronger with face-to-face finger joint.

13.1.1.2 For structural finger jointed members for interior dry locations, adhesives based on melamine formaldehyde cross linked polyvinyl acetate (PVA) are suited. For high humid and exterior conditions, phenol formaldehyde and resorcinol formaldehyde type adhesives are recommended. Proper adhesives should be selected in consultation with the designer and adhesive manufacturers and assessed in accordance with accepted standard [6-3A(11)].

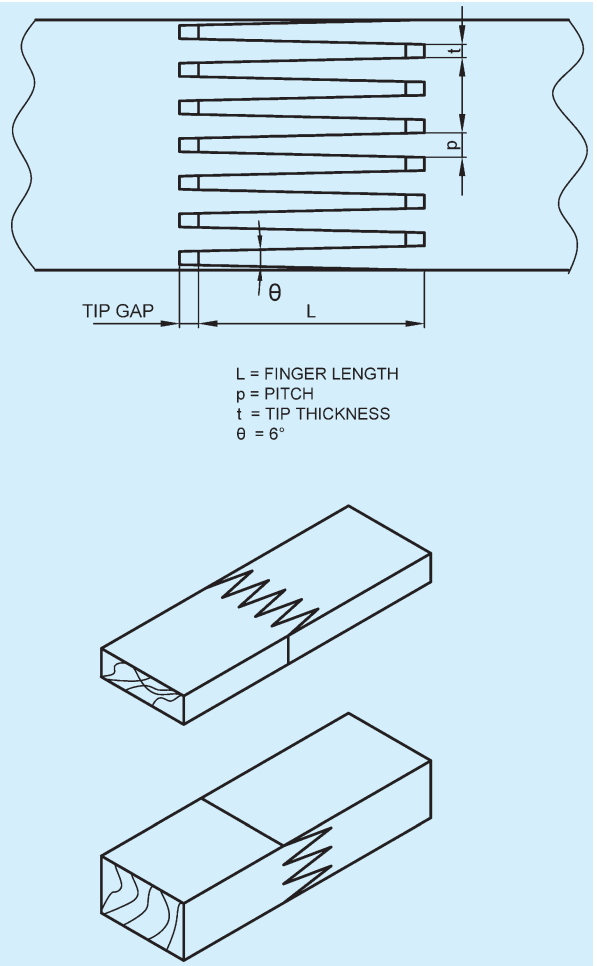


FIG. 14 TYPICAL FINGER JOINT GEOMETRY

13.1.2 *Manufacturing Process*

In the absence of sophisticated machinery, the finger joints shall be manufactured through intermediate technology with the following steps:

a) Drying of wood
b) Removal of knots and other defects
c) Squaring the ends of the laminating planks
d) Cutting the profile of finger joint in the end grain
e) Applying adhesives on the finger interfaces
f) Pressing the joint together at specified pressure
g) Curing of adhesive line at specified temperature
h) Planing of finger-jointed planks for smooth surface

13.1.3 *Strength*

Strength of finger joints depends upon the geometry of

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the profile for structural purpose; this is generally 50 mm long, 12 mm pitch.

13.1.3.1 The strength properties of glued finger joints are given in Table 21 for information and guidance in design.

13.1.3.2 Tip thickness shall be as small as practically possible.

14 STRUCTURAL USE OF PLYWOOD

Unlike sawn timber, plywood is a layered panel product comprising veneers of wood bonded together with adjacent layers usually at right angles. As wood is strongest when stressed parallel to grain, and weak perpendicular to grain, the lay up or arrangement of veneers in the panel determines its properties. When the face grain of the plywood is parallel to the direction of stress, veneers parallel to the face grain carry almost all the load. Some information/guidelines for structural use of plywood which should be manufactured in accordance with accepted standards [6-3A(13)] are given in **14.1** to **14.3**.

14.1 The plywood has a high strength to weight ratio, and is dimensionally stable material available in sheets of a number of thicknesses and construction. Plywood can be sawn, drilled and nailed with ordinary wood working tools. The glues used to bond these veneers together are derived from synthetic resins which are set and cured by heating. The properties of adhesives can determine the durability of plywood.

14.2 In glued plywood construction, structural plywood is glued to timber resulting in highly efficient and light structural components like web beams (I and box sections) (*see* Fig. 15 and Fig. 16) stressed skin panels (*see* Fig. 17) used for flooring and walling and pre-fabricated houses, cabins, etc. Gluing can be carried out by nail gluing techniques with special clamps. High shear strength of plywood in combination with high flexural strength and stiffness of wood result in structures characterized by high stiffness for even medium spans. Plywood can act as web transmitting shear stress in web bearing or stressed skin or sandwich construction. The effective moment of inertia of web beam and stressed skin construction depends on modular ratio that is, E of wood to E of plywood.

14.3 Structural plywood is also very efficient as cladding material in wood frame construction such as houses. This type of sheathing is capable of resisting racking due to wind and earthquake forces. Structural plywood has been widely used as diaphragm (horizontal) as in roofing and flooring in timber frame construction. It has been established that 6 mm thick plywood can be used for sheathing and even for web and stressed skin construction, 9 mm to 12 mm thick plywood is suitable for beams, flooring diaphragms, etc. Phenol formaldehyde (PF) and PRF adhesive are suitable for fabrication of glued plywood components. 6 mm to 12 mm thick structural plywood can be very well used as nailed or bolted gussets in fixing members of trusses or lattice girders or trussed rafters.

Normally, scarf joints are used for fixing plywood to required length and timber can be joined by using either finger or scarf joints. Arch panels, folded plates, shelves are other possibilities with this technique.

15 TRUSSED RAFTER

15.1 General

A roof truss is essentially a plane structure which is very stiff in the plane of the members, that is the plane in which it is expected to carry loads, but very flexible in every other direction. Thus it can virtually be seen as a deep, narrow girder liable to buckling and twisting under loads. In order, therefore, to reduce this effect, eccentricity of loading and promote prefabrication for economy, low-pitched trussed rafters are designed with bolt ply/nail ply joints. Plywood as gussets, besides being simple have inherent constructional advantage of grain over solid wood for joints, and a better balance is achievable between the joint strength and the member strength.

Trussed rafters are light weight truss units spaced at close centres for limited spans to carry different types of roof loads. They are made from timber members of uniform thickness fastened together in one plane. The plywood gussets may be nailed or glued to the timber to form the joints. Conceptually a trussed rafter is a triangular pin jointed system, traditionally meant to carry the combined roof weight, cladding services and wind loads. There is considerable scope for saving timber by minimizing the sections through proper design without affecting structural and functional requirements.

Trussed rafters are required to be supported only at their ends so that there is no need to provide load bearing internal walls, purlins, etc. In comparison with traditional methods of construction they use less timber and considerably reduce on-site labour, and mass production of reliable units can be carried out under workshop controls.

15.2 Design

15.2.1 The design may be based on the use of Group 'C' species of standard grade timber in accordance with good practice [6-3A(7)] for nail jointed timber construction. As the strength and stiffness of any framing depends upon efficiency of joints, design calls for proper size and number of fasteners, their spacings

Table 21 Strength Characteristics of Glued Finger Joints

(*Clause* 13.1.3.1)

Timber species — *Pinus wallichiana* (Kail)

(Averaged test results)

Sl No.	Character → / Treatment ↓	Compressive Parallel to Grain Tests			Tension Parallel to Grain Tests			Static Bending Tests											
								Central Point Loading						Two Point Loading					
								Edge-wise			Flat-wise			Edge-wise			Flat-wise		
		Maximum Compressive Stress (N/mm^2)	Fibre Stress at EL (N/mm^2)	MOE ($\times 10^3$ N/mm^2)	Maximum Tensile Stress (N/mm^2)	Tensile Stress at EL (N/mm^2)	MOE ($\times 10^3$ N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE ($\times 10^3$ N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE ($\times 10^3$ N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE ($\times 10^3$ N/mm^2)	Fibre Stress at EL (N/mm^2)	MOR (N/mm^2)	MOE ($\times 10^3$ N/mm^2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	UL_1	31.196	16.971	10.202	30.019	23.446	10.202	20.993	29.136	6.769	39.142	46.401	8.142	25.114	28.743	8.044	32.471	38.553	9.516
ii)	UL_2	37.474	17.462	11.282	30.607	23.642	10.301	20.209	31.686	6.671	35.120	46.205	7.161	23.446	42.085	7.652	41.202	51.306	9.712
iii)	UL_3	35.905	19.914	10.595	32.667	23.838	10.006	22.171	35.022	6.867	38.750	47.480	8.437	25.898	29.234	7.848	29.626	38.357	8.633
iv)	PL_1	28.743	21.484	9.908	20.895	17.560	10.497	20.699	23.446	8.142	22.955	27.076	9.123	18.443	21.876	7.848	25.506	27.174	8.927
v)	PL_2	28.743	19.424	10.006	18.149	17.069	9.614	16.285	18.639	5.984	24.133	26.095	8.731	16.579	17.854	7.259	26.389	28.547	8.535
vi)	PL_3	27.860	20.111	9.908	24.721	19.326	10.497	15.009	17.069	7.652	21.680	26.193	8.829	10.301	11.183	6.867	26.487	30.313	11.183
vii)	C	35.512	27.959	10.301	31.490	23.152	10.104	25.506	45.518	7.063	36.788	57.192	7.063	31.883	44.537	7.946	38.161	52.582	9.221

MOE — Modulus of elasticity (values rounded off for decimals)

MOR — Modulus of rupture

EL — Elastic limit

U — Urea formaldehyde with liquid hardener

P — Cold setting phenolic glue with hardener

L_1 — Finger length 38 mm

L_2 — Finger length 50 mm

L_3 — Finger length 62 mm

C — Control (unjointed specimen)

NOTE — The information given in the above table is based on the tests conducted on glued finger joints of varying lengths/pitch with two types of adhesives.

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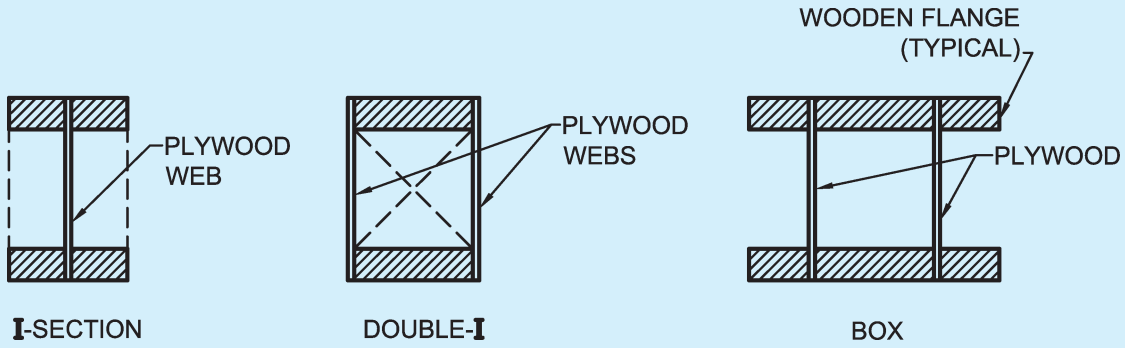


FIG. 15 TYPICAL CROSS-SECTION OF WEB BEAMS

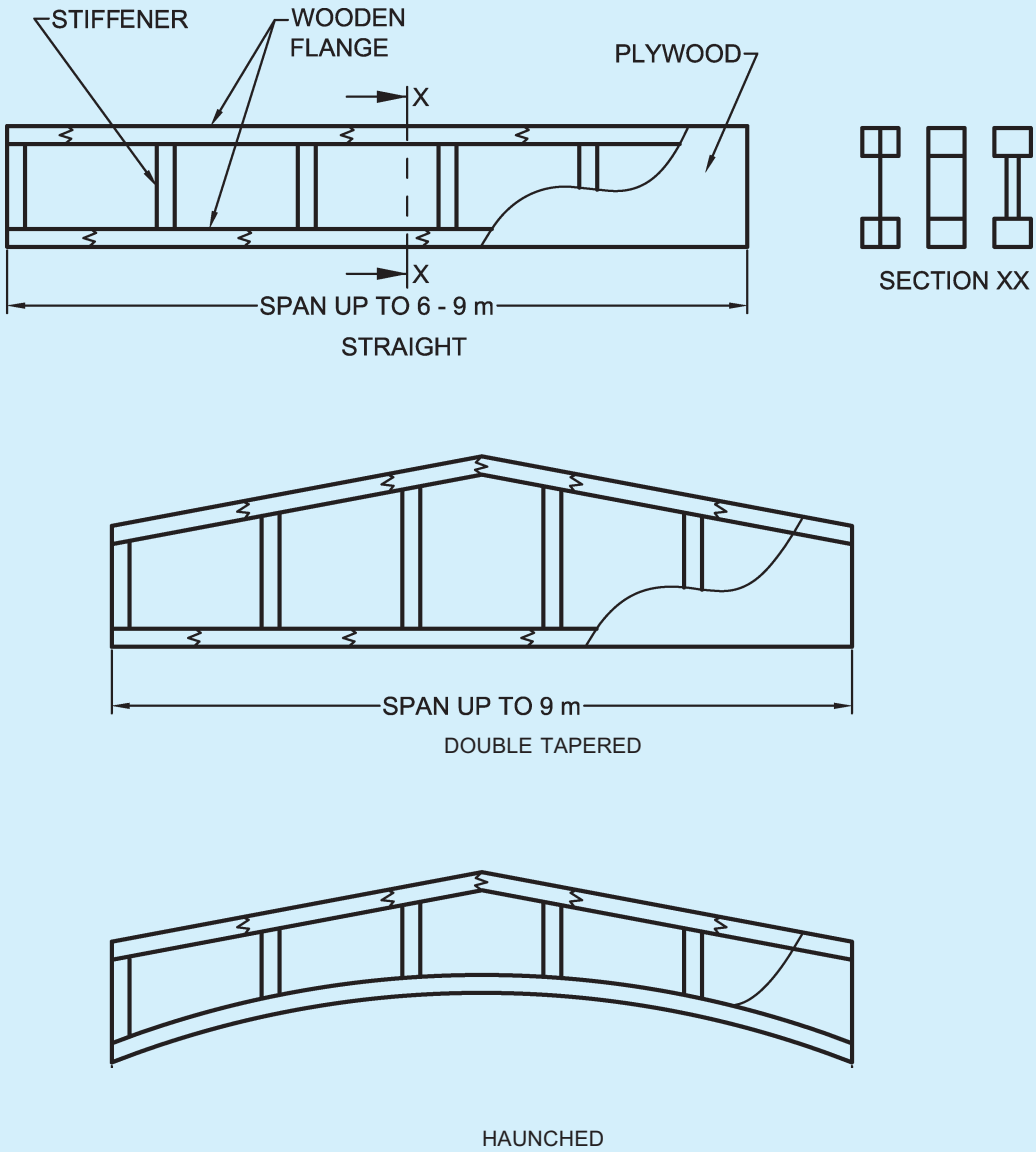


FIG. 16 WEB BEAM CONFIGURATIONS

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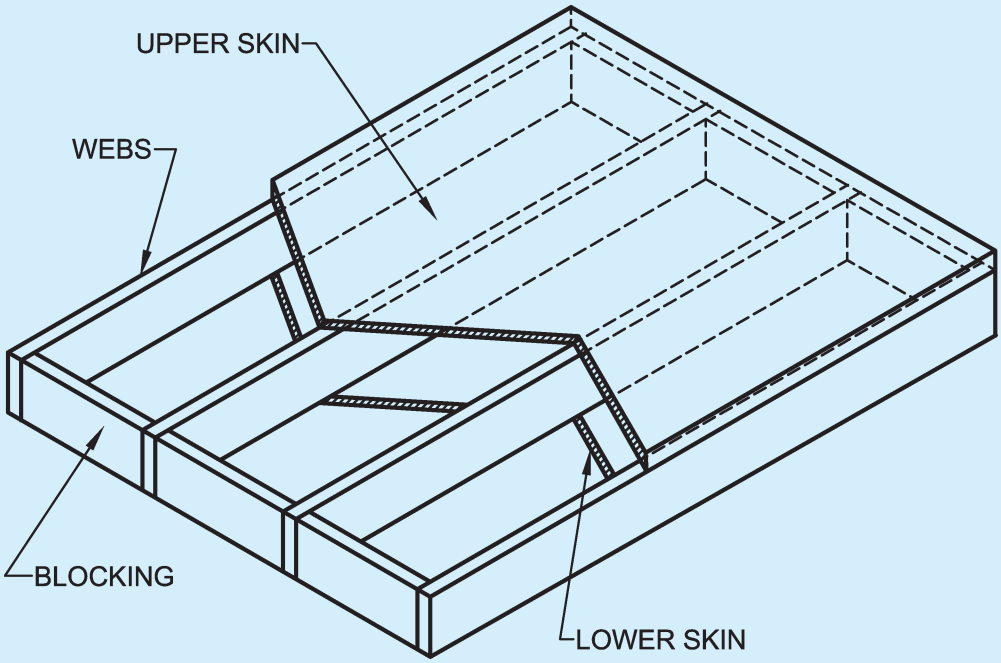


FIG. 17 STRESSED SKIN PANEL CONSTRUCTION (SINGLE SKIN OR DOUBLE SKIN)

and thickness of gusset plates for transfer of stress from one member to the other.

Trussed rafter shall be designed to sustain the dead and imposed loads specified in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code and the combinations expected to occur. Extra stresses/ deflections during handling, transportation and erection shall be taken care of. Structural analysis, use of load-slip and moment, rotation characteristics of the individual joints may be used if feasible. Alternatively, the maximum direct force in a member may be assessed to be given by an idealized pin-jointed frame-work, fully loaded with maximum dead and imposed load in the combination in which they may reasonably be expected to occur.

NOTE — Some trussed rafters with plywood gusseted joint, span 6 m, designed in *Pinus roxburghii* (Chir) were tested in prototypes at Forest Research Institute, Dehra Dun for structural adequacy as under, in accordance with accepted standards [6-3A(14)],

a) destructive test (short-term); and

b) proof test (long-term).

Results demonstrated an apparent factor at safety of 4 and actual factor of safety of 3. Deflection was well within the allowable deflection at design load. A pre-camber of 1/240 of span at the bottom chord was recommended.

15.3 Timber

The species of timber including plantation grown species which can be used for trussed rafter construction and permissible stresses thereof shall be in accordance with Table 1. Moisture contents shall be as per zonal requirements in accordance with **4.4**.

15.4 Plywood

Boiling water proof (BWP) grade preservative treated plywood shall be used in accordance with accepted standards [6-3A(13)]. Introduction of a plywood gusset simplifies the jointing and in addition provides rigidity to the joint. Preservation of plywood and other panel products shall be done in accordance with good practice [6-3A(15)].

15.5 Some design data on the lateral load bearing strength of common wire nails in plywood-to-wood joints are presented for timber species, Sal and Chir in Table 22, for guidance in design.

16 STRUCTURAL SANDWICHES

16.1 General

Sandwich constructions are composites of different materials including wood based materials formed by bonding two thin facings of high strength material to a light weight core which provides a combination of desirable properties that are not attainable with the individual constituent materials (*see* Fig. 18). The thin facings are usually of strong dense material since that are the principal load carrying members of the construction. The core should be stiff enough to ensure the faces remain at the correct distance apart. The sandwiches used as structural elements in building construction shall be adequately designed for their intended services and shall be fabricated only where there are adequate facilities for gluing or otherwise bonding cores to facings to ensure a strong and durable

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product. The entire assembly provides a structural element of high strength and stiffness in proportion to its mass.

Non-structural advantages can also be derived by proper selection of facing and core material, for example, an impermeable facings can be used to serve as a moisture barrier for walls and roof panels and core may also be selected to provide thermal and/or acoustic insulation, fire resistance, etc, besides the dimensional stability.

16.2 Cores

Sandwich cores shall be of such characteristics as to give to the required lateral support to the stressed facings to sustain or transmit the assumed loads or stresses. Core generally carries shearing loads and to support the thin facings due to compressive loads. Core shall maintain the strength and durability under the conditions of service for which their use is recommended. A material with low *E* and small shear modulus may be suitable.

16.3 Facings

Facings shall have sufficient strength and rigidity to resist stresses that may come upon them when fabricated into a sandwich construction. They shall be thick enough to carry compressive and tensile stresses and to resist puncture or denting that may be expected in normal usages.

16.4 Designing

Structural designing may be comparable to the design of I-beams, the facings of the sandwich represent the flanges of the I-beam and the sandwich core I-beam web.

16.5 Tests

Panels of sandwich construction shall be subject to testing in accordance with accepted standards [6-3A(17)]. Tests shall include, as applicable, one or more of the following:

a) Flexural strength/stiffness,
b) Edge-wise compressions,
c) Flat-wise compression,
d) Shear in flat-wise plane,
e) Flat-wise tensions,
f) Flexural creep (creep behaviour of adhesive),

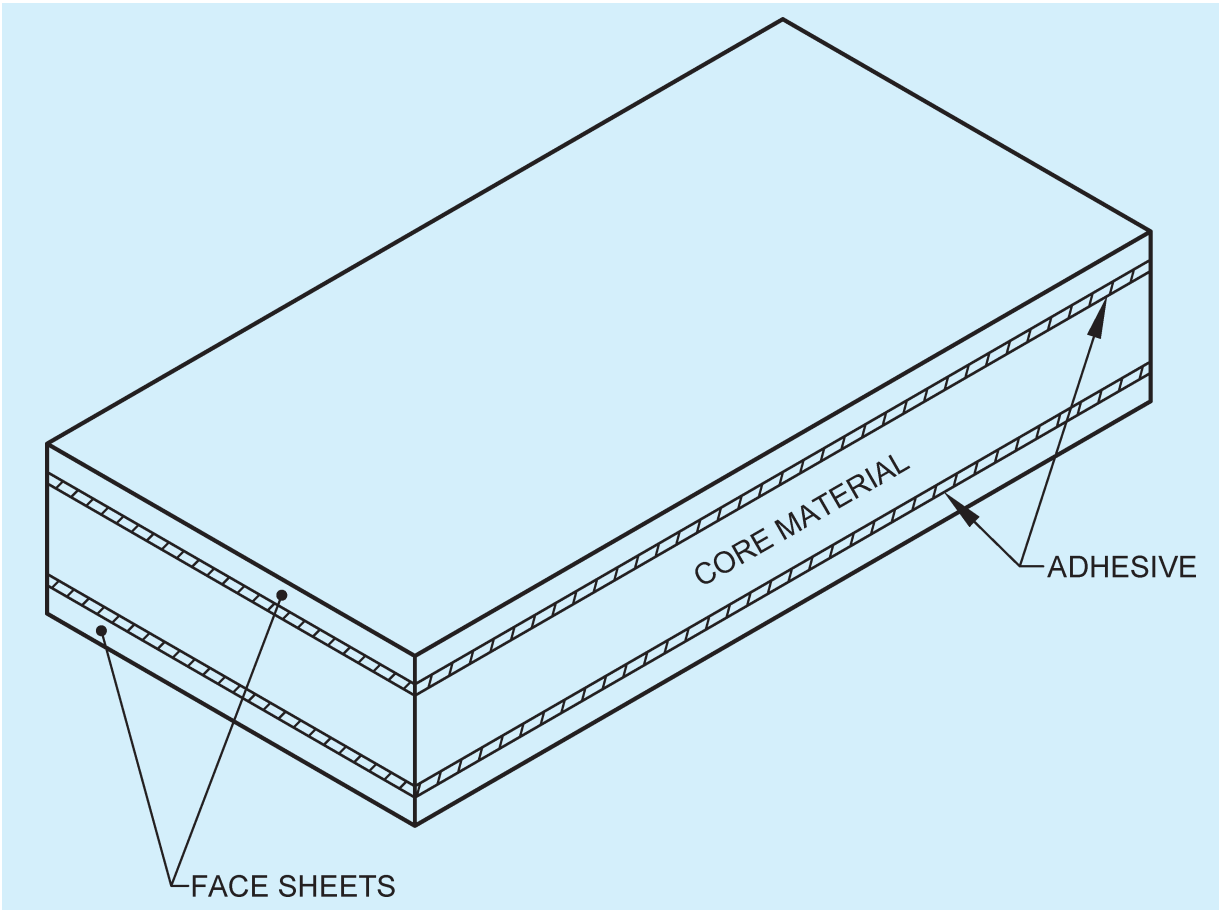


FIG. 18 SANDWICH CONSTRUCTION IN STRUCTURAL APPLICATIONS

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Table 22 Lateral Load Bearing Strength of Wire Nails in Plywood-to-Wood Composite Joints Permissible Lateral Strength of 9 SWG (3.55 mm dia) Nail in Double Shear (kg) Safe Load per Nail

(*Clause* 15.5)

Thickness of Members mm		Facing Veneer of Plywood Along the Loading Direction (Loading Direction in the Main Member of the Joint)								Across Loading Direction (Loading Direction in the Main Member of the Joint) Loaded Parallel to Grain	
Main Member Timber	Side Members Plywood	Parallel to Grain		Perpendicular to Grain		At 60° Inclination to Grain		At 30° Inclination to Grain			
		Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures	Permanent Structures	Temporary Structures
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
						Species: *Shorea robusta* (Sal)					
30		109	121	135	156	151	168	140	164		
40	9	123	124	121	166	142	181	145	158	142	151
50		89	123	157	167	162	170	99	139		
30		157	177	150	154	164	179	111	171		
40	12	179	191	145	193	154	194	132	192	135	180
50		151	183	149	191	155	202	128	182		
30		245	283	Larger thickness of plywood is generally not recommended to be used							
40	19	259	264	in structures unless heavily stressed						150	209
50		231	316								
						Species: *Pinus roxburghii* (Chir)					
30		102	127	112	141	60	125	92	124		
40	9	103	148	100	153	98	142	101	141	107	148
50		87	133	119	150	50	168	50	114		
30		133	163	116	111	80	132	127	150		
40	12	114	173	112	136	64	157	137	174	118	174
50		99	194	117	138	90	170	119	161		
30		219	309	Larger thickness of plywood generally not used in structures unless							
40	19	238	306	heavily stressed.						158	249
50		236	333								

NOTES

1 Plywood shall be of shuttering grade as per the accepted standard [6-3A(16)].

2 Subject to satisfying all the design requirements in structures,

a) For denser species, timber thickness of 30 mm may be used by means of a plywood of 9 mm thickness for all practical purposes. For species like Chir, plywood thickness of 12 mm may be used with 30 mm or 40 mm timber thickness.

b) Regarding aligning the veneers of plywood plate; nail strength data may be used as design function irrespective of alignment of face veneer to overcome practical difficulties.

c) While prebore is essential to drive nail in structural timber as per the good practice [6-3A(7)], plywood plates need not be prebored for nailing.

g) Cantilever vibrations (dynamic property), and

h) Weathering for dimensional stability.

17 LAMELLA ROOFING

17.1 General

The lamella roofing offers an excellent architectural edifice in timber, amenable to prefabrication, light weight structure with high central clearance. It is essentially an arched structure formed by a system of intersecting skewed arches built-up of relatively short timber planks of uniform length and cross-section. Roof is designed as a two hinged arch with a depth equal to the depth of an individual lamella and width equal to the span of the building. The curved lamellas (planks) are bevelled and bored at the ends and bolted together at an angle, forming a network (grid) pattern of mutually braced and stiffened members (*see* Fig. 19 and Fig. 20).

The design shall be based on the balanced or unbalanced assumed load distribution used for roof arches. Effect of deformation or slip of joints under load on the induced stresses shall be considered in design. Thrust components in both transverse and longitudinal directions of the building due to skewness of the lamella arch shall be adequately resisted. Thrust at lamella joints shall be resisted by the moment of inertia in the continuous lamella and roof sheathing (decking) of lamella roofing. The interaction of arches in two directions adds to the strength and stability against horizontal forces. For design calculations several assumption tested and observed derivations, long-duration loading factors, seasoning advantages and effects of defects are taken into account.

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17.2 Lamellas

Planking shall be of a grade of timber that is adequate in strength and stiffness to sustain the assumed loads, forces, thrust and bending moments generated in lamella roofing. Lamella planks shall be seasoned to a moisture content approximating that they will attain in service. Lamella joints shall be proportioned so that allowable stresses at bearings of the non-continuous lamellas on the continuous lamellas or bearings under the head or washer of bolts are not exceeded.

17.2.1 *Design Sequence and Methods*

A lamella roof is essentially an arch (segmental, parabolic or elliptical) formed by a system of intersecting skewed arches, built up of relatively short members of small dimensional planks called 'lamellas'. The arch is designed as a two hinged arch with a depth equal to the depth of the individual lamella and a width equal to the span of the building of certain length. For design purposes, a unit length of the given span forming a single arch is considered loaded with the given loads. For the particular arch, curvature offers resultant outward suction on the roof to be less than its self weight to facilitate design and construction for economy. (This is possible only when the semi-angle of arch is less than 42°).

Some design assumptions are:

a) Self weight of timber components (in particular species), namely lamella planks, roof boarding, wall plates, etc is assumed for the particular timber section.

b) Imposed loads as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code for curved roofs where slope at springing point is greater than 10°. Take the reduced worked out values of imposed loads for actual design for timber components as per this Subsection.

c) Wind load is taken as per Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code for structures with large openings, that is, openings larger than 20 percent of wall area (or as the case may be).

d) Stresses developed in curved lamella planks should not exceed the allowable safe stresses of timber species used.

e) Range of various sizes of timber planks for lamellas shall be as under:
   1) *Length* — 1.0 m to 2.5 m
   2) *Section*:
      i) *Thickness* — 25 mm to 50 mm
      ii) *Width of uncurved plank* — 100 mm to 250 mm

f) Limitations to be observed for spacing of lamellas over wall plate (or bressummer):
   1) i) For skew angle of 21° (diamond angle 42°).
      ii) For 2.5 m length of plank, spacing shall be 870 mm.
      iii) For 1.0 m length, spacing shall be 360 mm.
   2) i) For skew angle of 19° (diamond angle 38°).
      ii) For 2.5m length of plank, spacing shall be 800 mm.
      iii) For 1.0 m length of plank, spacing shall be 320 mm.

g) Value of horizontal thrust, resultant thrust and maximum bending moment, are taken on per metre length of structure in case of transverse direction of arch.

h) Bending moment may be suitably reduced, if so desired by the designer, by applying stability factor if the ratio of the length of structure to the curved length of arch so warrants (as this ratio increases, the stability of the structure decreases).

j) The thrust in the skewed direction of arch, within one spacing of lamellas is shared by two lamella-lines in skewed direction.

k) More than one bolt (MS) shall be used for nodal joint. For design check of bolt against tension, half the value of thrust in skewed direction will be considered for calculations purposes in light of (j) [in case of stiff roof covering material (that is, CGI sheet, close boarding, etc) all lamella planks will be held jointly-behaving as a monolithic unit to a large extent and the actual stresses developed in bolt will be reduced resulting in lesser actual tension in bolts than the calculated design value].

17.2.1.1 *Horizontal thrust*

Any of the known methods for solving a statically indeterminate structure is used to evaluate horizontal thrust, bending moment, etc, to which a segmental arch will be subjected under the given condition of loadings. For 60° segmental arch, the radius of an arch will be equal to the span of the arch. Horizontal thrust can be calculated by the following two methods:

a) *Method 1*

Horizontal thrust (H_B) per length of one bay (that is, distance between 'tie-rod spacing' or 'column centres'):

$$H_B = (DL + IL) \times \left[\frac{l^2 + s_t^2}{8r} \right]$$

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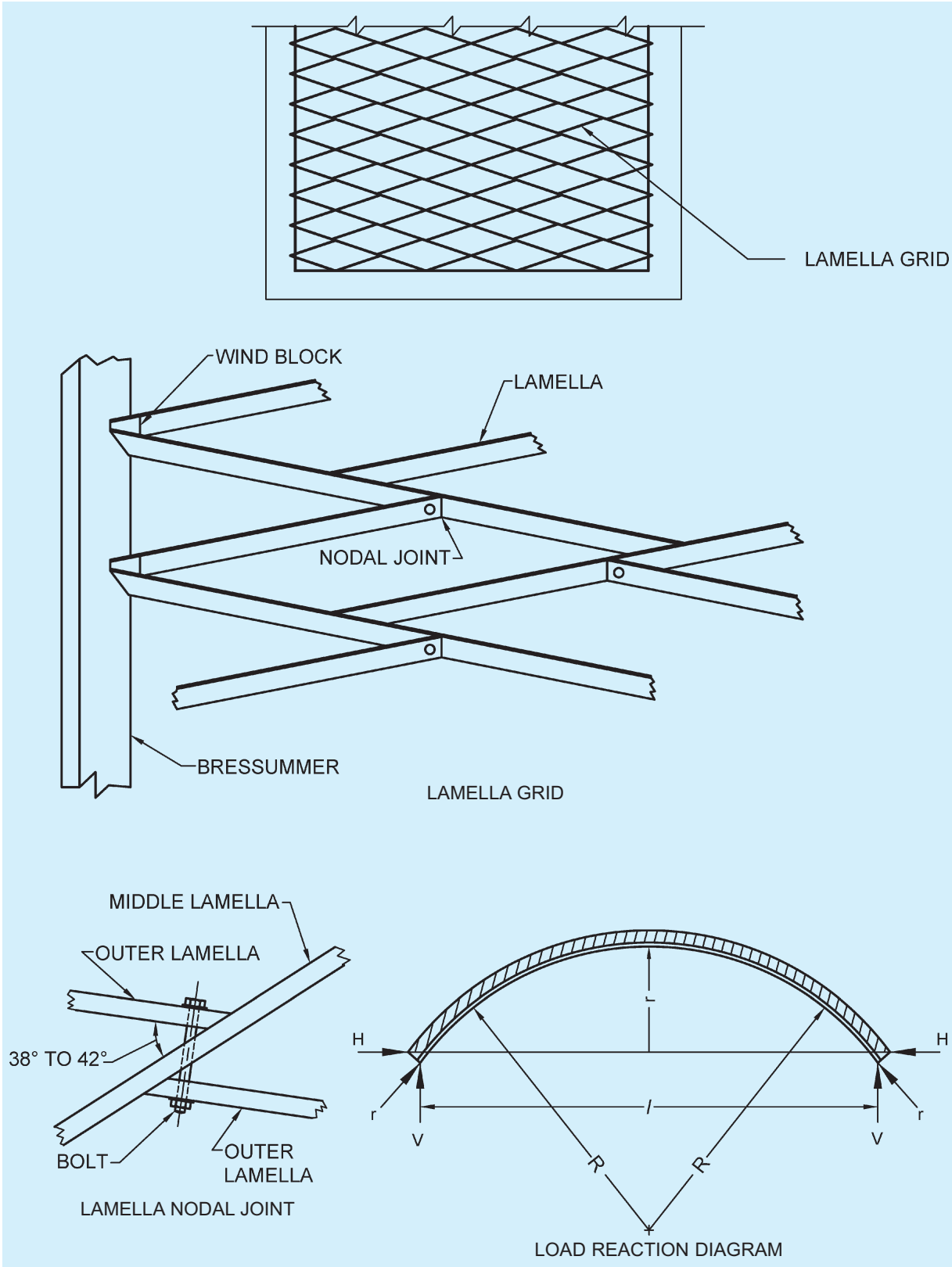
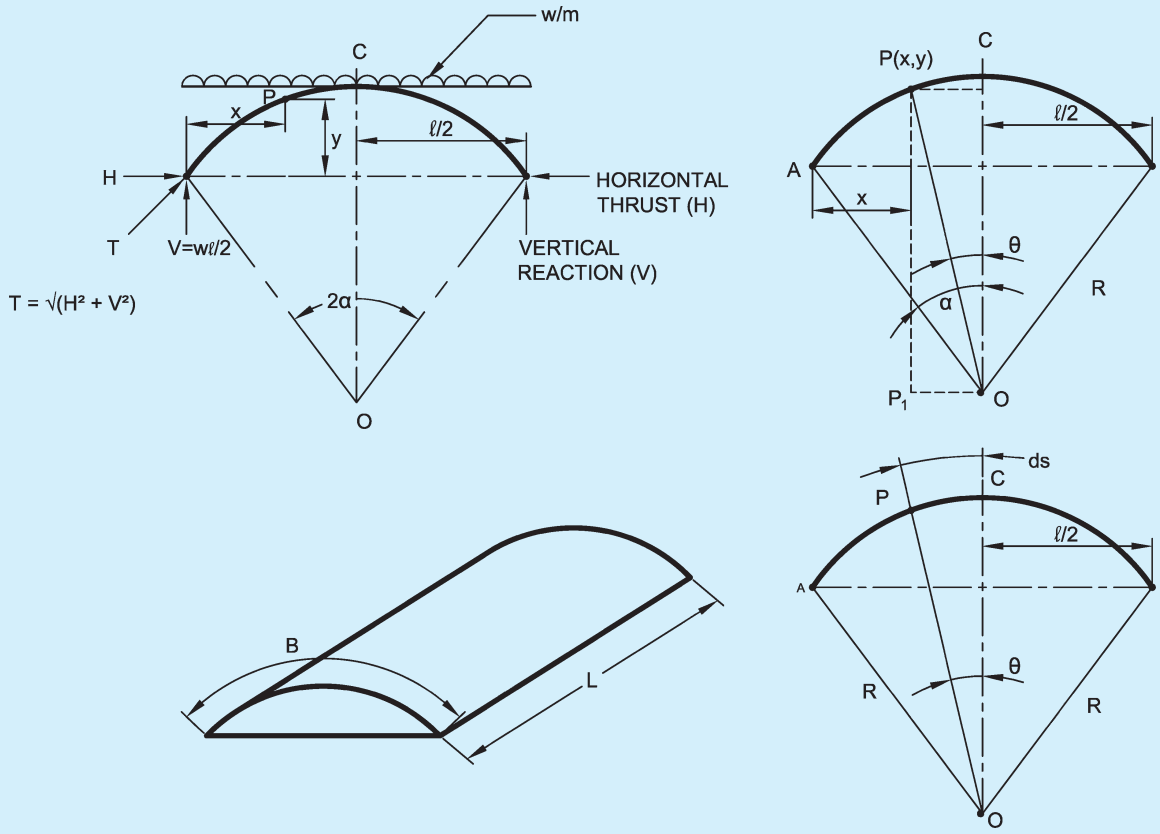


FIG. 19 TYPICAL ARRANGEMENT OF LAMELLA ROOFING

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NOTES

1 When the ratio of the length of the structure (L) to the circumference of the arch (B) increases, stability of the structure decreases. The roof should be designed as,

a) short roof (say, L/B = 1), or

b) long roof (say, L/B = 1.5).

Shorter roofs have an advantage over long roofs for economical design. However, there is no such advantage beyond L/B of 4.

2 Due to stiff roof covering material, stiffness is induced in an arch, which results in safer design.

FIG. 20 STABILITY OF LAMELLA ARCH ROOF

where

H_B = horizontal thrust, in N;
DL = dead load, in N;
IL = imposed load, in N;
l = span of arch, in m;
s_t = tie-rod spacing, in m; and
r = rise of roof arch, in m.

b) *Method 2*

Horizontal thrust (H_1) per metre length of structure (in N):

$$H_1 = C \times w \times R$$

where

C = coefficient varying with the angle of arch and radius of arch;
w = equivalent distributed load per metre of span, in N/m; and
R = radius of circular arch, in m.

Horizontal thrust (H_1) is evaluated as:

$$H_1 = \frac{\int \mu y ds}{\int y^2 ds}$$

where

H_1 = horizontal thrust (per metre length of structure), in N.
μ = bending moment at any point 'P' distance 'x' metre from one end of springing point of arch and for vertical loads only (consider arch as a beam simply supported carrying the same load).
y = height of point 'P' above springing line of arch.
θ = angle which the point 'P' makes at the centre of arch with the vertical.
ds = $Rd\theta$

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Now solution for numerator,

$$\mu = \frac{wl}{2}x - wx\frac{x}{2}$$

$$= \frac{wx}{2}(l - x)$$

where

$$x = \frac{l}{2} - R\sin\theta$$

$$= \frac{R}{2} - R\sin\theta$$

$$= R\left(\frac{1}{2} - \sin\theta\right)$$

and $y = R\cos\theta - R\cos\alpha$

$y = R(\cos\theta - \cos\alpha)$

and $ds = Rd\theta$

Substitute the values in expression

$$\int \mu y ds = \int \frac{wx(l-x)}{2} R(\cos\theta - \cos\alpha) R d\theta$$

Solve for limits of θ from $-\alpha$ to $+\alpha$

$$= \int_0^{\alpha} wR^4\left(\frac{1}{4} - \sin^2\theta\right)(\cos\theta - \cos\alpha)d\theta$$

Again for denominator,

$$\int y^2 ds = \int_{-\alpha}^{+\alpha} R^2(\cos\theta - \cos\alpha)^2 R d\theta$$

$$= 2R^3\int_0^{\alpha}(\cos\theta - \cos\alpha)^2 d\theta$$

Therefore, $H_1 = \dfrac{\int \mu y ds}{\int y^2 ds}$

$$= \frac{wR^4\int_0^{\alpha}\left(\frac{1}{4} - \sin^2\theta\right)(\cos\theta - \cos\alpha)d\theta}{2R^3\int_0^{\alpha}(\cos\theta - \cos\alpha)^2 d\theta}$$

On simplification of the above equation for a particular arch, $\alpha = 30°$, $R = l$ (α in radian = 0.5 approx),

$$\sin\alpha = 1/2$$

$$\cos\alpha = \sqrt{3}/2$$

$H_1 = 0.923\ wR$

Vertical reaction, $V_1 = \dfrac{\text{Total load} \times \text{Span}}{2}$ at each end of arch due to dead and live loads per metre length (curved strip) of arch roofing.

17.2.1.2 *Resultant thrust*, T_1

Due to horizontal thrust and the vertical reaction, resultant transverse thrust, in kg per metre length on the arch can be worked out:

$$T_1 = \sqrt{H_1^2 + V_1^2}$$

17.2.1.3 *Maximum bending moment*

Bending moment at any point '*P*' on arch making an angle of θ with the vertical line OC is, $BM = \mu - (H \times y)$

$$= \frac{wR^2}{2}\left(\frac{1}{4} - \sin^2\theta\right) - 0.923wR^2\left(\cos\theta - \frac{\sqrt{3}}{2}\right)$$

Differentiating the above expression for BM, we get

$$\frac{dM}{d\theta} = \left(-\sin\theta\cos\theta + 0.923\sin\theta\right)wR^2$$

It is well known that $\dfrac{dM}{d\theta} = \text{shear force}$

This shear is zero when BM is maximum, that is,

either θ = zero

or $\cos\theta = 0.923$

Therefore, $\theta = \cos^{-1}0.923 = 22.6°$

Substituting these values in the above equation of bending moment, we get maximum BM, that is, the maximum BM occurs at,

a) crown of arch, and
b) at 22.6° from the central line OC.

Thus when $\theta = 0$,

$$BM = \frac{wR^2}{2} \times \frac{1}{4} - 0.923wR^2\left(1 - \frac{\sqrt{3}}{2}\right)$$

$$= wR^2\ (0.125 - 0.123\ 68)$$

$$= 0.001\ 32\ wR^2$$

When $\theta = 22.6°$, $\sin\theta = 0.384$

$$BM = \frac{wR^2}{2}\left(\frac{1}{4} - 0.384\right)^2 - 0.923wR^2\left(0.923 - 0.866\right)$$

$$= wR^2\ (0.125 - 0.073\ 728) - 0.923 \times 0.057\ wR^2$$

$$= -0.001\ 339wR^2 \text{ or say } -0.001\ 34wR^2$$

The arch has to be designed for the greater of the two values (subject to the longitudinal stiffness coefficient on the basis of ratio L/B of length of the structure to the circumference of the arch) for economical design.

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NOTE — Value of horizontal thrust, H_1, resultant thrust, T_1 and bending moment, M_1 will be for 1 m length of building.

17.2.1.4 *Spacing of lamellas*

Lengthwise spacing of lamellas depends upon the angle of skew lamellas and the length of the planks used for lamellas (As a general guidance it may be stated that the angle enclosed between the intersecting skewed arches should not exceed 45°. An angle between 38° and 40° is always preferred.)

17.2.1.5 *Design of lamella sizes*

Net section of each of lamellas is assumed in curved profile conforming to the curvature of the roof surface.

Maximum BM = M_s over 600 mm spacing of lamella in the direction of skew angle, for example

$$= \frac{0.6M_1 \times 10}{\cos 19°} \text{ Nm}$$

where

M_1 = maximum bending moment per metre length of structure in transverse direction.

And maximum thrust N (in Newton) on this strip of 600 mm in skewed direction is:

$$N = \frac{0.6T_1}{\cos 19°} \times \frac{1}{2}$$

(as the force T_1 is shared by two lines of lamellas)

where

N = maximum thrust on 600 mm strip in skewed direction.

T_1 = resultant thrust in transverse direction (in N) per metre length of structure.

Now total compressive and flexural stresses should not exceed the allowable safe stress of timber species used for lamella plank. For fulfilling this condition the following equation should be checked:

$$\frac{N/A}{f_{c\text{II}}} + \frac{M_s/Z}{f_t} \leq 1$$

where

N = maximum thrust in skewed direction on strip of 600 mm (in N) corresponding to the maximum bending moment;

Z = section modulus of lamella plank, in mm^3;

A = cross-sectional area of lamella plank, in mm^2;

$f_{c\text{II}}$ = safe compression strength of timber fibre parallel to grain, in N/mm^2;

f_t = safe tensile strength of timber parallel to grain, in N/mm^2; and

M_s = bending moment over 600 mm strip of arch in skewed direction, in Nmm;

NOTE — In case the lamella plank is under stressed, the minimum section for practical reasons shall be 25 mm × 100 mm subject to satisfying minimum edge and intermediate distances for accommodating bolts at nodal joints.

17.2.1.6 *Design of bolts for nodal joint*

To avoid any possibility of hinge action with the use of bolts, it is imperative to adopt two or more bolts of smaller diameter and adequately spaced in accordance with the good practice [6-3A(9)].

Assume diameter of bolt 'd' in mm, and length of bolt in one plank 't' mm, that is, thickness of middle lamella plank.

Area of contact of bolt with timber plank = $d \times t$ mm^2

a) *Check against crushing of timber at contact point of bolt* — For the bolt to transmit load without crushing the timber fibres, the following condition shall be satisfied:

$t \times d \times$ compressive stress perpendicular to grain for the timber species > P

where

P= total load to be transmitted through bolt, in N.

b) *Check against tension in bolt* — Arrangement of bolts at the junction of lamellas result in pure tension in bolt as bolt line is at right angle to the outer two lamellas.

Therefore, $Z_t = N \times \cot 2\phi$

where

Z_t = tension in bolt, in N.

N = normal thrust corresponding to maximum moment M_s, in N

$$= \frac{T_1}{\cos \phi} \times \frac{1}{2}$$

T_1 = resultant thrust in transverse direction (in N) per metre length of structure.

Therefore,

Area of bolt (A_t) × tensile stress of steel (F_t) ≥ Z_t

Area of bolt required for safe design = Z_t/F_t

Select the diameter to engage at least two bolts.

(Required area of bolt is the effective area after considering reduction of area at the threaded end, which is generally 17 percent of the actual bolt diameter)

17.2.1.7 *Design of steel washer at joints*

Area of steel plate = A_t mm^2

Stress perpendicular to grain of wood at the point of contact with steel plate washer = Z_t/A_t N/mm^2

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If $Z_t/A_t \leq$ compressive stress perpendicular to grain of the species of timber used, the assumed section is safe.

17.3 Construction

Design and construction of lamella roofs in India assumes the roof surfaces to be cylindrical with every individual lamella an elliptic segment of an elliptical arch of constant curved length but of different curvature. Lamella construction is thus more of an art than science as there is no analytical method available for true generation of schedule of cutting lengths and curvature of curved members forming the lamella grid. Dependence of an engineer on the practical ingenuity of master carpenter is almost final. All the lamella joints shall be accurately cut and fitted to give full bearing without excessive deformation or slip. Bolts at lamella splices shall be adequate to hold the members in their proper position and shall not be over tightened to cause bending of the lamellas or mashing of wood under the bolt heads. Connection of lamellas to the end arches shall be adequate to transmit the thrust or any other force. Sufficient false work or sliding jig shall be provided for the support of lamella roof during actual construction/erection. To avoid excessive deformation in a lamella system, all joints should be carefully fitted and well tightened.

18 NAIL AND SCREW HOLDING POWER OF TIMBER

18.1 General

One of the most common ways of joining timber pieces to one another is by means of common wire nails and wood screws. Timber is used for structural and non-structural purposes in form of scantlings, rafters, joists, boarding, crating and packing cases, etc, needing suitable methods of joining them. Nevertheless it is the timber which holds the nails or screws and as such pulling of the nails/screws is the chief factor which come into play predominantly. In structural nailed joints, nails are essentially loaded laterally, the design data for which is already available in good practice [6-3A(7)]. Data on holding power of nails/screws in different species is also useful for common commercial purposes. The resistance of mechanical fastenings is a function of the specific gravity of wood, direction of penetration with respect to the grain direction, depth of penetration and the diameter of fastener assuming that the spacing of fasteners should be adequate to preclude splitting of wood.

18.2 Nails

Nails are probably the most common and familiar fastener. They are of many types and sizes in accordance with the accepted standard [6-3A(18)]. In general nails give stronger joints when driven into the side grain of wood than into the end grain. Nails perform best when loaded laterally as compared to axial withdrawal so the nailed joints should be designed for lateral nail bearing in structural design. Information on withdrawal resistance of nails is available and joints may be designed for that kind of loading as and when necessary.

18.3 Screw

Next to the hammer driven nails, the wood screw may be the most commonly used fastener. Wood screws are seldom used in structural work because of their primary advantage is in withdrawal resistance for example for fixing of ceiling boards to joists, purlin cleats, besides the door hinges, etc. They are of considerable structural importance in fixture design and manufacture. Wood screws are generally finished in a variety of head shapes and manufactured in various lengths for different screw diameters or gauges in accordance with the accepted standards [6-3A(19)].

The withdrawal resistance of wood screws is a function of screw diameter, length of engagement of the threaded portion into the member, and the specific gravity of the species of wood. Withdrawal load capacity of wood screws are available for some species and joints may be designed accordingly. End grain load on wood screws are un-reliable and wood screws shall not be used for that purpose.

18.4 Nail and screw holding power is one of the very important properties of timber which governs its utilization in diverse industrial and engineering fields. This has been evaluated by experimental method followed for evaluation of such properties as per normal procedure given in the accepted standards [6-3A(20)], using,

a) *Specimen* — Of size 150 mm × 50 mm × 50 mm;
b) *Nail* — Diamond pointed wire nail of 50 mm length and 2.50 mm shank diameter;
c) *Screw* — Galvanized gimlet pointed, No. 8; and
d) *Conditions* — Penetration 25 mm. While nails were driven by a hand hammer, screws were driven by a screw driver in a 2.5 mm diameter prebore on radial, tangential and end faces.

Composite nail and screw holding power of some Indian timbers, evaluated as above, is presented in Table 23 for guidance in design.

19 PROTECTION AGAINST TERMITE ATTACK IN BUILDINGS

19.1 Two groups of organisms which affect the mechanical and aesthetic properties of wood in houses

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Table 23 Composite Nail and Screw Holding Power of Some Indian Timbers

(*Clause* 18.4)

Sl No.	Timber Species	Locality	Standard Specific Gravity (Weight Oven Dry)/ Volume Green	Composite Holding Power N	
				Nail	Screw
(1)	(2)	(3)	(4)	(5)	(6)
i)	*Acacia catechu* (Khair)	UP	0.888	2 119	5 454
ii)	*Acacia ferruginea*	Maharashtra	0.876	1 893	5 700
iii)	*Acacia leucophloea*	MP	0.660	1 776	4 503
iv)	*A. nilotica* (Babul)	UP	0.670	1 815	5 219
v)	*Acrocarpus fraxinifolius* (Mundani)	UP	0.662	1 020	2 865
vi)	*Adina oligocephala*	Arun. Pr.	0.612	1 795	3 453
vii)	*Aesculus indica* (Horse chestnut)	HP	0.428	755	2 119
viii)	*Albizia lucida*	Arun. Pr.	0.501	1 462	3 188
ix)	*Anogeissus sericea*	MP	0.738	1 570	4 944
x)	*Aphanamixis polgstachya* (Pitraj)	WB	0.557	1 648	3 110
xi)	*Araucaria cunning hanvil*	UP	0.486	1 128	2 943
xii)	*Aritocarpus lakoocha* (Lakooch)	UP	0.530	1 050	2 982
xiii)	*Azadirachta indica* (Neem)	UP	0.693	2 001	5 219
xiv)	*Betula alnoides* (Birch)	WB	0.569	1 648	3 237
xv)	*Broussonetia papyrifera*	UP	0.394	746	1 383
xvi)	*Canarium strictum* (White dhup)	Assam	0.486	1 207	2 619
xvii)	*Cassia fistula* (Amaltos)	UP	0.746	2 109	4 748
xviii)	*Cassia siamea*	MP	0.697	1 315	3 649
xix)	*Castanopsis indica* (Indian chestnut)	Megh.	0.591	1 697	3 090
xx)	*Cupressus cashmeriana*	UP	0.409	903	2 325
xxi)	*Dipterocarpus bourdilloni* (Gurjan)	Kerala	0.577	912	2 766
xxii)	*Dipterocarpus indicus* (Gurjan)	Karnataka	0.618	1 109	2 904
xxiii)	*Eucalyptus hybrid*	UP	0.632	1 736	2 453
xxiv)	*Exbucklandia –populnea* (Pipli)	WB	0.558	1 403	3 443
xxv)	*Fraxinus udheri*	UP	0.539	1 354	3 483
xxvi)	*Gluta travancorica* (Gluta)	TN	0.621	1 324	2 923
xxvii)	*Grewia tiliifolia* (Dhaman)	Karnataka	0.679	1 746	2 884
xxviii)	*Holarhena antidysenterica* (Kurchi)	UP	0.445	1 020	2 698
xxix)	*Lagerstroemia specicosa* (Jarul)	Kerala	0.531	1 697	2 717
xxx)	*Lannea coromendelica* (Jhingan)	Rajasthan	0.497	1 216	2 894
xxxi)	*Magnolia hookeri*	Arun. Pr.	0.403	1 128	1 746
xxxii)	*Mangifera indica* (Mango)	UP	0.411	1 383	2 433
xxxiii)	*Manglietia spp.*	Assam	0.409	912	2 031
xxxiv)	*Mesna assamica* (Sianhor)	Assam	0.687	1 795	3 502
xxxv)	*Michelia champaca* (Champ)	Assam	0.488	1 128	2 737
xxxvi)	*Mimusops elengi*	Karnataka	0.762	2 158	5 101
xxxvii)	*Morus alba* (Mulberry)	UP	0.557	1 030	4 091
xxxviii)	*Morus laevigata* (Bola)	Assam	0.567	932	2 600
xxxix)	*Morus spp.*	UP	0.594	1 589	3 129
xl)	*Nephelium litchi*	UP	0.762	1 825	4 238
xli)	*Oroxylum indicum*	Andaman	0.370	961	1 736
xlii)	*Ougenia oogeinensis* (Sandan)	UP	0.701	1 570	5 317
xliii)	*Pinus kesiya*	Nagaland	0.489	1 089	2 354
xliv)	*Pinus kesiya*	Orissa	0.453	1 118	2 325
xlv)	*Pinus roxburghii* (Chir)	UP	0.453	1 128	2 482
xlvi)	*Pinus wallichiana* (Kail)	HP	0.468	873	1 521
xlvii)	*Pistacia integerrima*	J & K	0.733	1 324	4 120
xlviii)	*Polyalthia spp.* (Debdara)	MP	0.586	1 452	2 953
xlix)	*Pometa pinnata*	Andaman	0.636	1 579	3 532
l)	*Prunus nepalensis* (Arupati)	WB	0.482	1 099	2 531
li)	*Pterocarpus marsupium*	Bihar	0.587	1 305	2 982
lii)	*Pterygota alata* (Narikel)	Assam	0.475	1 403	3 463
liii)	*Pterygota alata* (Narikel)	Kerala		1 089	2 639
liv)	*Robinia spp.*	J & K	0.629	2 227	3 777
lv)	*Sageraea elliptica* (Chooi)	Andaman	0.682	1 805	4 522
lvi)	*Schleichera oleosa* (Kusum)	Bihar	0.841	1 884	4 277
lvii)	*Shorea robusta* (Sal)	UP	0.774	1 216	3 620
lviii)	*Soymida ferifuga*	TN	0.965	1 687	6 033
lix)	*Tectona grandis* (Teak)	UP	0.574	1 020	3 404

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Table 23 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)
lx)	*Tectona grandis* (Teak)	TN	0.633	1 364	3 483
lxi)	*Tectona grandis* (Teak)	Maharashtra	0.526	971	3 728
lxii)	*Terminalia alata* (Laurel)	UP	0.806	2 521	3 806
lxiii)	*Terminalia citrina*	Assam	0.629	1 540	3 855
lxiv)	*Terminalia paniculata* (Kindal)	Kerala	0.630	1 982	3 257
lxv)	*Tetrameles nudiflora* (Maina)	Assam	0.289	667	1 413
lxvi)	*Thespesia populnea* (Bhendi)	Maharashtra	0.647	1 923	5 425
lxvii)	*Tsuga brunonsiana*	WB	0.380	540	2 050
lxviii)	*Ulmus coallichiana* (Elm)	HP	0.455	834	1 766
lxix)	*Zanthoxylum spp.*	WB	0.496	1 138	3 071

are fungi and insects. The most important wood destroying insects belong to termites and beetles. Of about 250 species of wood destroying termites recorded in India, not more than a dozen species attack building causing about 90 percent of the damage to timber and other cellulosic materials. Subterranean termites are the most destructive of the insects that infest wood in houses justifying prevention measures to be incorporated in the design and construction of buildings.

19.1.1 Control measures consist in isolating or sealing off the building from termites by chemical and non-chemical construction techniques. It is recognized that 95 percent damage is due to internal travel of the termites from ground upwards rather than external entry through entrance thus calling upon for appropriate control measures in accordance with good practices [6-3A(21)].

19.2 Chemical Methods

Termites live in soil in large colonies and damage the wooden structure in the buildings by eating up the wood or building nests in the wood. Poisoning the soil under and around the building is a normal recommended practice. Spraying of chemical solution in the trenches of foundations in and around walls, areas under floors before and after filling of earth, etc. In already constructed building the treatment can be given by digging trenches all around the building and then giving a liberal dose of chemicals and then closing the trenches.

19.3 Wood Preservatives

Natural resistance against organisms of quite a few wood species provides durability of timber without special protection measure. It is a property of heartwood while sapwood is normally always susceptible to attack by organisms. Preservatives should be well applied with sufficient penetration into timber. For engineers, architects and builders, the following are prime considerations for choice of preservatives:

a) Inflammability of treated timber is not increased and mechanical properties are not decreased;
b) Compatibility with the glue in laminated wood, plywood and board material;
c) Water repellent effect is preferred;
d) Possible suitability for priming coat;
e) Possibility of painting and other finishes;
f) Non-corrosive nature in case of metal fasteners; and
g) Influence on plastics, rubber, tiles and concrete.

19.4 Constructional Method

Protection against potential problem of termite attack can simply be carried out by ordinary good construction which prevents a colony from gaining access by,

a) periodic visual observations on termite galleries to be broken off;
b) specially formed and properly installed metal shield at plinth level; and
c) continuous floor slabs, apron floors and termite grooves on periphery of buildings.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of the enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code. In the following list, the number appearing in the first column within parantheses indicates the number of reference in this Subsection.

	IS No.	*Title*
(1)	707 : 2011	Timber technology and utilization of wood, bamboo and cane — Glossary of terms (*third revision*)
(2)	1708 (Parts 1 to 18) : 1986	Methods of testing small clear specimens of timber (*second revision*)
	2408 : 1963	Methods of static tests of timbers in structural sizes
	2455 : 1990	Methods of sampling of model trees and logs for timber testing and their conversion (*second revision*)
(3)	4970 : 1973	Key for identification of commercial timbers (*first revision*)
(4)	287 : 1993	Recommendations for maximum permissible moisture content of timber used for different purposes (*third revision*)
(5)	3629 : 1986	Specification for structural timber in building (*first revision*)
(6)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)
(7)	2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
(8)	4983 : 1968	Code of practice for design and construction of nail laminated timber beam (*first revision*)
(9)	11096 : 1984	Code of practice for design construction of bolt-jointed construction
(10)	4907 : 2004	Methods of testing timber connector joints (*first revision*)
(11)	9188 : 1979	Performance requirements for adhesive for structural laminated wood products for use under exterior exposure condition
(12)	14616 : 1999	Specification for laminated veneer lumber
(13)	10701 : 2012	Specification for structural plywood (*first revision*)
	4990 : 2011	Specification for plywood for concrete shuttering works (*third revision*)
(14)	4924	Method of test for nail-jointed timber trusses
	(Part 1) : 1968	Destructive test
	(Part 2) : 1968	Proof test
(15)	12120 : 1987	Code of practice for preservation of plywood and other panel products
(16)	4990 : 2011	Specification for plywood for concrete shuttering works (*third revision*)
(17)	9307 (Parts 1 to 7) : 1979	Methods of test for wood based structural sandwich construction
(18)	723 : 1972	Specification for steel countersunk head wire nails (*first revision*)
(19)	451 : 1999	Technical supply conditions for wood screws (*fourth revision*)
	6736 : 1972	Specification for slotted countersunk head wood screw
	6739 : 1972	Specification for slotted round head wood screw
	6760 : 1972	Specification for slotted countersunk head wood screws
(20)	1708 (Parts 1 to 18) : 1986	Methods of testing small clear specimens of timber (*second revision*)
(21)	6313	Code of practice for anti-termite measures in buildings
	(Part 1) : 1981	Constructional measures (*first revision*)
	(Part 2) : 2013	Pre-constructional chemical treatment measures (*third revision*)
	(Part 3) : 2013	Treatment for existing buildings (*third revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3B Bamboo

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 3B) covers the general principles involved in the design of structural bamboo in buildings with regard to mechanical resistance and durability of structures. Design of both bamboo (round bamboo, split bamboo, glued laminated bamboo) and bamboo-based panels joined together with adhesives or mechanical fasteners are covered in this Subsection. It also covers minimum strength data, dimensional stability, grading requirements and traditional bamboo joints for quality assurance. Constructional aspects using bamboo, such as, work on site, fabrication of components off-site and their erection on site is also covered to the extent necessary to indicate and ensure the quality of material and standard of workmanship to comply with the assumptions of the design rules and the limitations.

Bamboo is a versatile resource possessing high strength-to-weight ratio and cost ratio and offers considerable ease in working with simpler tools. It has a long and well established tradition as a building material. The application of bamboo as a constructional material is largely based on established traditions and intuitions of forefathers throughout the tropical and sub-tropical regions.

Resilience coupled with light weight makes bamboo an ideal material for housing in disaster prone/earthquake prone areas. It has the capacity to withstand repetitive loadings and absorb more energy and show larger deflections before collapse and as such is safer under earth tremors. As the design guidelines were inadequate, the application of bamboo as an engineering material was largely based on practical and engineering experience. A need was therefore felt to develop a Code for design and construction with bamboo so as to cater to a number of social and trade advantages, engineering recognition and the improved status of bamboo as an engineering material. This was achieved by adding a new chapter in the last revision of the Code, covering structural design with bamboo. Forest Research Institute, Dehradun and some other organizations were engaged in bamboo research to establish its silviculture, botanical, entomological and pathological aspects besides creating a utilization base. All these works were utilized in the preparation of the last version of this Subsection of the Code.

Some of the suitable species grown in India and neighbouring countries are enlisted in Annex A along with their local names and source, for general information.

The bamboo culm has a tubular structure consisting essentially of nodes and inter-nodes. In the inter-nodes the cells are axially oriented while the nodes provide the transverse inter-connection. The disposition of the nodes and the wall thickness are significant in imparting strength to bamboo against bending and crushing. In a circular cross-section, bamboo is generally hollow and for structural purposes this form is quite effective and advantageous. Each of the species of bamboo has widely different characteristics affecting its usefulness as constructional material. The strength of bamboo culms, their straightness, lightness combined with hardness, range and size of hollowness make them potentially suitable for a variety of applications both structural and non-structural. With good physical and mechanical properties, low shrinkage and good average density, bamboo is well suited to replace wood in several applications, especially in slats and panel form. Mass production of bamboo components, if required, may be integrated with treatment facilities near to the site of plantation or site of construction, for speed and economy in construction.

The Section on structural design with bamboo was first published in 2005 as Subsection 3B of Part 6. In the 1983 version of the Code, timber was covered under Section 3 of Part 6 ‘Structural Design’ under the title ‘Wood’, which did not cover bamboo. In the last version of 2005, the scope of Section 3 was enlarged as Section 3 ‘Timber and Bamboo’, which was subdivided into Subsection 3A ‘Timber’ and Subsection 3B ‘Bamboo’. This Subsection pertains to ‘Bamboo’.

As a result of experience gained in implementation of 2005 version of this Code and further research work done and feedback received as well as formulation of new standards in the field and revision/updation of some of the existing standards, a need to revise this Subsection was felt. This revision has, therefore, been brought out to take care of these aspects.

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The significant changes incorporated in this revision include the following:

a) This Subsection now also covers construction practices with bamboo which were earlier covered in Part 7 'Construction Management, Practices and Safety' of the Code.
b) Definitions of some existing terms have been modified as per the prevailing engineering practice and new terms relating to bamboo based panel products have been added.
c) Provisions on bamboo trusses have been further updated.
d) Some details about bamboo foundations have been included.
e) Use of bamboo as reinforcement in concrete has been included.
f) Provisions for use of bamboo based materials/panel products as walling, flooring and roofing, and in in-fill panels for wall and common roof covering/cladding materials, have been included. Some provisions for reconstituted wood from destructured bamboo have also been included.
g) References to all the concerned Indian Standards have been updated.

With the standardization on design and construction aspects of bamboo in this Subsection of the Code, it is expected to ensure durable structures, however, some specific guidelines are required in the event of tropical cyclones in the sub-continent and the traditional non-engineered structures generally constructed. Keeping this in view, some recommendations are given in Annex B which may be followed in addition to provisions given in the main text of this Subsection.

The information contained in this Subsection is largely based on the works carried out at Forest Research Institute, Dehradun, Indian Plywood Industries Research and Training Institute, Bangalore, International Network for Bamboo and Rattan (INBAR) documents and Indian Standards given below. Assistance has also been derived from ISO 22156 : 2004 'Bamboo-Structural design'.

IS 9096 : 2006 Code of practice for preservation of bamboo for structural purpose (*first revision*)

IS 15912 : 2012 Code of practice for structural design using bamboo

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 3 Timber and Bamboo: 3B Bamboo

1 SCOPE

1.1 This Code (Part 6/Subsection 3B) covers the general principles involved in the design of structural bamboo in buildings with regard to mechanical resistance and durability of structures. Design of both bamboo (round bamboo, split bamboo, glued laminated bamboo) and bamboo-based panels joined together with adhesives or mechanical fasteners are covered in this Subsection. It also covers minimum strength data, dimensional stability, grading requirements and traditional bamboo joints for quality assurance. Constructional aspects using bamboo, such as, work on site, fabrication of components off-site and their erection on site are also covered to the extent necessary to indicate and ensure the quality of material and standard of workmanship to comply with the assumptions of the design rules and the limitations.

1.2 This Subsection also covers precautions and design limitations on bamboo. The provisions relating to proper procurement and storage of bamboo are covered in Part 7 'Construction Management, Practices and Safety' of the Code.

1.3 The following aspects are not covered in this Subsection:

a) Limit state design and performance of structures; and
b) Scientific designing of bamboo joints and their fastenings.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply.

2.1 Anatomical Purpose Definitions

2.1.1 *Bamboo* — Tall perennial grasses found in tropical and sub-tropical regions. They belong to the family *Poaceae* and sub-family *Bambusoideae*.

2.1.2 *Bamboo Culm* — A single shoot of bamboo usually hollow except at nodes which are often swollen.

2.1.3 *Bamboo Clump* — A cluster of bamboo culms emanating from two or more rhizomes in the same place.

2.1.4 *Cellulose* — A carbohydrate, forming the fundamental material of all plants and a main source of the mechanical properties of biological materials.

2.1.5 *Cell* — A fundamental structural unit of plant and animal life, consisting of cytoplasm and usually enclosing a central nucleus and being surrounded by a membrane (animal) or a rigid cell wall (plant).

2.1.6 *Cross Wall* — A wall at the node closing the whole inside circumference and completely separating the hollow cavity below from that above (Syn. Diaphragm, that is, horizontal partition in a standing culm) (*see also* **2.2.17** and **2.2.30**).

2.1.7 *Hemi Cellulose* — The polysaccharides consisting of only 150 to 200 sugar molecules, also much less than the 10 000 of cellulose.

2.1.8 *Lignin* — A polymer of phenyl propane units, in its simple form ($C_6H_5CH_3CH_2CH_3$).

2.1.9 *Sliver* — Thin strips of bamboo processed from bamboo culm.

2.1.10 *Tissue* — Group of cells, which in higher plants consist of (a) Parenchyma — a soft cell of higher plants as found in stem pith or fruit pulp, (b) Epidermis — the outermost layer of cells covering the surface of a plant, when there are several layers of tissue.

2.2 Structural Purpose Definitions

2.2.1 *Bamboo Mat Board* — A board made of two or more bamboo mats bonded with an adhesive.

2.2.2 *Bamboo Mat Corrugated Sheet* — A sheet made up of adhesive soaked and coated mats assembled and pressed under specified temperature and pressure to obtain sinusoidal or other suitable corrugations.

2.2.3 *Bamboo Mat Veneer Composite* — Panel manufactured with a combination of bamboo mat and veneer. Bamboo mat can be either as outer skins or as core/cross-bands. However, the composite panel shall be balanced construction on either side of central ply.

2.2.4 *Beam* — A structural member which supports load primarily by its internal resistance to bending.

2.2.5 *Breaking Strength* — A term loosely applied to a given structural member with respect to the ultimate load it can sustain under a given set of conditions.

2.2.6 *Bundle-Column* — A column consisting of three or more number of culms bound as integrated unit with wire or strap type of fastenings.

NOTE — During bunching of beams/columns, binders (5 mm tie bar/wire and 15 mm bamboo dowel pins) may be carefully inserted after proper pre-drilling the holes throughout the assembly as per the requirements of structural design.

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2.2.7 *Centre Internode* — A test specimen having its centre between two nodes.

2.2.8 *Characteristic Load* — The value of load which has a 95 percent probability of not exceeding during the life of the structure.

2.2.9 *Characteristic Strength* — The strength of the material below which not more than 5 percent of the test results are expected to fall.

2.2.10 *Cleavability* — The ease with which bamboo can be split along the longitudinal axis. The action of splitting is known as cleavage.

2.2.11 *Column* — A structural member which supports axial load primarily by inducing compressive stress along the fibres.

2.2.12 *Common Rafter* — A roof member which supports roof battens and roof coverings, such as boarding and sheeting.

2.2.13 *Curvature* — The deviation from the straightness of the culm.

2.2.14 *Delamination* — Separation of mats through failure of glue.

2.2.15 *De-Structured bamboo* — Raw material (green bamboo) reduced partially to a condition, as far as practicable, in which the element fibres remain interlocked and in their highly aligned state and which with the help of binder can be reconstituted into a valuable product of a desirable size.

2.2.16 *End Distance* — The distance measured parallel to the fibres of the bamboo from the centre of the fastener to the closest end of the member.

2.2.17 *Flattened Bamboo* — Bamboo consisting of culms that have been cut and unfolded till it is flat. The culm thus is finally spread open, the diaphragms (cross walls) at nodes removed and pressed flat.

2.2.18 *Full Culm* — The naturally available circular section/shape.

2.2.19 *Fundamental or Ultimate Stress* — The stress which is determined on a specified type/size of culms of bamboo, in accordance with standard practice and does not take into account the effects of naturally occurring characteristics and other factors.

2.2.20 *Inner Diameter* — Diameter of internal cavity of a hollow piece of bamboo.

2.2.21 *Inside Location* — Position in buildings in which bamboo remains continuously dry or protected from weather.

2.2.22 *Joint* — A connection between two or more bamboo structural elements.

2.2.23 *Joist* — A small beam directly supporting floor, ceiling or roof of a structure.

2.2.24 *Length of Internode* — Distance between adjacent nodes.

2.2.25 *Loaded End or Compression End Distance* — The distance measured from the centre of the fastener to the end towards which the load induced by the fastener acts.

2.2.26 *Machete* — A light cutting and slashing tool in the form of a large knife.

2.2.27 *Mat* — A woven sheet made using thin slivers.

2.2.28 *Mortise and Tenon* — A joint in which the reduced end (tenon) of one member fits into the corresponding slot (mortise) of the other.

2.2.29 *Net Section* — Section obtained by deducting from the gross cross-section (A), the projected areas of all materials removed by boring, grooving or other means.

2.2.30 *Node* — The place in a bamboo culm where branches sprout and a diaphragm is inside the culm and the walls on both sides of node are thicker.

2.2.31 *Outer Diameter* — Diameter of a cross-section of a piece of bamboo measured from two opposite points on the outer surface.

2.2.31.1 *Mean outer diameter* — The diameter taken twice on the outer surface, in direction perpendicular to each other at each cross-section on both the ends. Thus resulting in mean of four readings for the middle of culm.

2.2.32 *Outside Location* — Position in building in which bamboos are occasionally subjected to wetting and drying as in case of open sheds; and outdoor exposed structures.

2.2.33 *Permissible Stress* — Stress obtained after applying factor of safety to the ultimate stress. This is also the working stress unless adjusted to the particular structural form in design.

2.2.34 *Principal Rafter* — A roof member which supports purlins.

2.2.35 *Purlins* — A roof member directly supporting roof covering or common rafter and roof battens.

2.2.36 *Roof Battens* — A roof member directly supporting tiles, corrugated sheets, slates or other roofing materials.

2.2.37 *Roof Skeleton* — The skeleton consisting of bamboo truss or rafter over which solid bamboo purlins are laid and lashed to the rafter or top chord of a truss by means of galvanized iron wire, cane, grass, bamboo leaves, etc.

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2.2.38 *Slenderness Ratio* — The ratio of the length of member to the least radius of gyration is known as slenderness ratio of member (the length of the member is the equivalent length due to end conditions).

2.2.39 *Splits* — The pieces made from quarters by dividing the quarters radially and cutting longitudinally.

2.2.40 *Taper* — The ratio of difference between minimum and maximum outer diameter to length.

2.2.41 *Unloaded End Distance* — The end distance opposite to the loaded end.

2.2.42 *Wall Thickness* — Half the difference between outer diameter and inner diameter of the piece at any cross-section.

2.2.42.1 *Mean wall thickness* — The wall thickness taken four times in the same points as the diameter has been measured. Thus resulting in mean of eight values for the middle of culm.

2.2.43 *Wet Location* — Position in buildings in which the bamboos are almost continuously damp, wet or in contact with earth or water, such as piles and bamboo foundations.

2.3 Definitions Relating to Defects

2.3.1 *Bamboo Bore/Ghoon Hole* — The defect caused by bamboo ghoon beetle (*Dinoderus* spp. *Bostrichidae*), which attacks felled culms.

2.3.2 *Crookedness* — A localized deviation from the straightness in a piece of bamboo.

2.3.3 *Discolouration* — A change from the normal colour of the bamboo which does not impair the strength of bamboo or bamboo composite products.

2.4 Definition Relating to Drying Degrades

2.4.1 *Collapse* — The defect occurring on account of excessive shrinkage, particularly in thick walled immature bamboo. When the bamboo wall shrinks, the outer layers containing a larger concentration of strong fibro-vascular bundles set the weaker interior portion embedded in parenchyma in tension, causing the latter to develop cracks. The interior crack develops into a wide split resulting in a depression on the outer surface. This defect also reduces the structural strength of round bamboo.

2.4.2 *End Splitting* — A split at the end of a bamboo. This is not so common a defect as drying occurs both from outer and interior wall surfaces of bamboo as well as the end at the open ends.

2.4.3 *Surface Cracking* — Fine surface cracks not detrimental to strength. However, the cracking which occurs at the nodes reduces the structural strength.

2.4.4 *Wrinkled and Deformed Surface* — Deformation in cross-section, during drying, which occurs in immature round bamboos of most species; in thick walled pieces, besides this deformation the outer surface becomes uneven and wrinkled. Very often the interior wall develops a crack below these wrinkles, running parallel to the axis.

3 SYMBOLS

For the purpose of this Subsection, the following letter symbols shall have the meaning indicated against each, unless otherwise stated:

A = cross-sectional area of bamboo (perpendicular to the direction of the principal fibres and vessels), mm^2

$$= \frac{\pi}{4}\left[D^2 - (D-2w)^2\right];$$

A_B = area of reinforcement in bamboo reinforced cement concrete, mm^2;

D = mean outer diameter of bamboo culm, mm;

d = inner diameter, mm = $(D - 2w)$;

E = modulus of elasticity (MOE) in bending, N/mm^2;

f_c = calculated stress in axial compression, N/ m^2;

f_{cp} = permissible stress in compression along the fibres, N/mm^2;

I = moment of inertia (the second moment of area) of culm section, mm^4

$$= \frac{\pi}{64}\left[D^4 - (D-2w)^4\right];$$

ℓ = unsupported length of column, mm;

m = moisture content, percent;

r = radius of gyration, mm

$$= \sqrt{\frac{I}{A}};$$

R = modulus of rupture (MOR), N/mm^2;

w = mean of wall thickness of bamboo culm, mm;

Z = section modulus, mm^3

$$= \frac{\pi}{32}\left[\frac{D^4 - (D-2w)^4}{D}\right]; \text{ and}$$

δ = deflection or deformation, mm.

4 MATERIALS

The requirements shall be met by the choice of suitable materials, by appropriate design and detailing and by specifying control procedures for production, construction and use.

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4.1 Species of Bamboo

More than 100 species of bamboo are native to India and a few of them are solid but most of them are hollow in structure. In all 20 species have been systematically tested so far. Sixteen species of bamboo are recommended for structural usages in round form. Some physical and mechanical properties of the same are given in Table 1 both for air-dry conditions and green conditions.

4.1.1 Matured bamboo of at least 4 years of age shall be used. The bamboo shall be used after at least six weeks of felling period.

4.1.2 Bamboo shall be properly treated in accordance with the good practice [6-3B(1)].

4.1.3 Solid bamboos or bamboos whose wall thickness is comparatively more and which are generally having nodes very closer are often considered good for structural purposes.

4.1.4 Broken, damaged or collapsed bamboo shall be rejected. Dead and immature bamboos, bore/*Ghoon* holes, decay, collapse, checks more than 3 mm in depth, shall be avoided.

4.2 Grouping

4.2.1 Sixteen species of bamboo recommended for structural applications are classified in three groups on the basis of their strength properties, namely, modulus of elasticity (E) in bending in green condition and modulus of rupture (R) (extreme fibre stress in bending). For structural use in piles and mines' components, an additional criterion of compressive strength is considered in classification. The limits in ultimate strength values of these groups shall be as given in Table 2 (these are corresponding to the spread of properties in structural timber).

4.2.2 Bamboo species may be identified using suitable methods.

NOTE — Methods of identification of bamboo through anatomical characters have not been perfected so far. Identification through morphological characters could be done only on full standing culm by experienced sorters.

4.2.3 Species of bamboo other than those listed in the Table 3 may be used, provided their strength characteristics are determined and found more than the limits specified in Table 2.

4.3 Moisture Content in Bamboo

Normally only dry or seasoned bamboo shall be used otherwise special attention shall be given to dimensional changes occurring during the drying process in the joints, assemblies.

With decrease of moisture content, the strength of bamboo increases exponentially and bamboo has an intersection point (fibre saturation point) at around 25 percent moisture content depending upon the species. A typical moisture strength relationship is given at Fig. 1. The moisture content of bamboo shall be determined in accordance with method given in the accepted standard [6-3B(2)]. Matured culms shall be seasoned to about 20 percent moisture content before use.

Freshly felled bamboo with shoots and leaves intact, dry fairly well in the open sun with lesser surface cracking, etc, and reduced starch contents. Rapid drying in the open can control degrades.

4.4 Grading of Structural Bamboo

4.4.1 Bamboo shall be graded to ensure that the properties of bamboo are satisfactory for use particularly the strength and stiffness properties.

4.4.1.1 Grading is sorting out bamboo on the basis of characteristics important for structural utilization as under:

a) Diameter and length of culm;
b) Taper of culm;
c) Straightness of culm;
d) Inter nodal length and distribution of nodes;
e) Wall thickness;
f) Density and strength; and
g) Durability and seasoning.

One of the above characteristics or sometimes combination of two or three characteristics form the basis of grading. The culms shall be segregated species-wise.

4.4.2 *Diameter and Length*

4.4.2.1 *Gradation according to the mean outer diameter*

For structural Group A and Group B species, culms shall be segregated in steps of 10 mm of mean outer diameter as follows:

a) Special grade : 70 mm < Diameter ≤ 100 mm
b) Grade I : 50 mm < Diameter ≤ 70 mm
c) Grade II : 30 mm < Diameter ≤ 50 mm
d) Grade III : Diameter ≤ 30 mm

For structural Group C species culms shall be segregated in steps of 20 mm of mean outer diameter as follows:

1) Grade I : 80 mm < Diameter ≤ 100 mm
2) Grade II : 60 mm < Diameter ≤ 80 mm
3) Grade III : Diameter ≤ 60 mm

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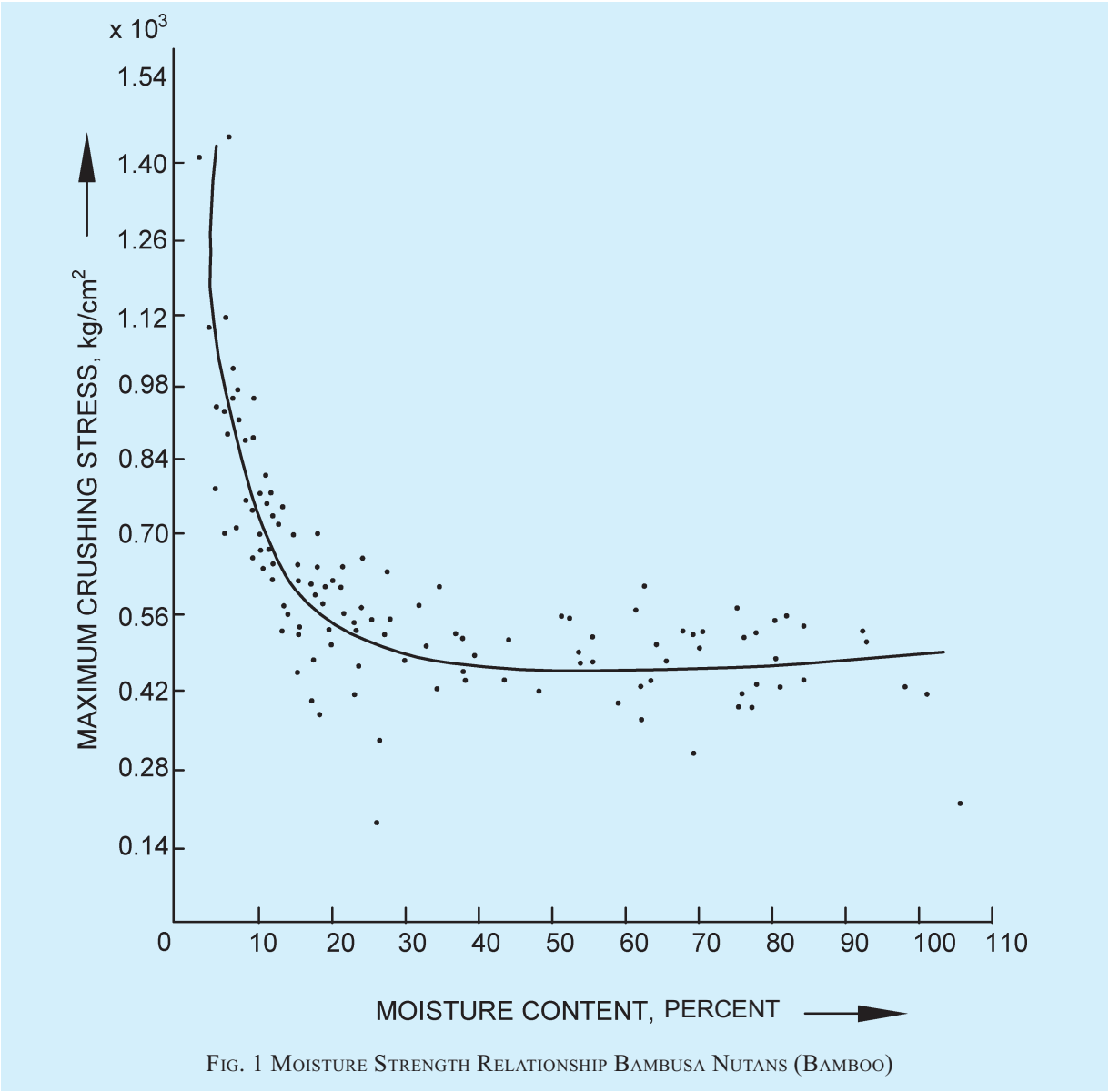


FIG. 1 MOISTURE STRENGTH RELATIONSHIP BAMBUSA NUTANS (BAMBOO)

4.4.2.2 The minimum length of culms shall be preferably 6 m for facilitating close fittings at joints, etc.

4.4.3 *Taper*

The taper shall not be more than 5.8 mm per metre length (or 0.58 percent) (1 in 170) of bamboo in any grade of bamboo.

4.4.4 *Curvature*

The maximum curvature should not be more than 75 mm in a length of 6 m of any grade of bamboo.

NOTE — Due to the constraint of preferential selection of straighter material out of a lot, more bent material may be accommodated to avoid high cost. Following remedial options may be helpful:

a) Adopt component assembly method to take care of some degree of curvature (bunching done after holding components straight).

b) Cut longer bamboo components with less curvature out of taller bamboo and use cambered ones for shorter length components.

4.4.5 *Wall Thickness*

Preferably minimum wall thickness of 8 mm shall be used for load bearing members unless calculations and the availability dictate otherwise.

4.5 Durability and Treatability

4.5.1 *Durability*

The natural durability of bamboo is low and varies between 12 months and 36 months depending on the species and climatic conditions. In tropical countries the bio-deterioration is very severe. Bamboos are generally destroyed in about one to two years' time when used in the open and in contact with ground; while a service life of two to five years can be expected from

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bamboo when used under cover and out of contact with ground. The mechanical strength of bamboo deteriorates rapidly with the onset of fungal decay in the sclerenchymatous fibres. Split bamboo is more rapidly destroyed than round bamboo. For making bamboo durable, suitable treatment for preserving bamboo shall be given in accordance with the good practice [6-3B(3)]. However, special attention shall be given to environmental impact and to the health aspects of labour and the users.

4.5.2 To ensure an adequately durable structure, bamboo shall be treated in accordance with the good practice [6-3B(1)] and the following inter-related factors shall be considered:

a) Expected service life of the bamboo;
b) Use of the structure and expected environmental conditions;
c) Required performance criteria; and
d) Quality of workmanship.

4.5.3 Fire safety of bamboo structures shall be ensured, for which the treatment prescribed in **7.3.4** may be followed.

5 PERMISSIBLE STRESSES

5.1 Ultimate stress values of different species and groups of bamboo shall be determined according to the accepted standard [6-3B(2)]. These values shall then be divided by appropriate factors of safety to obtain permissible stresses to cover the effects of variability, long term loading, grade, location of use and expected dynamic loading.

NOTE — As an information, it may be noted that the method of test for split bamboos is covered in the accepted standard [6-3B(4)].

5.1.1 The strength factors for deriving safe working stresses of bamboo shall be as under :

Extreme fibre stress in beams	: 4
Modulus of elasticity	: 4.5
Maximum compressive stress parallel to grain/fibres	: 3.5

5.2 The available data for the safe working stresses for 16 species of bamboos are given in Table 3.

5.3 For change in duration of load other than continuous (long-term), the permissible stresses given in Table 3 shall be multiplied by the modification factors given below:

For permanent loads	: 1.0
For imposed or medium term loading (permanent + temporary load)	: 1.25
For short term loading (permanent + temporary load + wind load)	: 1.50

Table 1 Physical and Mechanical Properties of Indian Bamboos (in Round Form)

(*Clause* 4.1)

Sl No.	Species	Properties							
		In Green Condition				In Air Dry Conditions			
		Density kg/m^3	Modulus of Rupture N/mm^2	Modulus of Elasticity × 10^3 N/mm^2	Maximum Compressive Strength N/mm^2	Density kg/m^3	Modulus of Rupture N/mm^2	Modulus of Elasticity × 10^3 N/mm^2	Maximum Compressive Strength N/mm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	*Bambusa auriculata*	594	65.1	15.01	36.7	670	89.1	21.41	54.3
ii)	*B. balcooa*	783	65.4	7.31	46.7	—	—	—	60.6
iii)	*B. bambos (Syn. B. arundinacea)*	559	58.3	5.95	35.3	663	80.1	8.96	53.4
iv)	*B. burmanica*	570	59.7	11.01	39.9	672	105.0	17.81	65.2
v)	*B. glancescens (Syn. B. nana)*	691	82.8	14.77	53.9	—	—	—	—
vi)	*B. nutans*	603	52.9	6.62	45.6	673	52.4	10.72	47.9
vii)	*B. pallida*	731	55.2	12.90	54.0	—	—	—	—
viii)	*B. tulda*	658	51.1	7.98	40.7	722	66.7	10.07	68.0
ix)	*B. ventricosa*	626	34.1	3.38	36.1	—	—	—	—
x)	*B. vulgaris*	626	41.5	2.87	38.6	—	—	—	—
xi)	*Cephalostachyum pergracile*	601	52.6	11.16	36.7	640	71.3	19.22	49.4
xii)	*Dendrocalamus longispathus*	711	33.1	5.51	42.1	684	47.8	6.06	61.1
xiii)	*D. strictus*	631	73.4	11.98	35.9	728	119.1	15.00	69.1
xiv)	*Melocanna baccifera*	817	53.2	11.39	53.8	751	57.6	12.93	69.9
xv)	*Oxytenanthera abyssinicia*	688	83.6	14.96	46.6	—	—	—	—
xvi)	*Thyrsostachys oliveri*	733	61.9	9.72	46.9	758	90.0	12.15	58.0

NOTE — The values of stress in N/mm^2 have been obtained by converting the values in kgf/cm^2 by dividing the same by 10.

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Table 2 Properties of Structural Bamboo
(*Clause* 4.2.1)

Sl No.	Group	Modulus of Rupture (R)	Modulus of Elasticity in Bending (E)	Maximum Compressive Strength ($f_{c,max}$)
		N/mm^2	$\times 10^3$ N/mm^2	N/mm^2
(1)	(2)	(3)	(4)	(5)
i)	A	$R > 70$	$E > 9$	$MCS > 35$
ii)	B	$70 \geq R > 50$	$9 \geq E > 6$	$35 > MCS > 30$
iii)	C	$50 \geq R > 30$	$6 \geq E > 3$	$30 > MCS > 25$

Table 3 Safe Permissible Stresses of Bamboos for Structural Designing[1)]
(*Clauses* 4.2.3, 5.2 *and* 5.3)

Sl No.	Species	Extreme Fibre Stress in Bending N/mm^2	Modulus of Elasticity $\times 10^3$ N/mm^2	Allowable Compressive Stress N/mm^2
(1)	(2)	(3)	(4)	(5)
i)	Group A:			
a)	*Bambusa glancescens (Syn.B.nana)*	20.7	3.28	15.4
b)	*Dendrocalamus strictus*	18.4	2.66	10.3
c)	*Oxytenanthera abyssinicia*	20.9	3.31	13.3
ii)	Group B:			
a)	*Bambusa balcooa*	16.4	1.62	13.3
b)	*B.pallida*	13.8	2.87	15.4
c)	*B.nutans*	13.2	1.47	13.0
d)	*B.tulda*	12.8	1.77	11.6
e)	*B.auriculata*	16.3	3.34	10.5
f)	*B.burmanica*	14.9	2.45	11.4
g)	*Cephalostachyum pergracile*	13.2	2.48	10.5
h)	*Melocanna baccifera (Syn.M.bambusoides)*	13.3	2.53	15.4
j)	*Thyrsotachys oliveri*	15.5	2.16	13.4
iii)	Group C:			
a)	*Bambusa arundinacea (Syn.B.bambos)*	14.6	1.32	10.1
b)	*B.ventricosa*	8.5	0.75	10.3
c)	*B.vulgaris*	10.4	0 .64	11.0
d)	*Dendrocalamus longispathus*	8.3	1.22	12.0

NOTE — The values of stress in N/mm^2 have been obtained by converting the values in kgf/cm^2 by dividing the same by 10.

[1)] The values given pertain to testing of bamboo in green condition.

6 DESIGN CONSIDERATIONS

6.1 Basic Requirements

A structure shall be designed and constructed by personnel having the appropriate skill and experience in such a way that,

a) with acceptable probability, it will remain fit for the use for which it is required, having due regard to its intended life and costs;

b) with appropriate degree of reliability, it will sustain all forces and effects likely to occur during execution and use and have adequate durability in relation to maintenance costs;

c) the structure will be adequately maintained;

d) the structure will be used in accordance with design limit briefs;

e) all structural members, assemblies or framework in a building shall be capable of sustaining, without exceeding the limits of relevant stress specified, the worst combination of all loadings;

f) a fundamental aspect of design will be to determine the forces to which the structure/ structural element might be subjected to, starting from the roof and working down to the soil by transferring the forces through various components and connections;

g) accepted principles of mechanics for analysis and specified design procedures shall be applied (or) the design requirements may be satisfied by prototype testing;

h) loads shall be in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code, keeping into consideration that permeability of walls, floors and roof made from bamboo cause internal pressure and can therefore affect the wind load factor; and

j) The worst combination and location of loads shall be considered for design. Also, wind and seismic forces shall not be considered to act simultaneously.

6.2 Unlike timber, bamboo properties do not relate well to species, being dependent among other factors, on position of the culm, geographic location and age. The practice in timber engineering is to base designs on safe working stresses (*see* Note) and the same may be adopted to bamboo with the limitations that traditional experience rather than precise calculations generally govern the detailing.

NOTE — Limit states are states beyond which the structure no longer satisfies the design performance requirements. Limit states are classified into ultimate limit state relating to collapse mode and serviceability limit states associated with deformations, vibrations, etc. Design is usually based on ultimate stages with partial factors of safety.

6.3 Age old traditional experience of construction with bamboo is to be well preserved as non-standard practices for similar situations considered as an informal based on general social pattern and wisdom. Confirmation of such structures be based on reports after they have sustained the severity of earthquakes,

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hurricanes, etc, as criteria for recommendations by the evaluation by competent engineer/builder with adequate experience in the field.

6.4 Net Section

It is determined by passing a plane or a series of connected planes transversely through the members. Least net sectional area is used for calculating load carrying capacity of a member. In the design of an intermediate or a long column, gross section shall be used in calculating load carrying capacity of column.

6.5 Structural Components

6.5.1 Main structural applications in bamboo may include roofing and flooring, shear walls, wall paneling, beams, piles, columns, arches, etc. Both from the point of view of capacity and deformation, trusses and framed skeletons are much better options in bamboo.

6.5.2 *Peculiarity of Bamboo as a Design Material*

This shall be based on the principles of applied mechanics involving the following assumptions:

a) Elastic behaviour of bamboo, until failure (plastic behaviour being considered to be not significant);
b) Bamboo culms are analysed as hollow-tube structures (not perfectly straight) member on mean diameter and mean wall thickness basis. Designing as a variable thickness hollow-tube structure is a bit complex;
c) Nodes do not occur at constant intervals;
d) Structural elements of bamboo shall be appropriately supported near the nodes of culm as and where the structural system demands. The joints in the design shall be located near nodes;
e) Bamboo structures are designed like any other conventional structural analysis taking care of details with regards to supports and joints; and the diameter, wall thickness and initial curvature; and
f) Joints shall be considered to generally act as a hinge or as pinned, unless substantiating data justify a fixed joint.

6.6 Flexural Members

6.6.1 All flexural members may be designed using the principles of beam theory.

NOTE — The tendency of bamboo beams to acquire larger deflections under long continual loading (including creep) has to be taken care of either by giving a factor of safety to *E* or by considering double the design dead loading in calculation of deflections.

6.6.2 The moment of inertia, *I* shall be determined as follows:

a) Outside diameter and the wall thickness shall be measured at both ends, correct up to 1 mm for diameter of culm and 0.1 mm for the wall thickness.
b) With these values the mean diameter and the mean thickness for the middle of the beam shall be calculated and moment of inertia determined.

6.6.3 The maximum bending stress shall be calculated and should be within the allowable stress.

6.6.4 The deflection shall be within the prescribed limits. The initial curvature shall also be considered in the calculation of the deflection.

6.6.5 The shear stress in the neutral layer at the small end shall be checked, if the length of the beam is less than 25 times the diameter at that end.

6.6.6 Forces acting on a beam, being loads or reaction forces at supports, shall act in nodes or as near to nodes as by any means possible.

6.7 Columns (Predominantly Loaded in Axial Direction)

6.7.1 Columns and struts are essential components sustaining compressive forces in a structure. They transfer load to the supporting media.

6.7.2 Design of columns shall be based on one of the following two criteria:

a) Full scale buckling tests on the same species, size and other relevant variables.
b) Calculations, based on the following:
    1) Moment of inertia shall be determined as per **6.6.2**.
    2) For bamboo columns the best available straight bamboo culms shall be selected.
    3) Bending stresses due to initial curvature, eccentricities and induced deflection shall be taken into account, in addition to those due to any lateral load.

NOTE — Unlike timber, MOE has already been provided a factor of safety in case of bamboo. This is on the basis of studies on variability of MOR and MOE. In the case of timber, no factor of safety for MOE was used because there has been an understanding that there is no variability in MOE. Subsequently it was confirmed that MOE varies as the MOR and there is very strong, highly significant correlation between the two. In fact this correlation has formed the basis of development of machine grading of timber world-over. However, somehow the practice of not giving factor of safety to MOE continued in Indian Standard. Later on when the standard on structural use of bamboo was formulated, factor of safety was given both in MOR and MOE on the basis of latest variability studies on strength of bamboo.

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6.7.3 Buckling calculation shall be according to Euler, with a reduction to 90 percent of moment of inertia, to take into account the effect of the taper which shall be less than 1:170.

6.7.4 For strength and stability, larger diameter thick walled sections of bamboo with closely spaced nodes shall be used. Alternatively, smaller sections may be tied together as a bundle-column.

6.8 A single bamboo culm is not an optimum component to structurally design different load bearing members. Bunching of bamboo is inevitable to fabricate beams, columns, etc. There is no end to the number of culmns in bunching. However, different components pose manufacturing problems during assembly, which should be appropriately taken care of (*see also* Fig. 9D and Fig. 9E).

6.8.1 Following precautions shall be taken to avoid possible split/crack in walling of bamboo:

a) Maintaining a minimum 100 mm distance of the drills from the end of the main bamboo culms drilled.

b) Choosing drilling points preferably within 30 mm from node.

c) Maintaining the interference fit between bamboo body and binders as under:

1) For wall thickness ≥ 8 mm : 0.25-0.30 mm, and

2) For wall thickness < 8 mm : 0.20-0.25 mm.

d) The inserting ends of the dowel pins may be dressed as tapered (conical).

6.9 Assemblies and Roof Trusses

6.9.1 Elements in structure are generally built-up in the form of assembled members for which a triangle is a simple figure of stability. Besides sloped chords, parallel chord construction is also appropriate as external profile.

6.9.2 A truss is essentially a plane structure which is very stiff in the plane of the members, that is the plane in which it is expected to carry load, but very flexible in every other direction. Roof truss generally consists of a number of triangulated frames, the members of which are fastened at ends and the nature of stresses at joints is either tensile or compressive and designed as pin-ended joints (*see* Fig. 2A). Bamboo trusses may also be formed using bamboo mat board or bamboo mat-veneer composite or plywood gusset (*see* Fig. 2B).

6.9.3 Trusses shall be analysed for the determination of axial forces in members and the deformation of joints. For the influence of eccentricities, due allowance shall be made in design.

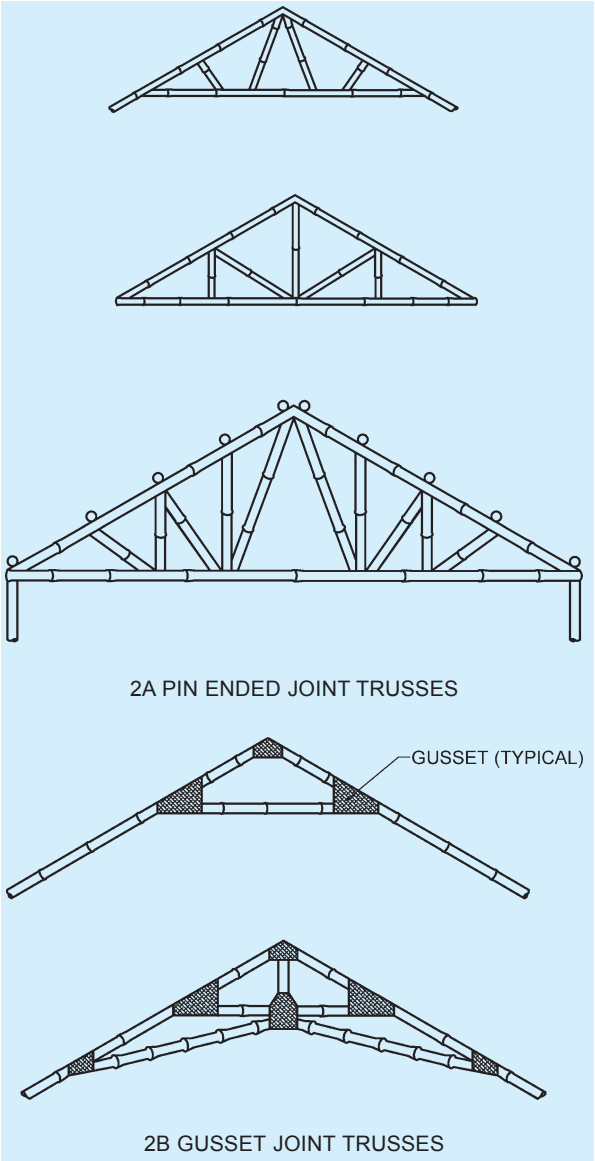


FIG. 2 SOME TYPICAL CONFIGURATIONS FOR SMALL AND LARGE TRUSSES IN BAMBOO

6.9.4 The truss height shall exceed 0.15 times the span in case of a triangular truss (pitched roofing) and 0.10 times the span in case of a rectangular (parallel) truss.

6.9.5 For members in compression, the effective length for in-plane strength verification shall be taken as the distance between two adjacent points of contraflexure. For fully triangulated trusses, effective length for simple span members without especially rigid end-connection shall be taken as the span length.

6.9.6 The spacing of trusses shall be consistent with use of bamboo purlins.

6.9.7 The ends in open beams, joists, rafters, purlins shall be suitably plugged. Bamboo roof coverings shall be considered as non-structural in function.

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6.9.8 Bamboo trusses with wire bound joints using bamboo pins and/or wooden splice plates fastened with bamboo pins when tested at load for factor of safety of at least 5, result in deflection within permissible range at design load; good recovery but abnormal deflection beyond ultimate load without collapse was observed.

NOTE — This is based on the work done on prototypes of a few bamboo trusses (span 4 m) tested at Forest Research Institute, Dehradun.

7 DESIGN, TECHNIQUES OF JOINTS AND CONSTRUCTION PRACTICES

7.1 Connecting the load-bearing elements together for effective transfer of stress and to achieve continuity between elements with controlled displacements is one of the serious problem. As joints are a source of weakness in any bamboo structure, they have to be made as strong and rigid as possible. Joints are quite critical in assemblies, and these should be stable in relation to time. For general information, the diagrams of typical joints given in Figs. 3 to 7 may be used based on tests for adequacy of strength.

7.2 Bamboo Joints

Susceptibility to crushing at the open ends, splitting tendency, variation in diameter, wall thickness and straightness are some of the associated issues which have to be taken care of while designing and detailing the connections with bamboo.

Joints shall be designed to include force transmissions in a required manner, predictable deformations to be within prescribed limits and specific geometry/load direction.

Tests on full scale joints or on components shall be carried out in accordance with the good practice [6-3B(5)] and the accepted standards [6-3B(6)] for nailed jointed timber structures.

7.2.1 *Traditional Practices*

Such joining methods revolve around lashing or tying by rope or string with or without pegs or dowels. Such joints lack stiffness and have low efficiency but have served the mankind for long in traditional bamboo construction.

7.2.1.1 *Lengthening joints (end jointing)* (*see* Fig. 3)

7.2.1.1.1 *Lap joint*

End of one piece of bamboo is made to lap over that of the other in line and the whole is suitably fastened. It may be full lapping or half lapping. Full section culms are overlapped by at least one internode and tied together in two or three places. Efficiency could be improved by using bamboo or hardwood dowels.

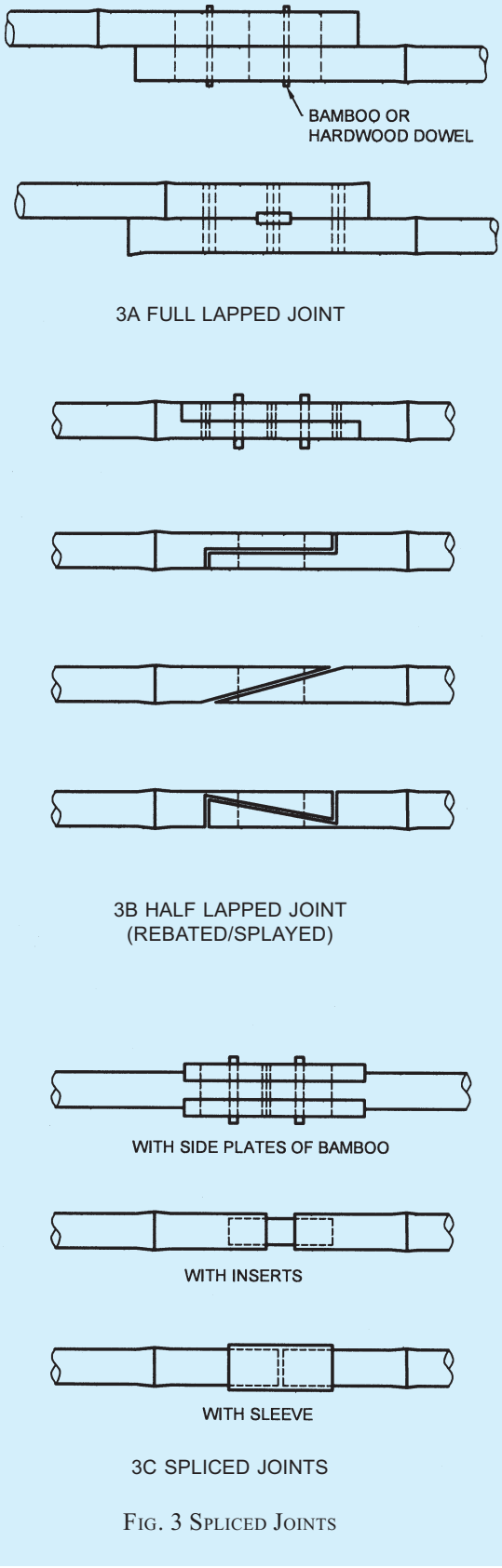


FIG. 3 SPLICED JOINTS

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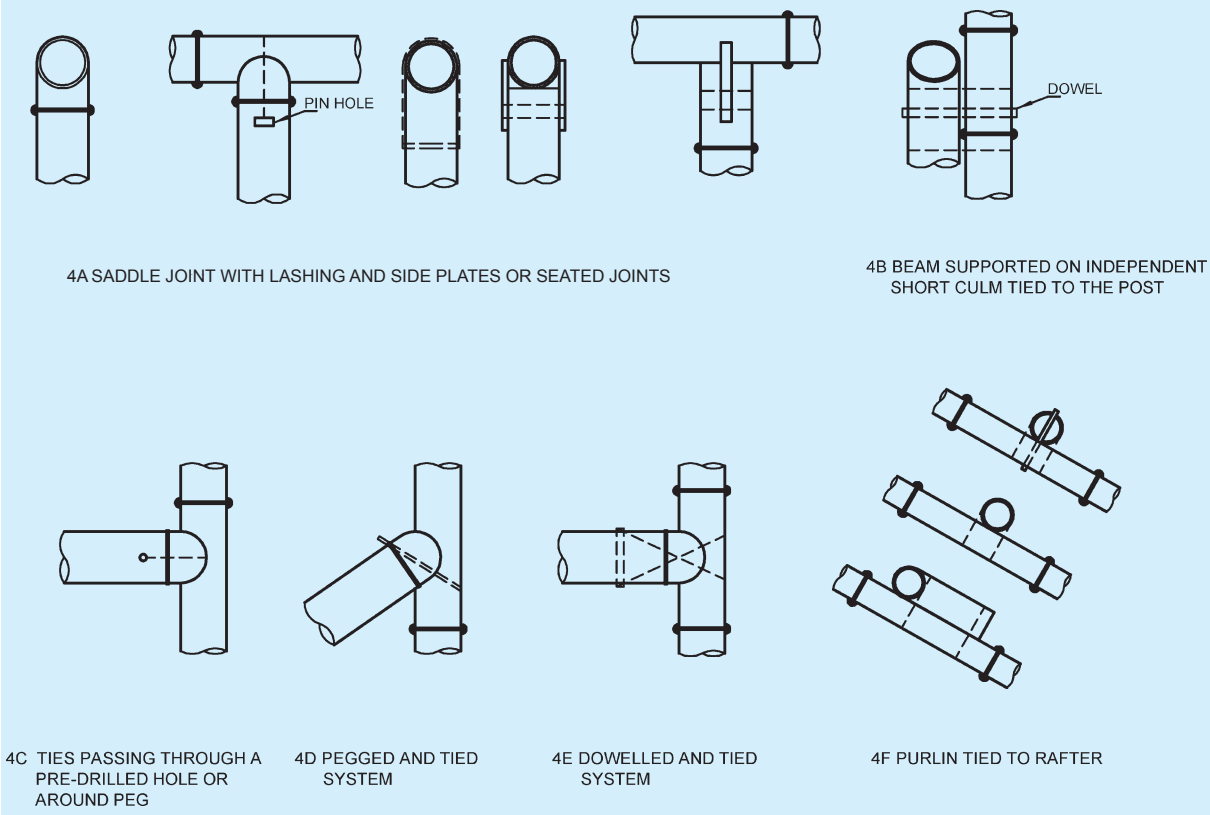


FIG. 4 BEARING JOINTS

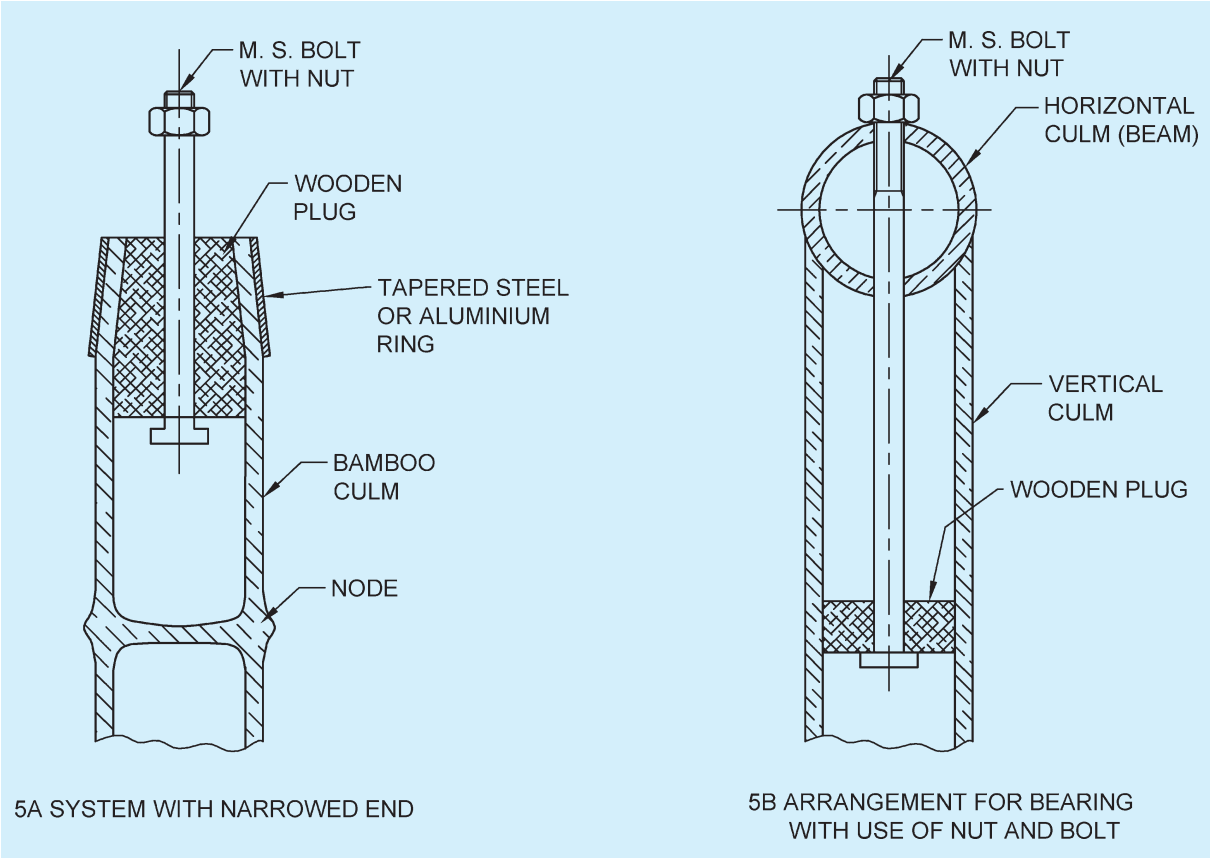


FIG. 5 SOME NUT BOLT JOINERY DETAILS

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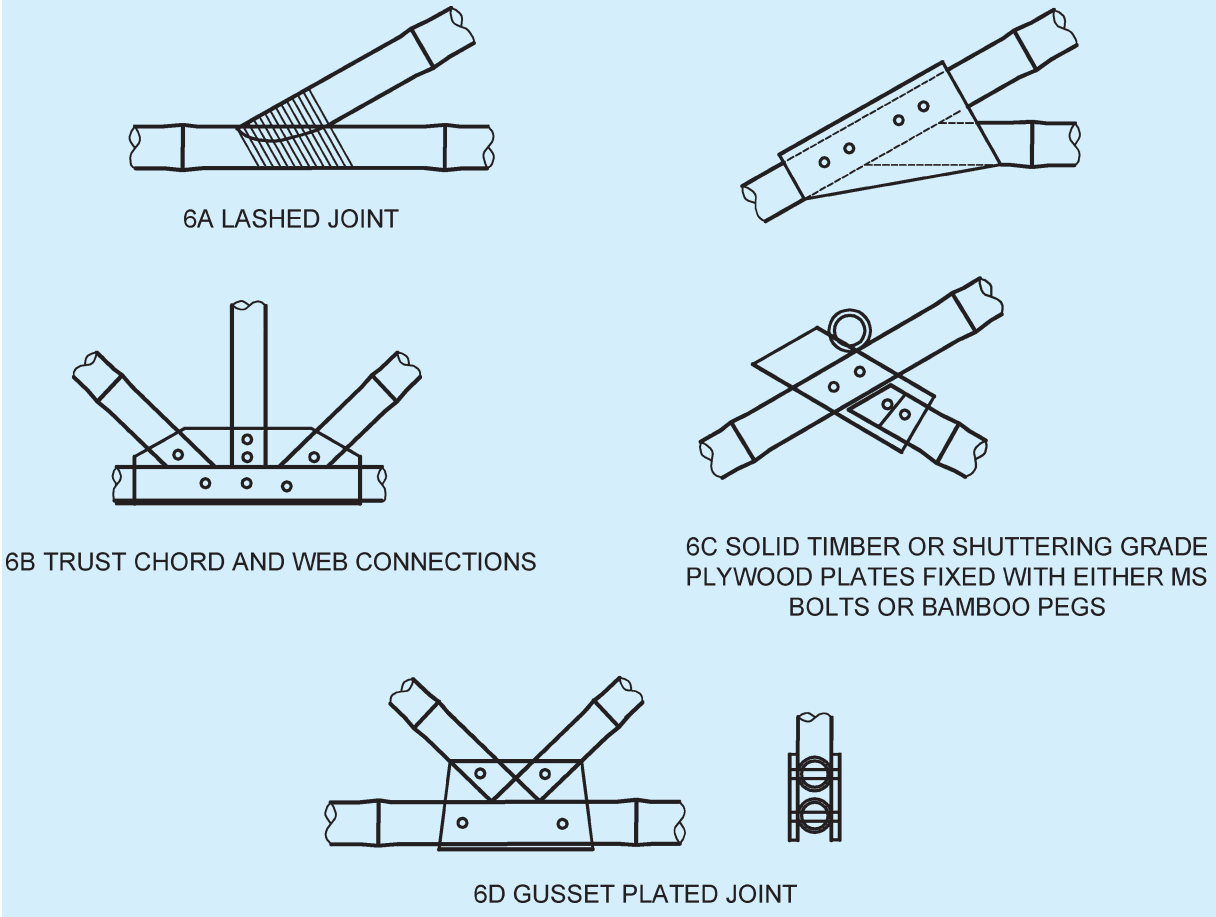


FIG. 6 GUSSET PLATED JOINTS

7.2.1.1.2 *Butt joints*

Culms of similar diameter are butted end to end, interconnected by means of side plates made of quarter-round culm of slightly large diameter bamboo, for two or more internode lengths. Assembly shall be fixed and tied preferably with dowel pins.

7.2.1.1.3 *Sleeves and inserts*

Short length of bamboo of appropriate diameter may be used either externally or internally to join two culms together.

7.2.1.1.4 *Scarf joints*

A scarf joint is formed by cutting a sloping plane 1 in 4 to 6 on opposite sides from the ends of two similar diameter bamboo culms to be joined. They shall be lapped to form a continuous piece and the assembly suitably fastened by means of lashings or glued.

7.2.1.2 *Bearing joints (see Fig.* 4*)*

For members which either bear against the other or cross each other and transfer the loads at an angle other than parallel to the axis, bearing joints are formed.

7.2.1.2.1 *Saddle joints*

The simplest form consists of a horizontal member supported directly on top of a vertical member. The top of the post may be cut to form a saddle to ensure proper seating of beam for good load transfer. The saddle should be close to a node to reduce risk of splitting.

7.2.1.2.2 *Angled joints*

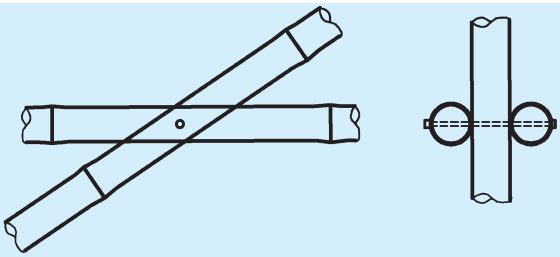
When two or more members meet or cross other than at right angles, angled joints are formed.

7.2.2 *Improved Practices in Bamboo Jointing*

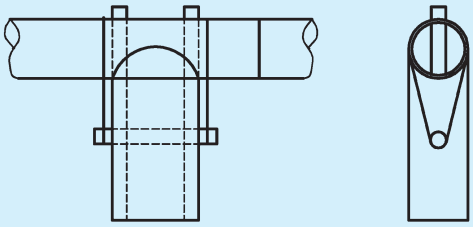
a) Plywood or solid timber gusset plates may be used at joint assemblies of web and chord connection in a truss and fixed with bamboo pins or MS (mild steel) bolts. Hollow cavities of bamboo need to be stuffed with wooden plugs or otherwise by suitable means.

b) Use of wooden inserts to reinforce the ends of the bamboo before forming the joints. Alternatively, steel bands clamps with integral bolt/eye may be fitted around bamboo sections for jointing.

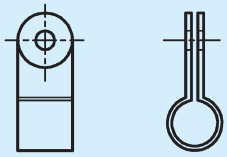
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7A SIMPLY BOLTED CONNECTION WITH MS ARC WASHERS



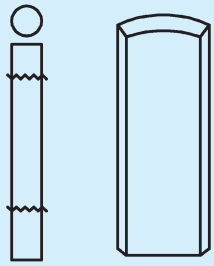
7B HORNED JOINT WITH PIN AND ROPE LASHING



7C STEEL BAND TO BE FITTED AROUND BAMBOO SECTION



7D HARDWOOD DOWEL (SQUARE OR CIRCULAR)



7E SOLID BAMBOO OR SPLIT BAMBOO PINS (WITH SKIN ON)

FIG. 7 OTHER JOINTS AND SECTIONS

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7.2.3 *Fixing Methods and Fastening Devices*

In case of butt joints the tie-wire may be passed through a pre-drilled hole or around hardwood or bamboo pegs or dowels inserted into preformed holes to act as horns. Pegs are driven from one side, usually at an angle to increase strength and dowels pass right through the member, usually at right angles. Normally 1.60 mm (16 SWG) diameter galvanized iron wire may be used for tight lashing.

NOTE — Drill size needs to be specified in order to avoid possible split/crack in walling of bamboo.

7.2.3.1 *Wire bound joints with or without pins*

Usually 2.00 mm (14 SWG) diameter galvanized iron wire is tightened around the joints by binding the respective pieces together. At least two holes are drilled in each piece and wire is passed through them for good results. Generally 10-12 mm diameter bamboo pins are driven and fastened to culms.

7.2.3.2 *Fish plates/gusset plated joints (see Fig. 6)*

At least 25 mm thick hardwood splice plate or 12 mm thick structural grade plywood are used. Solid bamboo pins help in fastening the assembly.

7.2.4 For any complete joint alternative for a given load and geometry, description of all fastening-elements, their sizes and location shall be indicated. Data shall be based on full scale tests.

7.2.5 Tests on full scale joints or on components shall be carried out in a recognized laboratory.

7.2.6 In case of high wind and seismic areas, good construction practices shall be followed taking care of joints, their damping and possible ductility. Bracings in walls shall be taken care of in bamboo structures.

7.2.7 Metal fasteners and other structural joints shall be made inherently corrosion resistant or be protected against corrosion, thereby making the joints more durable.

7.3 Construction Practices

7.3.1 Bamboo being a versatile resource characterized by high strength, low mass and ease of working with simple tools, it is desirable to increasingly make appropriate use of this material. Design of structures using bamboo shall be done in accordance with **6**. It shall be ensured that the elements of structure satisfy the appropriate fire resistance requirements as specified in Part 4 'Fire and Life Safety' of the Code, and quality of building materials/components used shall be in accordance with Part 5 'Building Materials' of the Code. For construction using bamboo, some of the important constructional provisions given in **7.3.2** to **7.3.7** shall be followed.

7.3.2 The following sound construction practices shall be taken into account:

a) Use of air dry bamboo; and ensure that bamboo in building remains air dry; and in case the bamboo has become wet, shall provide it the opportunity to dry again before the it deteriorates due to moisture.

b) Permeability of walls, floors and roofs made from bamboo, cause internal pressure and can therefore change the net wind-load acting on the roof, wall and floor.

c) Check whether the workmanship of the labour force is according to the assumptions.

7.3.3 *Working Finishing*

7.3.3.1 Bamboo can be cut and split easily with very simple hand tools. Immature bamboos are soft, pliable and can be moulded to desired shape. It takes polish and paint well.

7.3.3.2 While it is possible to work with bamboo simply using a machete, a few basic tools such as, machete, hack saw, axe, hatchet, sharpening tools, adze, chisel (20 mm), drill, wood rasps, steel rod, and pliers, will greatly increase the effectiveness of the construction process.

7.3.4 For providing safety to the structure against fire, bamboo may be given fire retardant treatment using following chemicals; a few drops of concentrated HCl shall be added to the solution to dissolve the precipitated salts:

Ammonium phosphate	:	3 parts
Boric acid	:	3 parts
Copper sulphate	:	1 part
Zinc chloride	:	5 parts
Sodium dichromate	:	3 parts
Water	:	100 parts

7.3.5 *Foundations*

Bamboo in direct contact with ground, bamboo on rock or preformed concrete footing, bamboo incorporated into concrete, may form the foundation structure (*see* Fig. 8). Also, arrangements with use of metallic strap, C-clamp and bunched bamboo columns embedded in concrete may be used for foundation of bamboo structures (*see* Fig. 9).

7.3.6 *Floors*

The floor of bamboo may be at ground level with covering of bamboo matting, etc. In elevated floors, bamboo members become an integral part of structural framework of building. The floor will comprise structural bamboo elements and bamboo decking.

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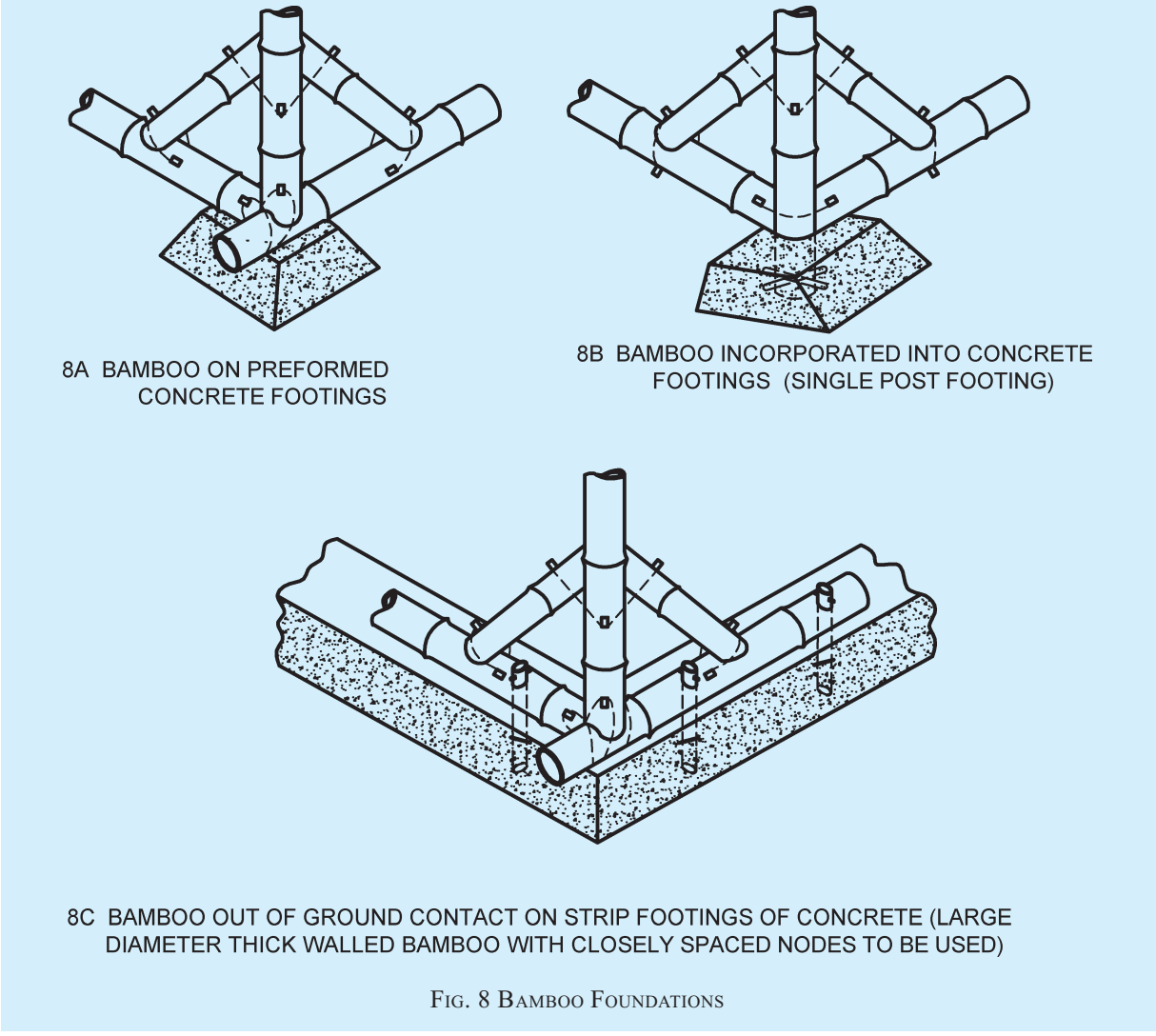


FIG. 8 BAMBOO FOUNDATIONS

7.3.7 *Jointing Techniques*

The jointing techniques in construction using bamboo shall be in accordance with **7.2**.

8 BAMBOO AS REINFORCEMENT IN CONCRETE

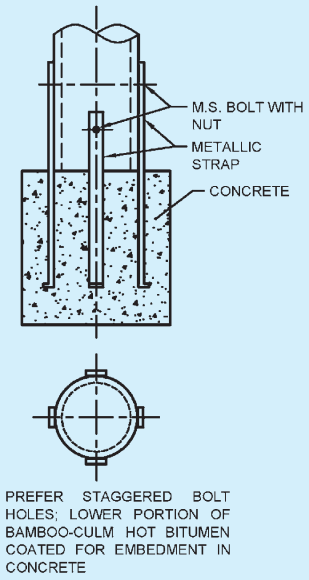
8.1 Due to its fibrous texture, bamboo possesses high tensile strength. This can act as an alternate material for reinforcement in concrete within the limitations of design and construction. The ultimate strength of some of the species of bamboo in direct tension is nearly the same as that of steel at its yield point. On an average it varies from 1 400 to 2 000 kg/cm^2. The principles adopted for design of concrete structure with steel is also applicable for the concrete member with bamboo. Strength characteristics of steel, concrete and bamboo are indicated in Table 4 and the design data for balanced section in beams/slabs reinforcement is given in Table 5.

Table 4 Strength Characteristics of Mild Steel, Bamboo and Concrete (For Reinforcement Purposes)

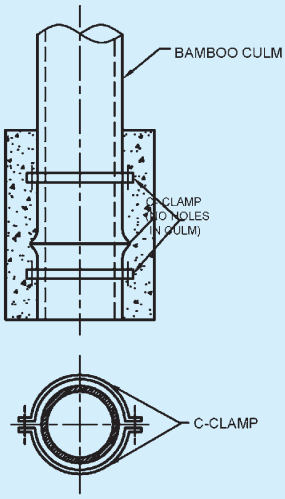
(*Clause* 8.1)

Sl No.	Related Strength Characteristics kgf/cm^2			
	Stress	Mild Steel	Bamboo (Green)	Mass Concrete
(1)	(2)	(3)	(4)	(5)
i)	Modulus of elasticity	2.1×10^6	175 750 to 196 640 (for all locations)	—
ii)	Tensile stress	1 265.5 to 1 400	158, Bending-tension (all locations)	—
iii)	Compressive stress	—	105 *(D. strictus)*	50
iv)	Bond stress	—	3.5 (green) to 5.6 (dry) reported (likely to increase up to 10)	4 - 10
v)	Shear stress	—	115-180	5

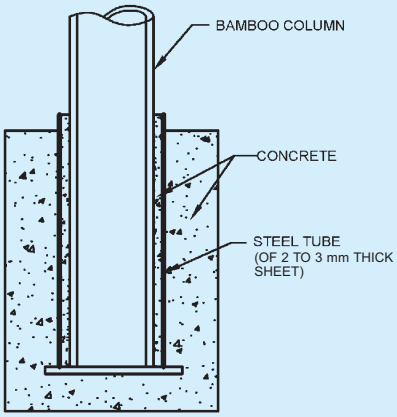
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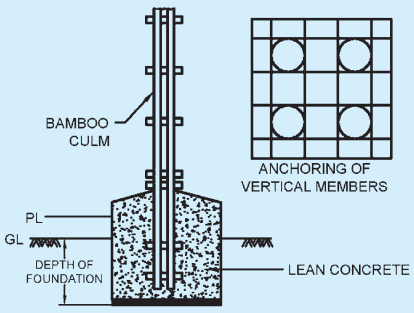
9A USING METALLIC STRAP



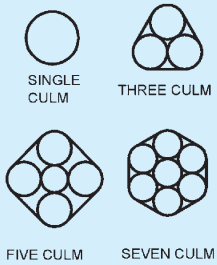
9B USING C-CLAMP



9C USING METAL TUBE



9D BUNCHED BAMBOO COLUMNS EMBEDDED WITHIN CONCRETE



9E INTEGRATED BAMBOO FOR FORMING BUNDLE COLUMNS AND THEIR FASTENING

FIG. 9 BAMBOO COLUMN IN CONCRETE

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Table 5 Design Data for Bamboo and Mild Steel Reinforced Cement Concrete for Balanced Section

(*Clause* 8.1)

Sl No.	Design Data for Balanced Section M 15 (1:2:4) Bamboo and Mild Steel Reinforced Cement Concrete		
	Design Parameters	Mild Steel	Bamboo
(1)	(2)	(3)	(4)
i)	Modular ratio	18	1 to 1.4
ii)	Position of neutral axis from the top	0.4d	0.25d to 0.254d
iii)	Lever arm of the resisting moment (MOR)	0.87d	0.917d to 0.915d
iv)	Constant for MOR (Q) where (Q = Bending moment/bd^2, d = depth or thickness, and b = width.)	137	86

8.2 The whole bamboo culms are halved longitudinally and again splitted into four and strips of the size of 20 to 25 mm width and 9 mm thickness are prepared for use as reinforcement. Bamboo strips with triangular lugs (formed at nodes) due to conversion of bamboo into strips improve the bond strength because of the protruding lugs beings gripped firmly in concrete. Strength properties of split bamboo out of a few species are given in Table 6.

8.3 Bamboo has a tendency to absorb water from concrete which results in initial swelling and subsequent shrinkage leading to cracks in concrete. Following processes are thus recommended as mandatory:

a) Chemical treatment with preference for pressure impregnation (full cell treatment with warm coal tar creosote is likely to preserve and at the same time act as water repellent).

b) Treated strips be further given a water repellent treatment with a coating of very hot bitumen 80/100 grade, followed by a liberal coating of coarse sand. Water inhibitor will also help maintain dimensional stability of strips.

8.4 Techniques in Placing the Reinforcement (*see also* Fig. 10)

Reinforcement shall be placed in the following manner:

a) Laid edge wise in sets of twin strips for main reinforcement.

b) Laid flatwise with smooth surface and rough surface alternating as distribution or subsidiary reinforcement (wedge effects increased bond).

c) For negative moments, bamboo strips of length equivalent to $\frac{\text{Span}}{6}$ laid flatwise in alternate rows of slab reinforcement.

d) For beams and lintels, twin strips are arranged in tiers, placed one above the other depending upon requirement and held in position with the help of vertical strips.

e) Split bamboo strip or preferably steel rod be used for diagonal tension to resist shear in beams, etc.

f) Bind the reinforcement with the help of galvanized iron binding wire (or nylon thread/ bamboo-cane string).

9 WALLING, FLOORING, ROOFING, AND IN-FILL PANELS FOR WALL, AND COMMON ROOF COVERING/CLADDING

9.1 Materials

9.1.1 *Bamboo Based Panel Products*

The common roof covering and in-fill materials shall include bamboo mat board, bamboo mat veneer

Table 6 Strength Properties of Split Bamboo in Green Condition[1)]

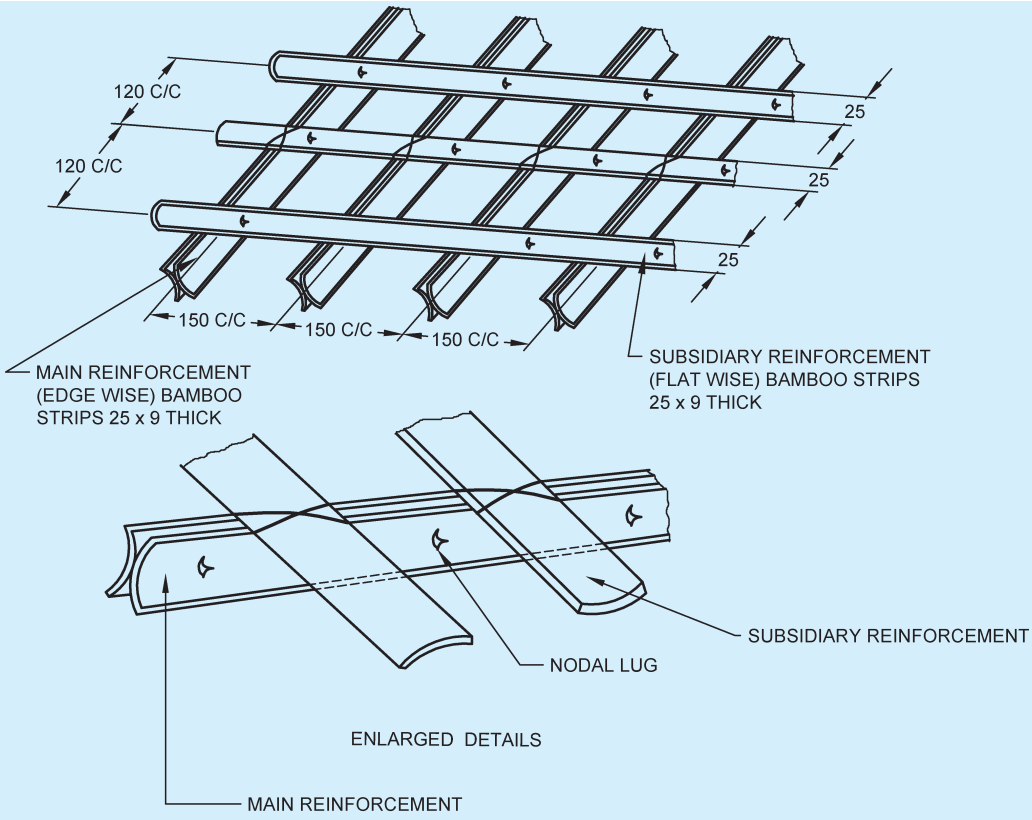
(*Clause* 8.2)

Sl No.	Species	Static Bending			Compression Parallel (Without Node)	Shear Parallel
		Fibre Stress at Elastic Limit kg/cm^2	Modulus of Rupture kg/cm^2	Modulus of Elasticity $\times 10^3$ kg/cm^2	Maximum Crushing Stress kg/cm^2	Maximum Shearing Stress kg/cm^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	*Bambusa pallida*[2)]	378	605	32.5	595	97.7
ii)	*B. Vulgaris*	464	885	52.3	403	94.4
iii)	*Dendrocalamus hamiltonii*	301	524	37.7	414	77.7
iv)	*D. giganteus*	472	848	50.7	360	88.5
v)	*Oxytenanthera abyssinica*[2)]	450	831	33.6	377	112.0

[1)] average of bottom, middle and top portions of culms.

[2)] average of bottom and middle portions only.

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All dimensions in millimetres.

FIG. 10 GENERAL DETAILS OF BAMBOO REINFORCEMENT

composite, bamboo mat corrugated sheet, bamboo tiles, plastered bamboo reeds, thatch, corrugated galvanized iron sheeting, asphaltic sheets, plain clay tiles, etc. The respective materials shall conform to the following:

a) *Bamboo mat board* — These shall conform to the accepted standard [6-3B(7)].
b) *Bamboo mat veneer composite* — These shall conform to the accepted standard [6-3B(8)].
c) *Bamboo mat corrugated sheet and bamboo mat ridge cap* — These shall conform to the accepted standard [6-3B(9)].
d) *Bamboo-jute composite corrugated and semi-corrugated sheets* — These shall conform to the accepted standard [6-3B(10)].

9.1.2 *Reconstituted Wood from Destructured Bamboo*

After lopping, bamboos are cross-cut into small lengths in the round and then split along the axis. The small cross-section strips are then passed between the counter revolving rollers till the material is fully destructured. This is then air dried and resin treated and suitably pressed without much disturbing the natural alignment of fibres thus retaining the directional properties of bamboo.

Some typical strength properties of reconstituted wood from destructured bamboo are given in Table 7. The reconstituted product from bamboo can be sawn, nailed, moulded, bored, screwed, polished and painted. Thus it offers a good substitute of solid wood for structural uses.

NOTE — Reconstituted boards/wood from destructured bamboo when tested for physical and mechanical properties in accordance with the accepted standards [6-3B(11)] and [6-3B(12)] yielded encouraging results. Gist of mechanical properties of these boards is excellent when compared with *Dendrocalamus strictus* (bamboo), teak and sal.

9.1.3 *Other Panel Products/Infill Materials*

Other panel products/infill materials shall be in accordance with relevant Indian standards. These shall be such that they maintain their integrity and strength in the assigned service class throughout the expected life of the structure.

9.1.4 *Adhesives*

Adhesive shall maintain their integrity in accordance with the accepted standard [6-3B(13)].

9.2 Structural Usage of Bamboo Based Products

9.2.1 *General*

Bamboo mat board (BMB) and bamboo mat veneer

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Table 7 Gist of Mechanical Properties of Reconstituted Wood from Bamboo (*Dendrocalamus Strictus*)

(*Clause* 9.1.2)

Sl No.	Board Material			Density	Modulus of Rupture	Tensile Strength Parallel to Grain	Compressive Strength Parallel to Grain	Izod Impact	Shear Strength	Modulus of Elasticity × 10^3	Screw Holding Power
	Set	Resin Contents	Pressure								
		Percent	kgf/cm^2	g/cm^3	kgf/cm^2	kgf/cm^2	kgf/cm^2	kgf/cm	kgf/cm^2	kgf/cm^2	kgf
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	I	6 to 29	56	0.99 to 1.25	1 769 to 2 255	1 049 to 2 024	1 057 to 1 596	343 to 281	202 to 364	278 to 308	398 to 508
				In the increasing order of resin percentage.							
ii)	II	9	21 to 28	0.62 to 0.93	1 062 to 1 615	6 99 to 1 210	675 to 1 030	186 to 202	128 to 247	155 to 232	361 to 486
	Wood/Bamboo										
iii)	*Shorea robusta* (at 12 percent dry moisture content)			0.749	1 249	—	685	124	110	152.8	369
iv)	*Tectona grandis* (at 12 percent dry moisture content)			0.596	959	—	532	68	102	119.6	326
v)	*Dendrocalamus strictus*			0.757	1 310	—	624	—	—	180.3	—

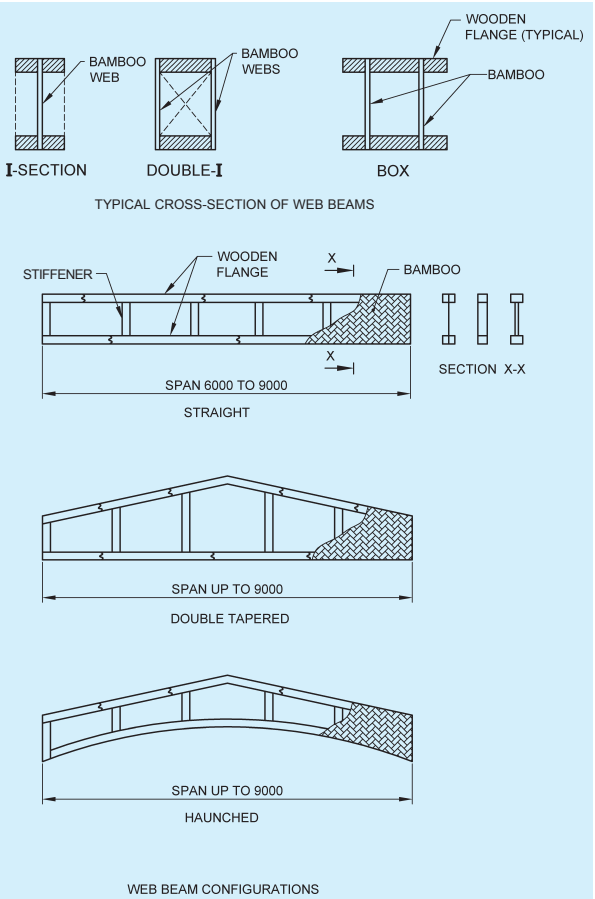
composite (BMVC) have high in-plane rigidity and hence high racking strength and are more flexible than equivalent plywood. This property of BMB and BMVC can be advantageously used in many engineering applications such as wall paneling, composite beams, composite floor deck and stress skinned panels. Bamboo mat corrugated sheet (BMCS) is water proof and resistant to decay, termites/insects and fire. These sheets may be used as roofing material. Precast bamboo reinforced cement concrete and reconstituted wood from destructured bamboo can also be used in structural applications.

9.2.2 *Bamboo Composites*

Along with bamboo, bamboo composites such as bamboo mat board, bamboo mat veneer composite, may also be successfully used in combination with timber for making efficient structural components like web because where high shear strength of bamboo mat board and bamboo mat veneer composite can be utilized as web and timber flanges for transmitting tensile and compressive stress. PF, PRF adhesives are commonly used for gluing web and flanges as shown in Fig. 11. Beams can be straight, single tapered, double tapered, haunched, as shown.

Bamboo mat board and bamboo mat veneer composite can also be used for roof and wall sheathing (shear walls) and diaphragms, gussets, arch panels, barrel vaults, etc. It can also be used as skin material in sandwich construction.

Permissible safe working stresses are given in Table 8.



All dimension in millimetres.

FIG. 11 BAMBOO MAT BOARD WEB BEAMS

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Table 8 Permissible Safe Working Stresses for Bamboo Mat Board and Bamboo Mat Veneer Composite

(*Clause* 9.2.2)

Sl No.	Properties	Bamboo Mat Board	Bamboo Mat Veneer Composite	
			Along	Across
		N/mm^2	N/mm^2	N/mm^2
(1)	(2)	(3)	(4)	(5)
i)	Tensile strength	8.5	10	10
ii)	Compressive strength	10.80	13	6.5
iii)	Modulus of rupture	19.00	19	10.5
iv)	Modulus of elasticity	3 200	4 600	—
v)	Modulus of rigidity	4 970	1 930	—

9.2.3 *Precast Bamboo Reinforced Cement Concrete*

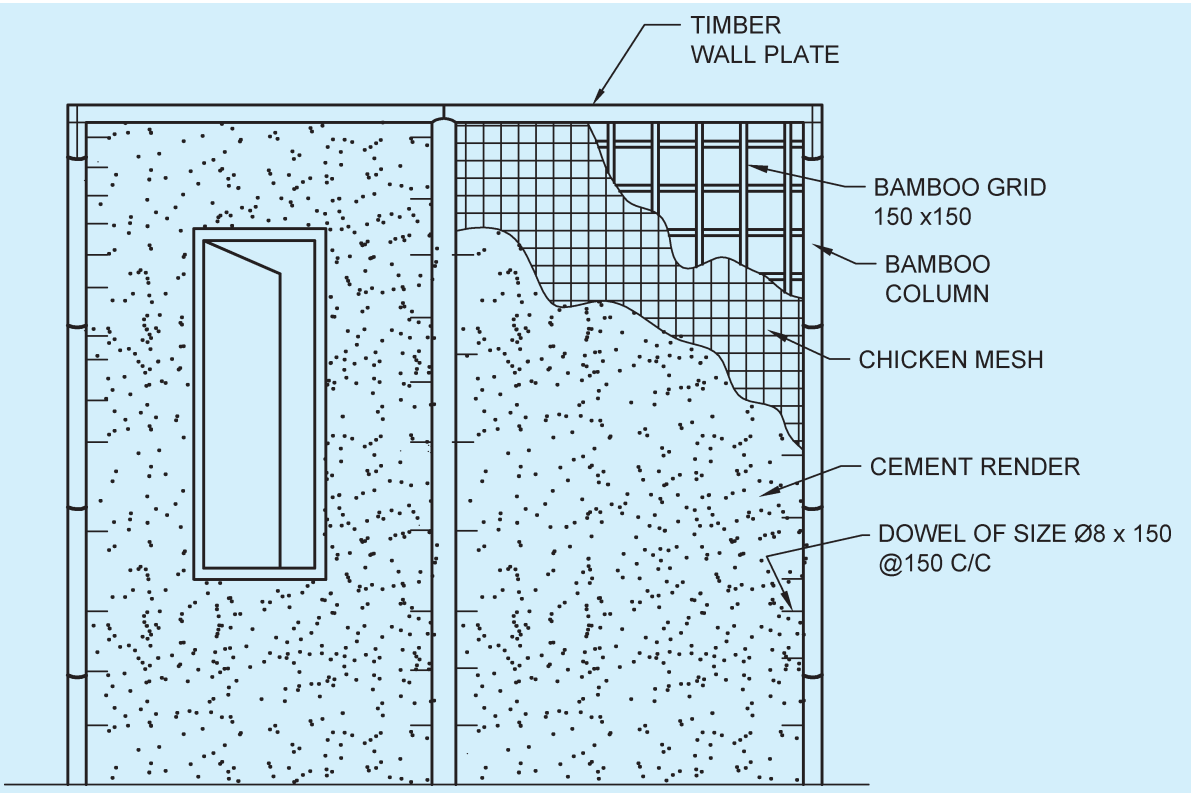
Precast bamboo reinforced cement concrete panels of dimensions 600 mm × 300 mm × 40 mm can serve for walling, when laid one above the other in a suitability located wall in low cost construction, etc. Bamboo strips 20 mm × 8 mm splits duly processed should be placed at 90 mm centre-to-centre both ways in form work and concreted.

9.2.4 *Wall Infill Panel*

The wall is considered non-load bearing although connected to the framing elements. It comprises a grid of split bamboo (19 mm × 9 mm) tied together with MS binding wire to form a 150 mm × 150 mm grid. The grid is tied to steel dowels passing through the columns. Chicken wire mesh is fixed on the outside face of the grid. Cement mortar (in the proportion 1 : 3) is applied to both sides of the grid to a finished thickness of about 50 mm. Fly ash can be utilized as part replacement of cement up to 35 percent by mass. This is similar to conventional ferrocement-type construction. The same principle is extended to the construction of gable walls**.** Alternatively, gable walls may be formed with bamboo mat board. Figure 12 shows the typical cross-section of the infill wall panel.

9.2.4.1 *Foundation detail*

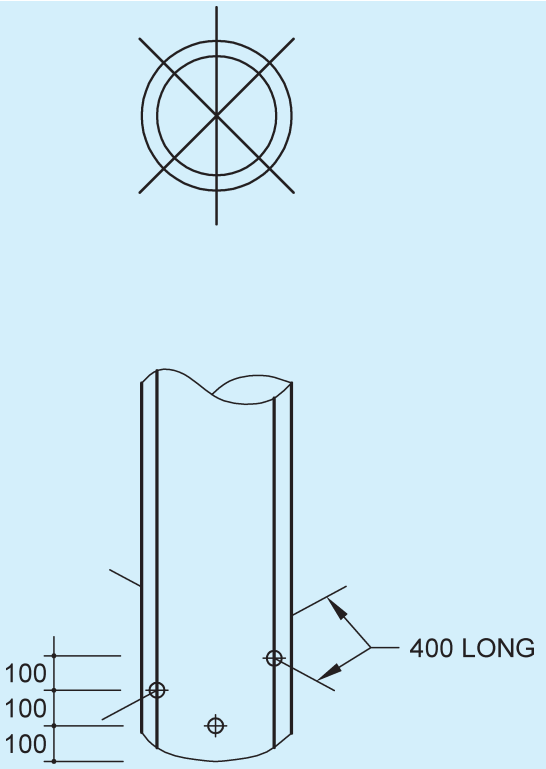
The columns pierced by steel dowels at 150 mm centre-to-centre provide connection to the bamboo grid infill. Fix 8 mm diameter MS rod of 400 mm length at 100 mm from one end of the column which has undergone treatment. For anchoring, fix two more MS rods of same diameter at 100 mm centre-to-centre starting from the first hole (*see* Fig. 13). Pour the concrete by giving temporary support. Foundation is limited to individual footings of size 400 mm × 400 mm × 600 mm deep for each bamboo column placed at 1 200 mm apart and two coarse concrete blocks or stone or other locally available material for infill wall foundation.



All dimensions in millimetres.

FIG. 12 BAMBOO STRUCTURAL WALLING SYSTEM

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All dimensions in millimetres.

FIG. 13 DETAILS OF BOTTOM OF BAMBOO COLUMN FOR ANCHORING IN CONCRETE FOR FOUNDATION

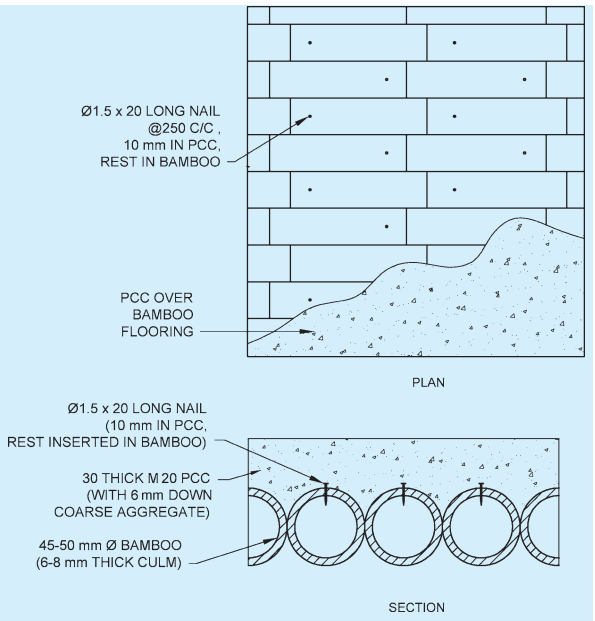
9.2.5 *Bamboo Concrete Flooring Using Round Bamboo*

Technology of such a flooring (for situations needing raised flooring) is based on the method of rigidly fixing round bamboo, where 30 mm thick M 20 grade PCC (with 6 mm down coarse aggregate) is placed over 6 to 8 mm thick culm, that are arranged side by side to form bamboo flooring.

The rigid fixing is achieved by using shear connectors in the form of 1.5 mm dia. 20 mm long MS nails partially inserted into the bamboo flooring and balance length with the heads of the nails embedded in the PCC layer, holding the two components together. The sectional properties of the combination are calculated based on the concept of flitched beams for design (*see* Fig. 14).

9.2.6 *Bamboo Concrete Walling Using Flat Bamboo*

Loads on walls and roof do not generally justify use of round bamboo as such. So, flat or split bamboo is preferred for use in these cases. The flat bamboo works like a wire-net used conventionally to hold cement plaster in critical applications. Partial plastering is done during the first day ensuring entry of plastering material in the gaps of flat bamboo. This provides the base for cement plastering or PCC laying next day. About 5 mm gap is essential for entry of plastering



All dimensions in millimetres.

FIG. 14 DETAIL OF A TYPICAL BAMBOO CONCRETE FLOORING

material of sufficient sectional area to sustain shear force. The gaps are generated by inserting a small wedge of bamboo strip and pulling it out after a part of the gap is filled by plaster. Such gaps have to be discontinuous, to retain the character of a wire-net. About 25 percent width of the flat bamboo is assumed to be gaps, part of it is the organized gap of 5 mm width as described, at an interval of about 50 mm width, to sustain shear force and the balance gap remains to be natural to flat bamboo. Minimum thickness of the flat bamboo is assumed to be 6 mm. Bamboo with thicker wall would be stronger.

Expected strength (using *Bambusa balcooa*) may be considered as follows:

a) Walling of 6 mm bamboo with 18 mm thick cement sand plaster in 1:3 would be able to withstand wind pressure of 112 kgf/m^2 if used as wall, either supported continuously 1.5 m apart, or supported simply 1.25 m apart.

b) As a roof, the wind suction load would be partly compensated by the dead load of the roof. The imposed load of a mason sitting at the centre of span needs to be considered. This load can be accommodated by use of 18 mm M 20 PCC with 6 mm flat bamboo, supported 1.0 m apart; neatly finished.

The engineered houses for application of the above bamboo concrete walling are designed with stiffeners and diagonals in all the three planes, keeping the deformation of walls along plane of walls almost nil and deflection of columns across the plane of wall at a minimum.

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ANNEX A

(*Foreword*)

SOURCE AND LOCAL NAMES OF SOME OF THE SPECIES OF BAMBOO

Sl No.	Species	Source/Local Names
(1)	(2)	(3)
i)	*Bambusa auriculata*	Assam, Bangladesh, Myanmar; introduced in Calcutta Botanical Garden (now Acharya Jagadish Chandra Bose Indian Botanic Garden).
ii)	*B. balcooa*	Asm — Baluka; Ben — Balku bans; Duars — Bora bans; Garo — Wamnah, beru; Tripura — Barak.
iii)	*B. bambos (Syn.B.arundinacea)*	Asm — Kotoba; Ben — Baroowa, behor, ketuas, ketwa; Manip — Saneibi; Mah — Katang bamboo, oowga; Oriya — Daba, katuig; Tel — Mulkas veduru, Mullu vedurn; English — Spiny bamboo.
iv)	*B. burmanica*	Asm — Thaikawa.
v)	*B. multiplex Syn. B. glancescens (Syn. B. nana)*	Sans — keu-fa; Burmese — Pa-lau-pinan-wa; Malay — Bamboo tjeenah; China — Bamboo hower tjeenah.
vi)	*B. nutans*	Asm — Deobans, jotia-makal; Asm — Bidhuli, mukial; Ben — Makia; Bhutia — Jiu; Hin — Malabans; Kangra — Nal; Khasi — Seringjai; Kuki — Wa malang; Lepcha — Malubans, mahlu, mallo; Oriya — Badia bansa; Sylhet (Bangladesh) — Peechli; Tripura — Kali.
vii)	*B. pallida*	Asm — Bijli, jowa, makal, walkthai; Cachar — Bakhal, burwal; Khasi — Seskien, skhen, ineng, usker; Lepcha — Pashipo, pshi, pushee; Mikir — Loto; Naga — Tesero, watoi; Tripura — Makal.

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(1)	(2)	(3)
viii)	*B. polymorpha*	Asm — Jama betwa, betwa; Ben — Batua, jaibarouwa, jama; Burma — Kyathaung-wa; MP-Korku — Narangi bhas; Tripura — Basi.
ix)	*B. tulda*	Asm — Wamunna, wagi, nal-bans; Ben — Tulda, jowa; Duars — Karanti, matela; Garo — Watti; Hin — Peka; Kamrup — Bijuli, jati, joo, ghora; Tripura — Mirtinga.
x)	*B. vulgaris*	Ben and Manip — Bakal; Oriya — Sunarkania bans.
xi)	*B. Wamin Syn. B.ventricosa (Syn. B. Vulgaris var. Wamin)*	Common name — Pitcher bamboo.
xii)	*Cephalostachyum pergracile*	MP — Bhalan bans; Manip — Wootang; Naga — Latang; Oriya — Darrgi.
xiii)	*Dendrocalamus giganteous*	English — Giant Bamboo; Asm — Worra; Manip — Maroobeb.
xiv)	*D. hamiltonii*	Nep — Tamo; Asm — Kokwa; Tripura — Pecha.
xv)	*D. longispathus*	Tripura — Rupai.
xvi)	*D. membranaceus*	Native of Myanmar; introduced in Kerala.
xvii)	*D. strictus*	English — Male bamboo; Ben — Karail; Guj — Nakur bans; Kan — Kiri bidiru; Mah — Male bamboo, nanvel; Oriya — Salia; Tam — Kalmungil; Tel — Sadanapa vedur; Tripura — Lathi bans; Hin — Bans kaban, Nav bans;
xviii)	*Melocanna baccifera*	Asm — Tarai; Ben — Muli; Cachar — Wati; Garo — Watrai; Manip — Moubi; Mikir — Artem; Naga — Turiah.
xix)	*Oxytenanthera abyssinicia*	Native of tropical Africa; cultivated at FRI, Dehradun.

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(1)	(2)	(3)
xx)	*Thyrsostachys oliveri*	Native of Myanmar; Planted in Haldwani (Uttaranchal), Arunachal Pradesh, Kerala and Tamilnadu.

NOTES

1 The following abbreviations have been used in the above table:

Asm	Assam
Ben	Bengali
Guj	Gujarati
Hin	Hindi
Kan	Kannada
Mah	Maharashtra
Manip	Manipur
MP	Madhya Pradesh
Nep	Nepali
Sans	Sanskrit
Tam	Tamil
Tel	Telugu

2 The above table does not provide an exhaustive list. It only attempts to enlist some of the information readily available in regard to species of bamboo from India and some of the neighbouring countries, and some connected information.

ANNEX B

(*Foreword*)

RECOMMENDATIONS FOR BAMBOO STRUCTURES IN HIGH WIND/ CYCLONE PRONE AREAS

B-1 Given below are some recommendations for bamboo structures in high wind/cyclone prone areas, which are based on Rapid Visual Screening (RVS) of the damages of past events:

a) Prefer a square plan of the building symmetrical to the arrangement of partitions and openings for balanced distribution of forces within the structure. Window positioning be planned in such a way that wind entering through window could pass through similar opening on opposite wall in order to reduce built-up pressure, and incorporate ridge vents.

b) A hip-shaped, pyramidal or a conical roofing be preferred to gable end or mono-pitch ones for least wind resistance.

c) Wide mono-pitched *Verandas* abutting the entrance to residence should be structurally separated from the main building.

d) Roof overhangs be limited to 450 mm as they contribute to higher negative suction. Large overhangs should be properly tied back to wall frame-work.

e) Roof structure shall be properly secured with vertical load-bearing members (wooden or bamboo columns, brick piers or walling) for eliminating the chances of being blown away from the building. A continuous beam connecting all the columns would increase the framing action.

f) Roof cladding (G. I. sheets, clay tiles or thatch) be properly connected with holding down U-bolts, or sturdy anchorages to ensure safety. Thatch roof be tied by nylon ropes in diagonal pattern.

g) Sufficient depth for anchorage be provided; columns be embedded in pits within the foundation and secured by poured concrete. Wetting of column base be checked by raising it from the floor level.

h) Highest importance be given to strengthening the junctions between structural elements at

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different levels, that is, foundation, eaves and roof. Walls be linked together suitably by a continued collar beam at floor, sill, lintel and roof level.

j) Fastening any two mutually perpendicular load bearing members should be done in accordance with good practice of spacing the connecting bolts with reference to loads direction and the centre of stiffness. This will increase the moment-resisting capacity of the joint and prevent hinge formation. A minimum of two bolts be provided to prevent rotation of members at a joint.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this Code. The latest version of the standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Subsection.

	IS No.	*Title*
(1)	9096 : 2006	Code of practice for preservation of bamboo for structural purposes (*first revision*)
(2)	6874 : 2008	Method of tests for bamboo (*first revision*)
(3)	1902 : 2006	Code of practice for preservation of bamboo and cane for non-structural purposes (*second revision*)
(4)	8242 : 1976	Method of tests for split bamboo
(5)	2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
(6)	4924	Method of test for nail-jointed timber trusses
	(Part 1) : 1968	Destructive test
	(Part 2) : 1968	Proof test
(7)	13958 : 1994	Specification for bamboo mat board for general purposes
(8)	14588 : 1999	Specification for bamboo mat veneer composite for general purposes
(9)	15476 : 2004	Specification for bamboo mat corrugated sheets
(10)	15972 : 2012	Specification for bamboo-jute composite corrugated and semi-corrugated sheets
(11)	1734 (Parts 1 to 20) : 1983	Methods of test for plywood (*second revision*)
(12)	1708 (Parts 1 to 18) : 1986	Methods of testing of small clear specimens of timber (*second revision*)
(13)	848 : 2006	Specification for synthetic resin adhesives for plywood (phenolic and aminoplastic) (*second revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 4 Masonry

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Section 4) covers the structural design of unreinforced and reinforced masonry elements in buildings. Provisions on reinforced brick and reinforced brick concrete floors and roofs have also been dealt with.

This Section was first published in 1970 and subsequently revised in 1983. The first revision of this Section was modified in 1987 through Amendment No. 2 to bring this Section in line with the latest revised masonry code. In the amendment, certain provisions were updated following the revision of IS 1905 'Code of practice for structural use of unreinforced masonry' on which the earlier version was based. In the amendment, requirements of masonry element for stability were modified; in the design of free standing wall, provisions were made for taking advantage of the tensile resistance in masonry under certain conditions; provision regarding effective height of masonry wall between openings was modified; method of working out effective height of wall with a membrane type DPC was modified; the criteria for working out effective length of wall having openings was modified; some general guidelines for dealing with concentrated loads for design of walls were included; and provision of cutting and chases in walls were amplified. The Section was thereafter revised in 2005.

In the second revision of this Section in 2005, the provisions of special considerations in earthquake zones were aligned in line with the revised Indian Standard, IS 4326 : 1993 'Code of practice for earthquake resistant design and construction of buildings'; a new clause covering guidelines for improving earthquake resistance of low strength masonry buildings was added; and reference to design of reinforced brick and reinforced brick concrete floors and roofs was included.

As a result of experience gained in the implementation of this Section and feedback received, as well as in view of revision of IS 4326, a need to revise this Section was again felt. This Section has, therefore, been revised to incorporate the following significant changes:

a) Detailed provisions relating to reinforced masonry have been included.
b) The provisions of special considerations in earthquake zones have been updated including by incorporation of suitable provisions relating to 'Confined masonry building construction'.
c) A separate table on compressive strength for different grades of mortar has been included for clarity.
d) Mix proportions and strength of mortars for masonry have been updated to be based on proportioning by mass (instead of by volume) to reflect sound engineering practices; and 28 day strength values of cement-sand mortar with cement having compressive strength of 43 MPa and above.
e) Provisions related to durability criteria for selection of masonry mortars have been included.
f) Use of one and a half brick thick wall up to ground level from foundation level has been suggested to reduce the slenderness ratio of the wall above it for ground floor walls.
g) Stabilized soil blocks have been included as masonry unit.
h) Number of storeys of masonry construction has been limited to 4, in line with the seismic design standards.
j) Masonry wall construction using rat-trap bond has been included.
k) Reference to all the concerned Indian Standards has been updated.

Structural design requirements of this section are largely based on following Indian Standards:

a) IS 1905:1987 'Code of practice for structural use of unreinforced masonry (*third revision*)',
b) IS 4326:2013 'Earthquake resistant design and construction of buildings — Code of practice (*third revision*)
c) IS 10440:1983 Code of practice for construction of RB and RBC floors and roofs, and
d) IS 13828:1993 'Improving earthquake resistance of low strength masonry buildings — Guidelines'.

Until further research material is available on rat-trap bond masonry, its usage is proposed to be limited up to two storeys.

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A reference to SP 20 : 1991 'Handbook on masonry design and construction (*first revision*)', may be useful. In the formulation of this Section, inputs were also derived from the IITK-GSDMA's publication, 'Guidelines for structural use of reinforced masonry'.

All standards, whether given herein above or cross-referred to in the main text of this section, are subject to revision. The parties to agreement based on this section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 4 Masonry

1 SCOPE

1.1 This Code (Part 6/Section 4) covers the structural design aspects of unreinforced load bearing and non-load bearing walls, constructed with masonry units permitted in accordance with this section.

1.2 This Section also deals with the selection of materials, special features of design and construction for masonry construction using rectangular masonry units. It also covers guidelines regarding earthquake resistant buildings constructed using masonry of low strength.

1.3 This Section also covers provisions for design of reinforced brick and reinforced brick concrete floors and roofs.

1.4 This Section also gives the recommendations for structural design aspects of reinforced load bearing and non-load bearing walls, constructed with different types of bricks and blocks.

1.5 The recommendations of the Section do not apply to walls constructed in mud mortars.

2 TERMINOLOGY

For the purpose of this Section, the definitions given below shall apply.

2.1 Bed Block — A block bedded on a wall, column or pier to disperse a concentrated load on a masonry element.

2.2 Bond — Arrangement of masonry units in successive courses to tie the masonry together both longitudinally and transversely; the arrangement is usually worked out to ensure that no vertical joint of one course is exactly over the one in the next course above or below it, and there is maximum possible amount of lap.

2.3 Column, Pier and Buttress

a) *Column* — An isolated vertical load bearing member, width of which does not exceed four times the thickness.

b) *Pier* — A thickened section forming integral part of a wall placed at intervals along the wall, to increase the stiffness of the wall or to carry a vertical concentrated load. Thickness of a pier is the overall thickness including the thickness of the wall or, when bonded into a leaf of a cavity wall, the thickness obtained by treating that leaf as an independent wall (*see* Fig. 1)

c) *Buttress* — A pier of masonry built as an integral part of wall and projecting from either or both surfaces, decreasing in cross-sectional area from base to top.

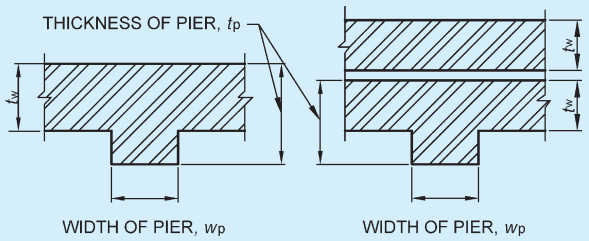
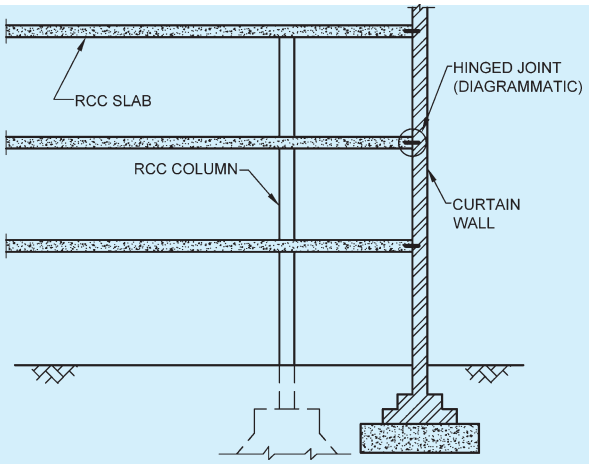


FIG. 1 DEFINITION OF PIER

2.4 Cross-Sectional Area of Masonry Unit — Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cellular space. Gross cross-sectional area of cored units shall be determined to the outside of the coring but cross-sectional area of grooves shall not be deducted from the gross cross-sectional area to obtain the net cross-sectional area.

2.5 Curtain Wall — A non-load bearing wall subject to lateral loads. It may be laterally supported by vertical or horizontal structural members, where necessary (*see* Fig. 2).



NOTE — The figure is only illustrative to explain about the term curtain wall and is not intended to be an exhaustive provision.

FIG. 2 TYPICAL MASONRY CURTAIN WALL

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2.6 Effective Height — The height of a wall or column, to be considered for calculating slenderness ratio.

2.7 Effective Length — The length of a wall to be considered for calculating slenderness ratio.

2.8 Effective Thickness — The thickness of a wall or column to be considered for calculating slenderness ratio.

2.9 Hollow Unit — A masonry unit of which net cross-sectional area in any plane parallel to the bearing surface is less than 75 percent of its gross cross-sectional area measured in the same plane.

2.10 Grout — Mortar of pourable consistency.

2.11 Joint — A junction of masonry units, which can be classified as:

a) *Bed joint* — A horizontal mortar joint upon which masonry units are laid.
b) *Cross joint* — A vertical joint, normal to the face of the wall.
c) *Wall joint* — A vertical joint parallel to the face of the wall.

2.12 Leaf — Inner or outer section of a cavity wall.

2.13 Lateral Support — A support which enables a masonry element to resist lateral load and/or restrains lateral deflection of a masonry element at the point of support.

2.14 Load Bearing Wall — A wall designed to carry an imposed vertical load in addition to its own weight, together with any lateral load.

2.15 Masonry — An assemblage of masonry units properly bonded together with mortar.

2.16 Masonry Unit — Individual units which are bonded together with the help of mortar to form a masonry element such as wall, column, pier, buttress, etc.

2.17 Partition Wall — An interior non-load bearing wall, one storey or part storey in height.

2.18 Panel Wall — An exterior non-load bearing wall in framed construction, wholly supported at each storey but subjected to lateral loads.

2.19 Shear Wall — A wall designed to carry horizontal forces acting in its plane with or without vertical imposed loads.

2.20 Slenderness Ratio — Ratio of effective height or effective length to effective thickness of a masonry element.

2.21 Types of Walls

a) *Cavity wall* — A wall comprising two leaves, each leaf being built of masonry units and separated by a cavity and tied together with metal ties or bonding units to ensure that the two leaves act as one structural unit, the space between the leaves being either left as continuous cavity or filled with a non-load bearing insulating and water-proofing material.
b) *Faced wall* — A wall in which facing and backing of two different materials are bonded together to ensure common action under load (*see* Fig. 3).

NOTE — To ensure monolithic action in faced walls, shear strength between the facing and the backing shall be provided by toothing, bonding or other means.

c) *Veneered wall* — A wall in which the facing is attached to the backing but not so bonded as to result in a common action under load.

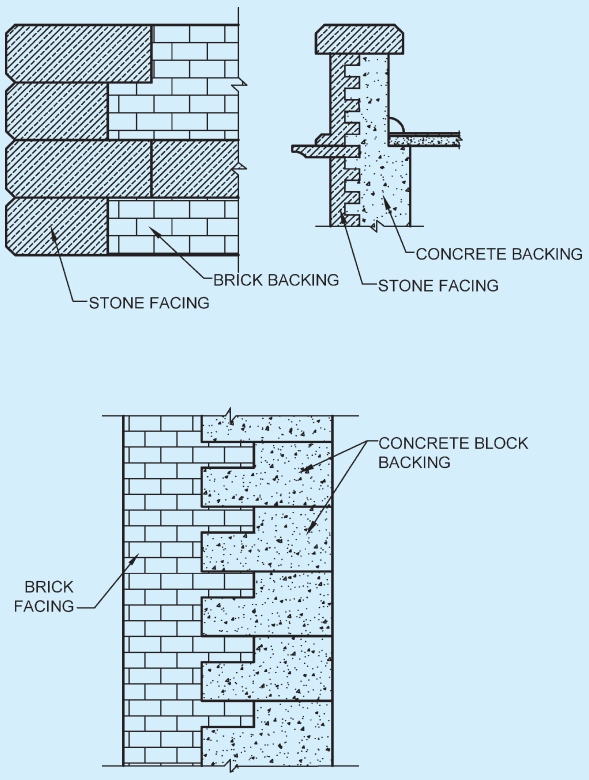


FIG. 3 TYPICAL FACED WALL

2.22 Reinforced Brick Slab (RB Slab) — Reinforced brick slab is particularly same as reinforced concrete slab in all its essential features except that brickwork is substituted partly for cement concrete. *See* Fig. 4A for details.

2.23 Reinforced Brick Concrete Slab (RBC Slab) — These are reinforced brick slab using concrete in the joints and on the top of bricks. *See* Fig. 4B for details.

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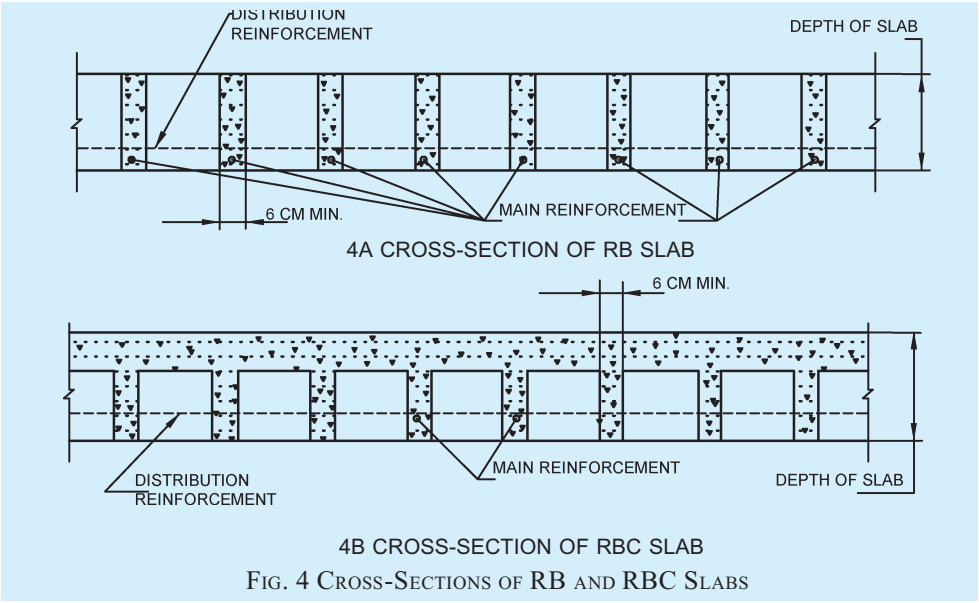


FIG. 4 CROSS-SECTIONS OF RB AND RBC SLABS

3 MATERIALS

3.1 General

The materials used in masonry construction shall be in accordance with Part 5 'Building Materials' of the Code. Storage of materials shall be in accordance with good practice [6-4(1)].

3.2 Masonry Units

Masonry units used in construction shall conform to accepted standards [6-4(2)].

3.2.1 Masonry units may be of the following types:

a) Common burnt clay building bricks,
b) Burnt clay fly ash building bricks,
c) Pulverized fuel ash lime bricks,
d) Stones (in regular sized units),
e) Sand-lime bricks,
f) Concrete blocks (solid and hollow),
g) Lime based blocks,
h) Burnt clay hollow blocks,
j) Gypsum partition blocks,
k) Autoclaved cellular concrete blocks,
m) Stabilized soil blocks, and
n) Concrete stone masonry blocks.

NOTES

1 Gypsum partition blocks are used only for construction of non-load bearing partition walls.

2 Use of other masonry units such as precast stone blocks, fly-ash-lime-gypsum bricks, stabilized soil blocks and other bricks/ blocks not covered by the above specifications may also be permitted based on test results.

3.2.2 Masonry units that have been previously used shall not be reused in brickwork or blockwork construction, unless they have been thoroughly cleaned and conform to this Section for similar new masonry units.

3.3 Mortar

Mortar for masonry shall conform to good practice [6-4(3)].

3.3.1 Minimum compressive strength for different grades of mortar on the basis of mix proportions as per **3.3.2** are given in Table 1.

Table 1 Compressive Strength for Different Grades of Mortar

(*Clause* 3.3.1)

Sl No.	Grade of Mortar	Minimum Compressive Strength at 28 Days N/mm^2
(1)	(2)	(3)
i)	H1	10
ii)	H2	6.0
iii)	M1	5.0
iv)	M2	3.0
v)	M3	1.5
vi)	L1	0.7
vii)	L2	0.5

3.3.2 Mix proportions and compressive strengths of some of the commonly used mortars are given in Table 2.

3.4 Durability Criteria for Selection of Masonry Mortars

3.4.1 The selection of masonry mortars from durability considerations shall cover both the loading and exposure conditions of the masonry. The requirements for masonry mortar shall generally be as given in **3.4.2** to **3.4.6** (*see also* Table 1).

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Table 2 Mix Proportions and Strength of Mortars for Masonry

(*Clause* 3.3.2)

Sl No.	Mix Proportions (By Mass)					Minimum Compressive Strength at 28 Days in N/mm^2 (with Cement Compressive Strength at 28 Days, in N/mm^2, Between 33 and 43)	Minimum Compressive Strength of Cement : Sand Mortar at 28 Days in N/mm^2 (with Cement Compressive Strength at 28 Days, in N/mm^2 ≥ 43)
	Cement	Lime	Lime - Pozzolana Mixture	Pozzolana	Sand		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	1	¼ C or B	0	0	3	10	—
2(a)	1	¼ C or B	0	0	4	7.5	—
2(b)	1	½ C or B	0	0	4 ½	6	—
2(c)	1	0	0	0	4	6	7
3(a)	1	0	0	0	5	5	6
3(b)	1	1 C or B	0	0	6	3	—
3(c)	0	0	1(LP-40)	0	1 ½	3	—
4(a)	1	0	0	0	6	3	4
4(b)	1	2B	0	0	9	2	—
4(c)	0	1A	0	0	2	2	—
4(d)	0	1B	0	1	1	2	—
4(e)	0	1 C or B	0	2	0	2	—
4(f)	0	0	1(LP-40)	0	1 ¾	2	—
5(a)	1	0	0	0	7	2	3
5(b)	1	3B	0	0	12	1.5	—
5(c)	0	1A	0	0	3	1.5	—
5(d)	0	1B	0	2	1	1.5	—
5(e)	0	1 C or B	0	3	0	1.5	—
5(f)	0	0	1(LP-40)	0	2	1.5	—
6(a)	1	0	0	0	8	1	2
6(b)	0	1B	0	1	2	0.7	—
6(c)	0	1 C or B	0	2	1	0.7	—
6(d)	0	0	1(LP-40)	0	2 ¼	0.7	—
6(e)	0	0	1(LP-20)	0	1 ½	0.7	—
7(a)	0	1B	0	0	3	0.5	—
7(b)	0	1 C or B	0	1	2	0.5	—
7(c)	0	0	1(LP-7)	0	1 ½	0.5	—

NOTES

1 Sand for making mortar should be well graded. In case sand is not well graded, its proportions shall be reduced in order to achieve the minimum specified strength.

2 For mixes in Sl No. 1 and Sl No. 2, use of lime is not essential from consideration of strength as it does not result in increase in strength. However, its use is highly recommended since if improves workability.

3 For mixes in Sl No. 3(a), 4(a), 5(a) and 6(a) either lime C or B to the extent of ¼ part of cement (by mass) or some plasticizer should be added for improving workability.

4 For mixes in Sl No. 4(b) and 5(b), lime and sand should first be ground in mortar mill and then cement added to coarse stuff.

5 It is essential that mixes in Sl No. 4(c), 4(d), 5(d), 5(e), 6(b), 6(c), 7(a) and 7(b) are prepared by grinding in a mortar mill.

6 A, B and C denote eminently hydraulic lime, semi-hydraulic lime and fat lime respectively, as specified in appropriate standards listed in Part 5 'Building Materials' of the Code.

3.4.2 In the case of masonry exposed frequently to rains and where there is further protection by way of plastering or rendering or other finishes, the grade of mortar shall not be less than M3 but shall preferably be of grade M2. Where no protection is provided, the grade of mortar for external walls shall not be less than M2.

3.4.3 In the case of load bearing internal walls, the grade of mortar shall preferably be M3 or more for high durability but in no case less than L1.

3.4.4 In the case of masonry in foundations laid below damp-proof course, the grades of mortar for use in masonry shall be as specified below:

a) Where soil has little moisture, masonry mortar of grade not less M3 shall be used.

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b) Where soil is very damp, masonry mortar of grade preferably M2 or more shall be used. But in no case shall the grade of mortar be less than L1 and M3; and

c) Where soil is saturated with water, masonry mortar of grade M1 shall be used but in no case shall the grade of mortar be less than M2.

3.4.5 For masonry in buildings subject to vibration of machinery, the grade of mortar shall not be less than M1.

3.4.6 For parapets, where the height is greater than three times the thickness, the grade of masonry mortar used shall not be less than M1. In the case of low parapets, the grade of mortar shall be the same as that used in the wall masonry below.

3.4.7 The grade of mortar for bedding joints in masonry with large concrete blocks shall not be less than M1.

NOTE — For earthquake design consideration, recommended mortar mixes shall be as per Table 14.

4 DESIGN CONSIDERATIONS

4.1 General

Masonry structures gain stability from the support offered by cross walls, floors, roof and other elements such as piers and buttresses. Load bearing walls are structurally more efficient when the load is uniformly distributed and the structure is so planned that eccentricity of loading on the members is as small as possible. Avoidance of eccentric loading by providing adequate bearing of floor/roof on the walls providing adequate stiffness in slabs and avoiding fixity at the supports, etc, is especially important in load bearing walls in multistorey structures. These matters should receive careful consideration during the planning stage of masonry structures.

4.2 Lateral Supports and Stability

4.2.1 *Lateral Supports*

Lateral supports for a masonry element such as load bearing wall or column are intended,

a) to limit slenderness of a masonry element so as to prevent or reduce possibility of buckling of the member due to vertical loads; and

b) to resist horizontal components of forces so as to ensure stability of a structure against overturning.

4.2.1.1 Lateral support may be in the vertical or horizontal direction, the former consisting of floor/roof bearing on the wall or properly anchored to the same and latter consisting of cross walls, piers or buttresses.

4.2.1.2 Requirements of **4.2.1**(a) from consideration of slenderness may be deemed to have been met with, if

a) in case of a wall, where slenderness ratio is based on effective height, any of the following constructions are provided:

1) RCC floor/roof slab (or beams and slab) irrespective of the direction of span, bears on the supported wall as well as cross walls, to the extent of at least 90 mm;

2) RCC floor/roof slab not bearing on the supported wall or cross wall is anchored to it with non-corrodible metal ties of 600 mm length and of section not less than 6 mm × 30 mm, and at intervals not exceeding 2 m, as shown in Fig. 5; and

3) Timber floor/roof, anchored by non-corrodible metal ties of length 600 mm and of minimum section 6 mm × 30 mm, securely fastened to joists and built into walls as shown in Fig. 6 and Fig. 7. The anchors shall be provided in the direction of span of timber joists as well as in its perpendicular direction, at intervals of not more than 2 m in buildings up to two storeys and 1.25 m for buildings more than two storeys in height.

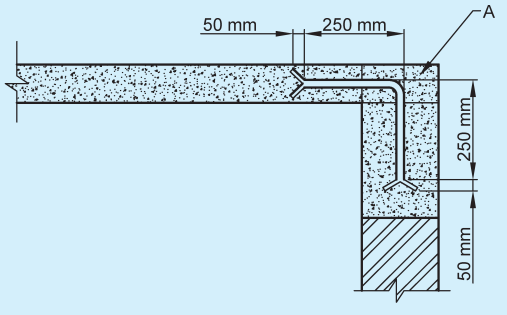
NOTES

1 In case precast RCC units are used for floors and roofs, it is necessary to interconnect them and suitably anchor them to the cross walls so that they can transfer lateral forces to the cross walls.

2 In case of small houses of conventional designs, not exceeding two storeys in height, stiffening effect of partitions and cross walls is such that metal anchors are normally not necessary in case of timber floor/roof and precast RCC floor/roof units.

b) in case of a wall, when slenderness ratio is based on its effective length; a cross wall/pier/buttress of thickness equal to or more than half the thickness of the supported wall or 90 mm, whichever is more, and length equal to or more than one fifth of the height of wall, is built at right angle to the wall (*see* Fig. 8) and bonded to it according to provision of **4.2.2.2** (d);

c) in case of a column, an RCC or timber beam/RS joist/roof truss, is supported on the column.



A = Cement concrete only at places where anchors are provided (200 mm in width in the direction perpendicular to the plane of paper)

FIG. 5 ANCHORING OF RCC SLAB WITH MASONRY WALL (WHEN SLAB DOES NOT BEAR ON WALL)

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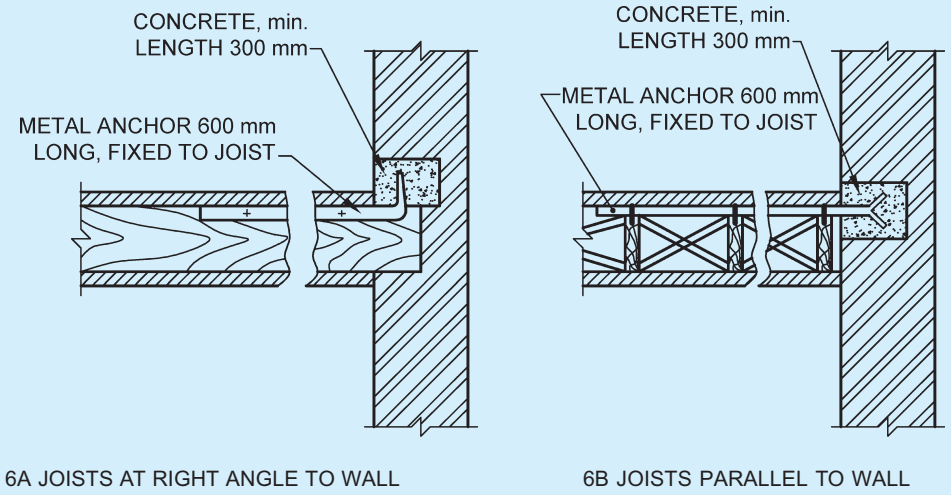
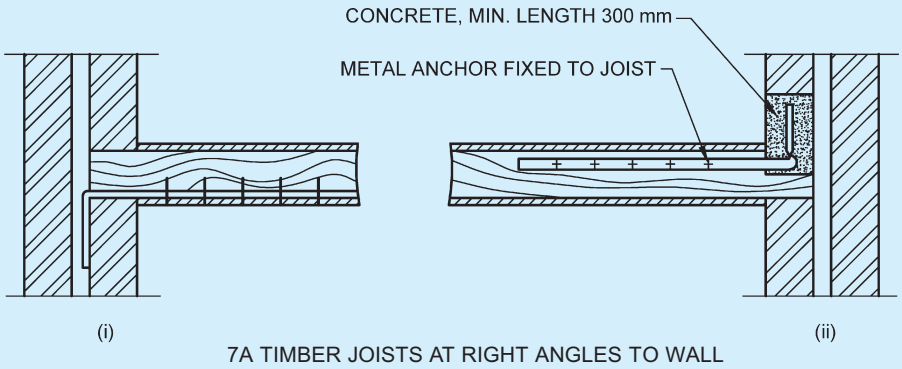
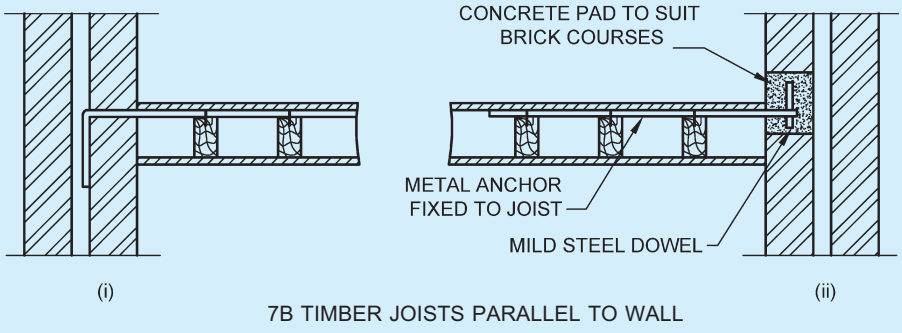


FIG. 6 TYPICAL DETAILS FOR ANCHORAGE OF SOLID WALLS





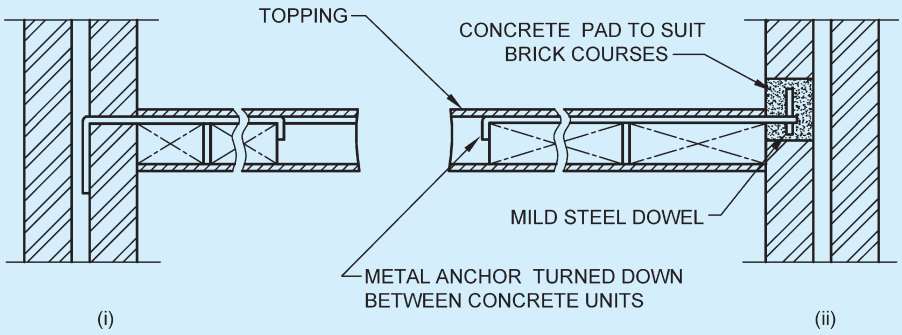


FIG. 7 TYPICAL DETAILS FOR ANCHORAGE OF CAVITY WALLS

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In this case, the column will not be deemed to be laterally supported in the direction at right angle to it; and

d) in case of a column, an RCC beam forming a part of beam and slab construction is supported on the column, and slab adequately bears on stiffening walls. This construction will provide lateral support to the column, in the direction of both horizontal axes.

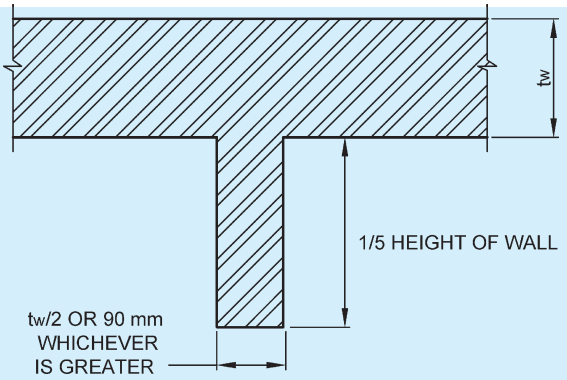


FIG. 8 MINIMUM DIMENSION FOR MASONRY WALL OR BUTTRESS EFFECTIVE LATERAL SUPPORT

4.2.2 *Stability*

A wall or column subjected to vertical and lateral loads may be considered to be provided with adequate lateral support from consideration of stability, if the construction providing the support is capable of resisting some of the following forces:

a) Simple static reactions at the point of lateral support to all the lateral loads; plus

b) 2.5 percent of the total vertical load that the wall or column is designed to carry at the point of lateral support.

4.2.2.1 For the purpose specified in **4.2.2**, if the lateral supports are in the vertical direction, these should meet the requirements given in **4.2.1.2** (a) and should also be capable of acting as horizontal girders duly anchored to the cross wall so as to transmit the lateral loads to the foundations without exceeding the permissible stresses in the cross walls.

4.2.2.2 In case of load bearing buildings up to four storeys, stability requirements of **4.2.2** may be deemed to have been met with, if

a) height to width ratio of building does not exceed 2;

b) cross walls acting as stiffening walls continuous from outer wall to outer wall or outer wall to a load bearing inner wall, and of thickness and spacings as given in Table 3 are provided. If stiffening wall or walls that are in a line, are interrupted by openings, length of solid wall or walls in the zone of the wall that is to be stiffened shall be at least one-fifth of height of the opening as shown in Fig. 9;

c) floors and roof either bear on cross walls or are anchored to those walls as in **4.2.1.2** such that all lateral loads are safely transmitted to those walls and through them to the foundation; and

d) cross walls are built jointly with the bearing walls and are jointly mortared, or the two interconnected by toothing. Alternatively, cross walls may be anchored to walls to be supported by ties of non-corrodible metal of minimum section 6 mm×35 mm and length 600 mm with ends bend at least 50 mm; maximum vertical spacing of ties being 1.2 m (*see* Fig. 10).

4.2.2.3 In case of halls exceeding 8.0 m in length, safety and adequacy of lateral supports shall always be checked by structural analysis.

Table 3 Thickness and Spacing of Stiffening Walls

[*Clause* 4.2.2.2(b)]

Sl No.	Thickness of Load Bearing Wall to be Stiffened	Height [1] of Storey Not to Exceed	Stiffening Wall [1]		
			Thickness not Less than		Maximum Spacing
	mm	m	1 to 3 Storeys mm	4 Storeys mm	m
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	3.2	100	—	4.5
ii)	200	3.2	100	200	6.0
iii)	300	3.4	100	200	8.0
iv)	Above 300	5.0	100	200	8.0

[1] Storey height and maximum spacings as given are centre-to-centre dimensions.

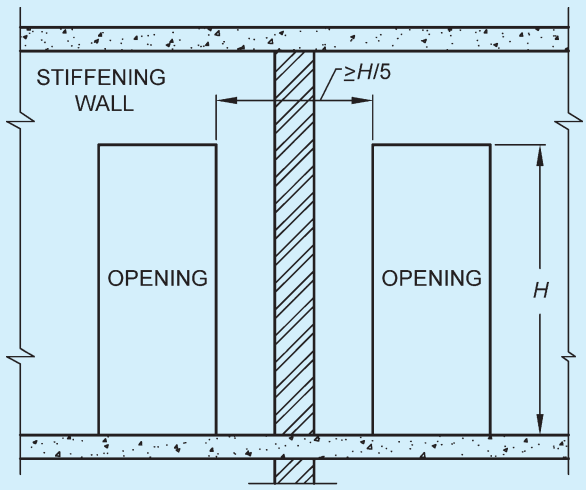


FIG. 9 OPENING IN STIFFENING WALL

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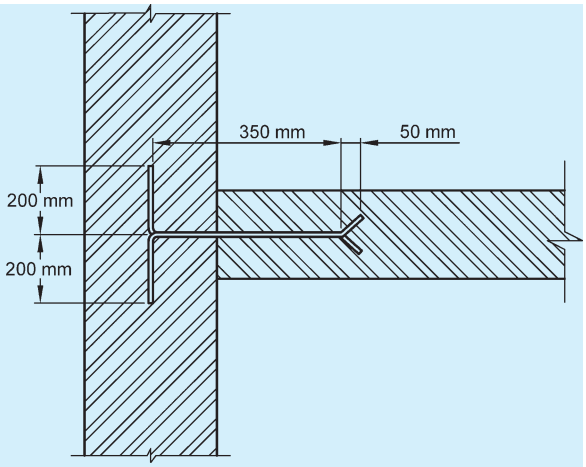


FIG. 10 ANCHORING OF STIFFENING WALL WITH SUPPORT WALL

4.2.2.4 A trussed roofing may not provide lateral support unless special measures are adopted to brace and anchor the roofing. However, in case of residential and similar buildings of conventional design with trussed roofing having cross walls, it may be assumed that stability requirements are met with by the cross walls and structural analysis for stability may be dispensed with.

4.2.2.5 Capacity of a cross wall, also called shear wall, sometimes to take horizontal loads and consequently bending moments increases, when parts of bearing walls act as flanges to the cross wall. Maximum overhanging length of bearing wall which could effectively function as a flange should be taken as 12 *t* or *H*/6, whichever is less in case of *T*/*I* shaped walls, and 6 *t* or *H*/16, whichever is less in case of *L*/*U* shaped walls, where *t* is the thickness of bearing wall and *H* is the total height of wall above the level being considered, as shown in Fig. 11.

4.2.2.6 *External walls of basement and plinth*

In case of external walls of basement and plinth, stability requirements of **4.2.2** may be deemed to have been met with, if

a) bricks used in basement and plinth have a minimum crushing strength of 5 N/mm^2 and mortar used in masonry is of Grade M1 or better;

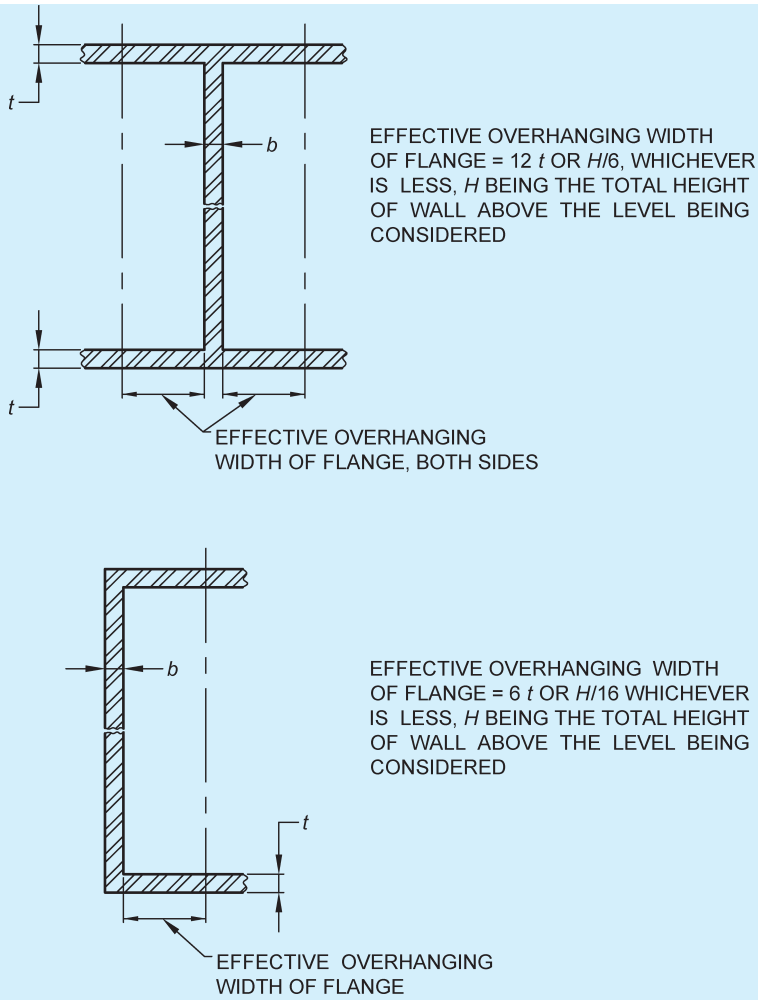


FIG. 11 TYPICAL DETAILS FOR ANCHORAGE OF SOLID WALLS

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b) clear height of ceiling in basement does not exceed 2.6 m;

c) walls are stiffened according to provisions of **4.2.2.1**;

d) in the zone of action of soil pressure on basement walls, traffic load excluding any surcharge due to adjoining buildings does not exceed 5 kN/m^2 and terrain does not rise; and

e) minimum thickness of basement walls is in accordance with Table 4. However, if percentage opening in the basement wall for purposes like ventilation are more than 25 percent, then stability analysis/check need to be performed particularly for resistance to seismic loads.

NOTE — In case there is surcharge on basement walls from adjoining buildings, thickness of basement walls shall be based on structural analysis.

Table 4 Minimum Thickness of Basement Walls

[*Clause* 4.2.2.6(e)]

Sl No.	Height of the Ground Above Basement Floor Level		Minimum Nominal Thickness of Basement Wall
	Wall Loading (Permanent Load) Less than 50 kN/m	Wall Loading (Permanent Load) More than 50 kN/m	mm
(1)	(2)	(3)	(4)
i)	Up to 1.4 m	Up to 1.75 m	300
ii)	Up to 2 m	Up to 2.5 m	400

4.2.2.7 *Walls mainly subjected to lateral loads*

a) *Free standing wall* — A free standing wall such as compound wall or parapet wall is acted upon by wind force which tends to overturn it. This tendency to over-turning is resisted by gravity force due to self-weight of wall, and also by flexural moment of resistance on account of tensile strength of masonry. Free standing walls shall thus be designed as in **5.5.2.1**. If mortar used for masonry cannot be relied upon for taking flexural tension (*see* **5.4.2**), stability of free standing wall shall be ensured such that stability moment of wall due to self-weight equals or exceeds 1.5 times the overturning moment.

b) *Retaining wall* — Stability for retaining walls shall normally be achieved through gravity action but flexural moment of resistance could also be taken advantage of under special circumstances at the discretion of the designer (*see* **5.4.2**).

4.3 Effective Height

4.3.1 *Wall*

Effective height of a wall shall be taken as shown in Table 5 (*see* Fig. 12).

NOTE — A roof truss or beam supported on a column meeting the requirements of **4.2.2.1** is deemed to provide lateral support to the column only in the direction of the beam/truss.

Table 5 Effective Height of Walls

(*Clause* 4.3.1)

Sl No.	Condition of Support	Effective Height
(1)	(2)	(3)
i)	Lateral as well as rotational restraint (that is, full restraint) at top and bottom. For example, when the floor/roof spans on the walls so that reaction to load of floor/roof is provided by the walls, or when an RCC floor/roof has bearing on the wall (minimum 90 mm), irrespective of the direction of the span foundation footings of a wall give lateral as well as rotational restraint	0.75 *H*
ii)	Lateral as well as rotational restraint (that is, full restraint) at one end and only lateral restraint (that is, partial restraint) at the other. For example, RCC floor/roof at one end spanning or adequately bearing on the wall and timber floor/roof not spanning on wall, but adequately anchored to it, on the other end	0.85 *H*
iii)	Lateral restraint, without rotational restraint (that is, partial restraint) on both ends. For example, timber floor/roof, not spanning on the wall but adequately anchored to it on both ends of the wall, that is, top and bottom	1.00 *H*
iv)	Lateral restraint as well as rotational restraint (that is, full restraint) at bottom but have no restraint at the top. For example, parapet walls with RCC roof having adequate bearing on the lower wall, or a compound wall with proper foundation on the soil.	1.50 *H*

NOTES

1 *H* is the height of wall between centres of support in case of RCC slabs and timber floors. In case of footings or foundation block, height (*H)* is measured from top of footing or foundation block. In case of roof truss, height (*H*) is measured up to bottom of the tie beam. In case of beam and slab construction, height should be measured from centre of bottom slab to centre of top beam. All these cases are illustrated by means of examples shown in Fig. 12.

2 For working out effective height, it is assumed that concrete DPC, when properly bonded with masonry, does not cause discontinuity in the wall.

3 Where membrane type damp-proof course or termite shield causes a discontinuity in bond, the effective height of wall may be taken to be greater of the two values calculated as follows :

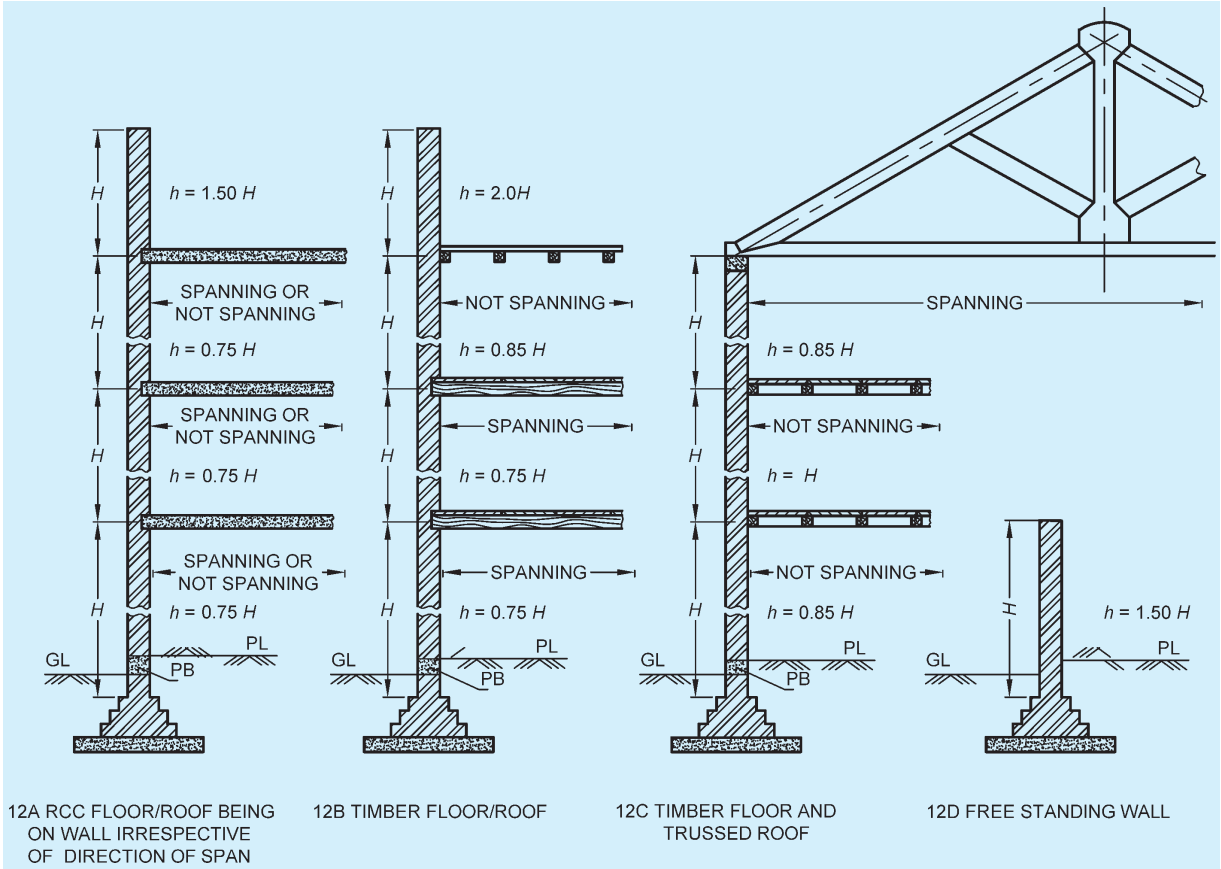
a) Consider *H* from top of footing ignoring DPC and take effective height as 0.75*H*.

b) Consider H from top of DPC and take effective height as 0.85 *H*.

4 When assessing effective height of walls, floors not adequately anchored to walls shall not be considered as providing lateral support to such walls.

5 When thickness of a wall bonded to a pier is at least two-thirds of the thickness of the pier measured in the same direction, the wall and pier may be deemed to act as one structural element.

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NOTE — If plinth band (PB) is equal to or more than 150 mm, height can be taken from above the plinth band.

FIG. 12 EFFECTIVE HEIGHT OF WALL

4.3.2 *Column*

In case of a column, effective height shall be taken as actual height for the direction it is laterally supported and as twice the actual height for the direction it is not laterally supported (*see* Fig. 13).

NOTES

1 A roof truss or beam supported on a column meeting the requirements of **4.2.2.1** is deemed to provide lateral support to the column only in the direction of the beam/truss.

2 When floor or roof consisting of RCC beams and slabs is supported on columns, the columns would be deemed to be laterally supported in both directions.

4.3.3 *Openings in Walls*

When openings occur in a wall such that masonry between the openings is by definition a column, effective height of masonry between the openings shall be reckoned as follows:

a) *When wall has full restraint at the top:*

1) Effective height for the direction perpendicular to plane of wall equals 0.75 H plus 0.25 H_1, where H is the distance between supports and H_1 is the height of the taller opening; and

2) Effective height for the direction parallel to the wall equals H, that is, the distance between the supports.

b) *When wall has partial restraint at the top and bottom*:

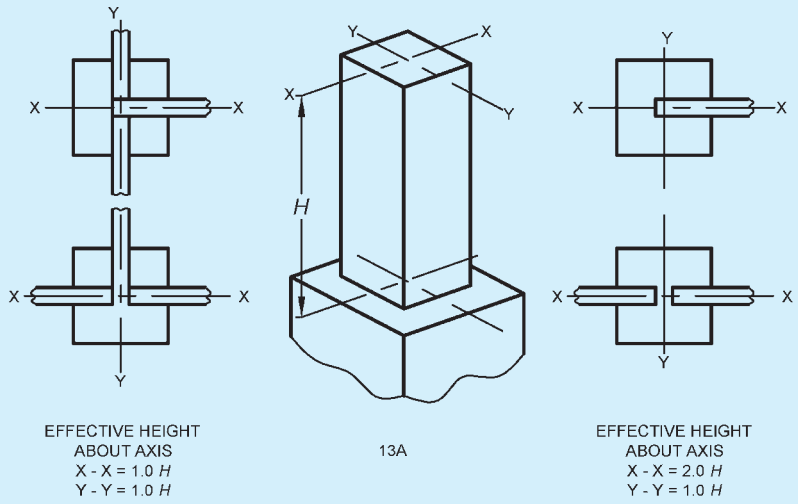
1) Effective height for the direction perpendicular to plane of wall equals H when height of neither opening exceeds 0.5 H and it is equal to 2 H when height of any opening exceeds 0.5 H; and

2) Effective height for the direction parallel to the plane of the wall equals 2 H.

4.4 Effective Length

Effective length of a wall shall be as given in Table 6.

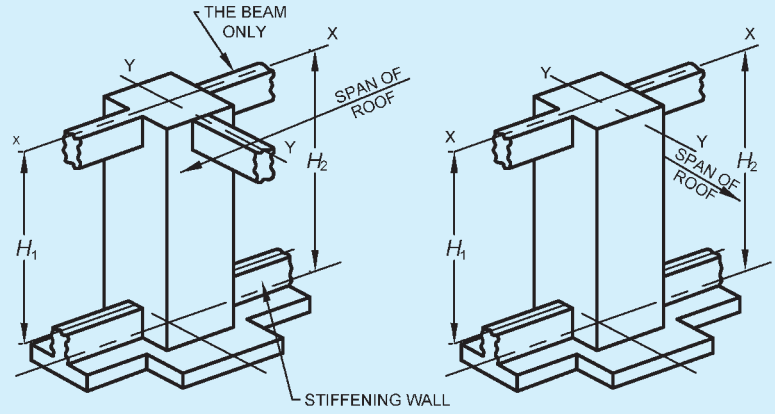
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EFFECTIVE HEIGHT ABOUT AXIS
X - X = 1.0 *H*
Y - Y = 1.0 *H*

13A

EFFECTIVE HEIGHT ABOUT AXIS
X - X = 2.0 *H*
Y - Y = 1.0 *H*



13B 13C

ROOF CONSTRUCTION	*EFFECTIVE HEIGHT ABOVE AXIS FIG. 13B*	*EFFECTIVE HEIGHT ABOVE AXIS FIG. 13C*
WITH PRECAST CONCRETE UNITS OF *IN-SITU* CONCRETE FLOOR OR ROOF	X - X = 1.0 H_2 Y - Y = 1.0 H_1 Y - Y = 1.5 H_1 (NO TIES)	X - X = 1.5 H_2 Y - Y = 1.0 H_1
WITH LIGHT DECK OR SIMILAR ROOF	X - X = 1.0 H_2 Y - Y = 1.0 H_1 Y - Y = 2.0 H_1 (NO TIES)	X - X = 2.0 H_2 Y - Y = 1.0 H_1

FIG. 13 EFFECTIVE HEIGHT OF WALL

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Table 6 Effective Length of Walls

(*Clause* 4.4)

Sl No.	Conditions of Support (*See* Fig. 14)	Effective Length
(1)	(2)	(3)
i)	Where a wall is continuous and is supported by cross wall and there is no opening within a distance of $H/8$ from the face of cross wall (*see* Fig. 14) or Where a wall is continuous and is supported by piers/buttresses conforming to **4.2.1.2** (b)	0.8 L
ii)	Where a wall is supported by a cross wall at one end and continuous with cross wall at other end or Where a wall is supported by a pier/buttress at one end and continuous with pier/buttress at other end conforming to **4.2.1.2** (b)	0.9 L
iii)	Where a wall is supported at each end by cross wall or Where a wall is supported at each end by a pier/buttress conforming to **4.2.1.2** (b)	1.0 L
iv)	Where a wall is free at one end and continuous with a pier/buttress at the other end or Where a wall is free at one end and continuous with a pier/buttress at the other end conforming to **4.2.1.2** (b)	1.5 L
v)	Where a wall is free at one end and supported at the other end by a cross wall or Where a wall is free at one end and supported at the other end by a pier/buttress conforming to **4.2.1.2** (b) where L = length of wall from or between centres of cross wall, piers or buttress; and H = actual height of wall between centers of adequate lateral support.	2.0 L

NOTE — In case there is an opening taller than 0.5 H in a wall, ends of the wall at the openingshall be considered as free. Cross walls shall conform to **4.2.2.2** (d).

4.5 Effective Thickness

Effective thickness to be used for calculating slenderness ratio of a wall or column shall be obtained as in **4.5.1** to **4.5.5**.

4.5.1 For solid walls, faced walls or columns, effective thickness shall be the actual thickness.

4.5.2 For solid walls adequately bonded into piers, buttresses, effective thickness for determining slenderness ratio based on effective height shall be the actual thickness of wall multiplied by stiffening coefficient as given in Table 7. No modification in effective thickness, however, shall be made when slenderness ratio is to be based on effective length of walls.

4.5.3 For solid walls or faced walls stiffened by cross walls, appropriate stiffening coefficient may be determined from Table 7 on the assumption that the cross walls are equivalent to piers of width equal to the thickness of the cross wall and of thickness equal to three times the thickness of stiffened wall.

Table 7 Stiffening Coefficient for Walls Stiffened by Piers, Buttresses or Cross Walls

(*Clauses* 4.5.2 *and* 4.5.3)

Sl No.	Ratio $\frac{S_p}{w_p}$	Stiffening Coefficient		
		$\frac{t_p}{t_w}=1$	$\frac{t_p}{t_w}=2$	$\frac{t_p}{t_w}=3$ or more
(1)	(2)	(3)	(4)	(5)
i)	6	1.0	1.4	2.0
ii)	8	1.0	1.3	1.7
iii)	10	1.0	1.2	1.4
iv)	15	1.0	1.1	1.2
v)	20 or more	1.0	1.0	1.0

where

S_p = centre-to-centre spacing of the pier or cross wall,

t_p = thickness of pier as defined in **2.1.3** (b) (*see* Fig. 1),

t_w = actual thickness of the wall proper (*see* Fig. 1), and

w_p = width of the pier in the direction of the wall or the actual thickness of the cross wall.

NOTE — Linear interpolation between the values given in this table is permissible but not extrapolation outside the limits given.

4.5.4 For cavity walls with both leaves of uniform thickness throughout, effective thickness shall be taken as two-thirds of the sum of the actual thickness of the two leaves.

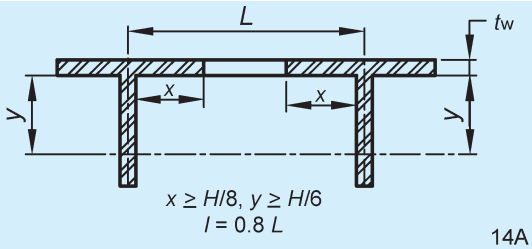
4.5.5 For cavity walls with one or both leaves adequately bonded into piers, buttresses or cross walls at intervals, the effective thickness of the cavity wall shall be two-thirds of the sum of the effective thickness of each of the two leaves; the effective thickness of each leaf being calculated using **4.5.1** or **4.5.2** as appropriate.

4.6 Slenderness Ratio

4.6.1 *Walls*

For a wall, slenderness ratio shall be effective height divided by effective thickness or, effective length divided by the effective thickness, whichever is less. In case of a load bearing wall, slenderness ratio shall not exceed that given in Table 8. To reduce the slenderness ratio one and a half brick thick wall shall be up to ground level.

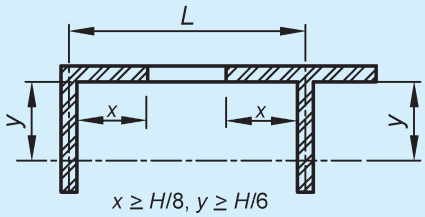
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$x \geq H/8$, $y \geq H/6$
$l = 0.8\ L$

Wall is continuous at both ends and is supported by cross walls of thickness $t_w/2$ or 100 mm whichever is more, length of cross wall is not less than $H/6$, opening in wall is not less than $H/8$ from cross wall

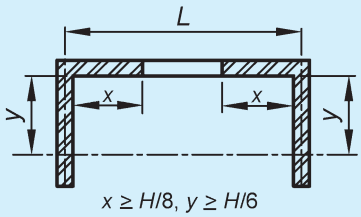
14A CASE 1



$x \geq H/8$, $y \geq H/6$
$l = 0.9\ L$

Same as case 1 except that one end of the wall is discontinuous

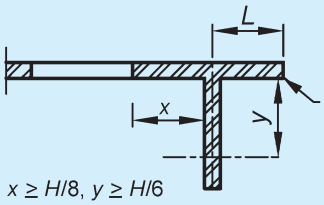
14B CASE 2



$x \geq H/8$, $y \geq H/6$
$l = L$

Same as case 1 except that wall is discontinuous on both ends

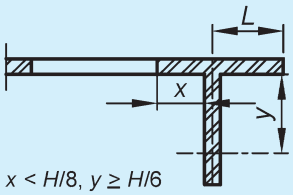
14C CASE 3



$x \geq H/8$, $y \geq H/6$
$l = 1.5\ L$

One end of the wall is free, other is supported by a cross wall and is continuous. There being no opening within $H/8$ from cross wall

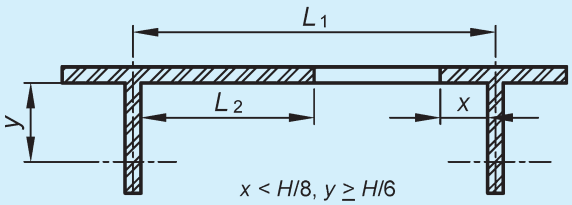
14D CASE 4



$x < H/8$, $y \geq H/6$
$l = 2\ L$

Same as case 4 but opening is within $H/8$ from cross wall and thus that end is taken as discontinuous

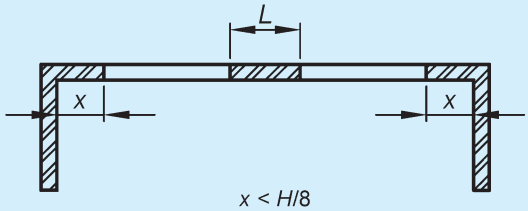
14E CASE 5



$x < H/8$, $y \geq H/6$
$l = 1.5\ L_2$

This illustration is with an opening which is within $H/8$ from cross wall

14F CASE 6



$x < H/8$

Wall length is between two opening which are closer than $H/8$ from cross walls

14G CASE 7

FIG. 14 EFFECTIVE LENGTH OF WALL

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Table 8 Maximum Slenderness Ratio for a Load Bearing Wall

(*Clause* 4.6.1)

Sl No.	Number of Storeys	Maximum Slenderness Ratio	
		Using Portland Cement or Portland Pozzolana Cement in Mortar	Using Lime Mortar
(1)	(2)	(3)	(4)
i)	Not exceeding 2	27	20
ii)	Exceeding 2	27	13

4.6.2 *Columns*

For a column, slenderness ratio shall be taken to be the greater of the ratios of effective heights to the respective effective thickness, in the two principal directions. Slenderness ratio for a load bearing column shall not exceed 12.

4.7 Eccentricity

Eccentricity of vertical loading at a particular junction in a masonry wall shall depend on factors, such as extent of bearing, magnitude of loads, stiffness of slab or beam, fixity at the support and constructional details at junctions. No exact calculations are possible to make accurate assessment of eccentricity. Extent of eccentricity under any particular circumstances has, therefore, to be decided according to the best judgment of the designer. Some guidelines for assessment of eccentricity are given in Annex A.

5 STRUCTURAL DESIGN

5.1 General

The building as a whole shall be analysed by accepted principles of mechanics to ensure safe and proper functioning in service of its component parts in relation to the whole building. All component parts of the structure shall be capable of sustaining the most adverse combinations of loads, which the building may be reasonably expected to be subjected to during and after construction.

5.2 Design Loads

Loads to be taken into consideration for designing masonry components of a structure are:

a) dead loads of walls, columns, floors and roofs;
b) imposed loads of floors and roof;
c) wind loads on walls and sloping roof; and
d) seismic forces.

NOTE — When a building is subjected to other loads, such as vibration from railways; machinery, etc, these should be taken into consideration accordingly to the best judgment of the designer (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

5.2.1 The design loads and other forces to be taken for the design of masonry structures shall conform to Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

NOTE — During construction, suitable measures shall be taken to ensure that masonry is not liable to damage or failure due to action of wind forces, back filling behind walls or temporary construction loads.

5.3 Load Dispersion

5.3.1 *General*

The angle of dispersion of vertical load on walls shall be taken as not more than 30° from the vertical.

5.3.2 *Arching Action*

Account may also be taken of the arching action of well-bonded masonry walls supported on lintels and beams, in accordance with established practice. Increased axial stresses in the masonry associated with arching action in this way, shall not exceed the permissible stresses given in **5.4**.

5.3.3 *Lintels*

Lintels that support masonry construction shall be designed to carry loads from masonry (allowing for arching and dispersion where applicable), and loads received from any other part of the structure. Length of bearing of lintel at each end shall not be less than 90 mm or one-tenth of the span, whichever is more, and area of the bearing shall be sufficient to ensure that stresses in the masonry (combination of wall stresses, stresses due to arching action and bearing stresses from the lintel) do not exceed the stresses permitted in **5.4** (*see* Annex C).

5.4 Permissible Stresses

5.4.1 *Permissible Compressive Stress*

Permissible compressive stress in masonry shall be based on value of basic compressive stress (f_b) as given in Table 9 and multiplying this value by factors known as stress reduction factor (k_s), area reduction factor (k_a) and shape modification factor (k_p) as detailed in **5.4.1.1** to **5.4.1.3**. Values of basic compressive stress given in Table 9 take into consideration crushing strength of masonry unit and grades of mortar, and hold good for values of slenderness ratio not exceeding 6, zero eccentricity and masonry unit having height to width ratio (as laid) equal to 0.75 or less.

Alternatively, basic compressive stress may be based on results of prism test given in Annex B on masonry made from masonry units and mortar to be actually used in a particular job.

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Table 9 Basic Compressive Stresses for Masonry (After 28 days)

(*Clauses* 5.4.1 *and* 6.3.1)

Sl No.	Mortar Type (Ref Table 1)	Basic Compressive Stresses, in N/mm², Corresponding to Masonry Units of which Height to Width Ratio does not Exceed 0.75 and Crushing Strength, in N/mm², is not Less than											
		3.5	5.0	7.5	10	12.5	15	17.5	20	25	30	35	40
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	H1	0.35	0.50	0.75	1.00	1.16	1.31	1.45	1.59	1.91	2.21	2.5	3.05
ii)	H2	0.35	0.50	0.74	0.96	1.09	1.19	1.30	1.41	1.62	1.85	2.1	2.5
iii)	M1	0.35	0.50	0.74	0.96	1.06	1.13	1.20	1.27	1.47	1.69	1.9	2.2
iv)	M2	0.35	0.44	0.59	0.81	0.94	1.03	1.10	1.17	1.34	1.51	1.65	1.9
v)	M3	0.25	0.41	0.56	0.75	0.87	0.95	1.02	1.10	1.25	1.41	1.55	1.78
vi)	L1	0.25	0.36	0.53	0.67	0.76	0.83	0.90	0.97	1.11	1.26	1.4	1.06
vii)	L2	0.25	0.31	0.42	0.53	0.58	0.61	0.65	0.69	0.73	0.78	0.85	0.95

NOTES

1 The table is valid for slenderness ratio up to 6 and loading with zero eccentricity.

2 The values given for basic compressive stress are applicable only when the masonry is properly cured.

3 Linear interpolation is permissible for units having crushing strengths between those given in the table.

4 The permissible stress for random rubble masonry may be taken as 75 percent of the corresponding stress for coarsed walling of similar materials.

5 The strength of ashlar masonry (natural stone masonry of massive type with thin joints) is closely related to intrinsic strength of the stone and allowable working stress in excess of those given in the table may be allowed for such masonry at the discretion of the designer.

6 For calculation of basic compressive stress of stabilized soil block having thickness 100 mm or more, reference to specialist literature may be made.

7 If the work is inadequately supervised, strength should be reduced to three-fourth or less at the discretion of the designer.

5.4.1.1 *Stress reduction factor*

This factor, as given in Table 10, takes into consideration the slenderness ratio of the element and also the eccentricity of loading.

Table 10 Stress Reduction Factor for Slenderness Ratio and Eccentricity

(*Clause* 5.4.1.1)

Sl No.	Slenderness Ratio	Eccentricity of Loading Divided by the Thickness of the Member					
		0	1/24	1/12	1/6	1/4	1/3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	6	1.00	1.00	1.00	1.00	1.00	1.00
ii)	8	0.95	0.95	0.94	0.93	0.92	0.91
iii)	10	0.89	0.88	0.87	0.85	0.83	0.81
iv)	12	0.84	0.83	0.81	0.78	0.75	0.72
v)	14	0.78	0.76	0.74	0.70	0.66	0.66
vi)	16	0.73	0.71	0.68	0.63	0.58	0.53
vii)	18	0.67	0.64	0.61	0.55	0.49	0.43
viii)	20	0.62	0.59	0.55	0.48	0.41	0.34
ix)	22	0.56	0.52	0.48	0.40	0.32	0.24
x)	24	0.51	0.47	0.42	0.33	0.24	—
xi)	26	0.45	0.40	0.35	0.25	—	—
xii)	27	0.43	0.38	0.33	0.22	—	—

NOTES

1 Linear interpolation between values is permitted.

2 Where in special cases the eccentricity of loading lies between 1/3 and 1/2 of the thickness of the member, the stress reduction factor should vary linearly between unity and 0.20 for slenderness ratio of 6 and 20, respectively.

3 Slenderness ratio of a member for sections within 1/8 of the height of the member above or below a lateral support may be taken to be 6.

5.4.1.2 *Area reduction factor*

This factor takes into consideration smallness of the sectional area of the element and is applicable when sectional area of the element is less than 0.2 m². The factor $k_a = 0.7 + 1.5A$, A being the area of section, in m².

5.4.1.3 *Shape modification factor*

This factor takes into consideration the shape of the unit, that is, height to width ratio (as laid) and is given in Table 11. This factor is applicable for units for crushing strength up to 15 N/mm².

Table 11 Shape Modification Factor for Masonry Units

(*Clause* 5.4.1.3)

Sl No.	Height to Width Ratio of Units (As Laid)	Shape Modification Factor (k_p) for Units Having Crushing Strength N/mm²			
		Up to 5.0	7.5	10.0	15.0
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 0.75	1.0	1.0	1.0	1.0
ii)	1.0	1.2	1.1	1.1	1.0
iii)	1.5	1.5	1.3	1.2	1.1
iv)	2.0 to 4.0	1.8	1.5	1.3	1.2

NOTE — Linear interpolation between values is permissible.

5.4.1.4 *Increase in permissible compressive stresses allowed for eccentric vertical loads, lateral loads under certain conditions*

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In members subjected to eccentric and/or lateral loads, increase in permissible compressive stress is allowed as follows:

a) When resultant eccentricity ratio exceeds 1/24 but does not exceed 1/6, 25 percent increase in permissible compressive stress is allowed in design.

b) When resultant eccentricity ratio exceeds 1/6, 25 percent increase in permissible stress is allowed but the area of the section under tension shall be disregarded for computing the load carrying capacity of the member.

NOTE — When resultant eccentricity ratio of loading is 1/24 or less, compressive stress due to bending shall be ignored and only axial stress need to be computed for the purpose of design.

5.4.1.5 *Increase in permissible compressive stress for walls subjected to concentrated loads*

When a wall is subjected to a concentrated load (a load being taken to be concentrated when area of supporting wall equals or exceeds three times the bearing area), certain increase in permissible compressive stress may be allowed because of dispersal of the load. Since, according to the present state of art, there is diversity of views in regard to manner and extent of dispersal, design of walls subjected to concentrated loads may, therefore, be worked out as per the best judgment of the designer. Some guidelines in this regard are given in Annex C.

5.4.2 *Permissible Tensile Stress*

As a general rule, design of masonry shall be based on the assumption that masonry is not capable of taking any tension. However, in case of lateral loads normal to the plane of wall, which causes flexural tensile stress, as for example, panel, curtain partition and free standing walls, flexural tensile stresses as follows may be permitted in the design for masonry:

a) Grade M1 or better mortar	1)	0.07 N/mm^2 for bending in the vertical direction where tension developed is normal to bed joints.
	2)	2) 0.14 N/mm^2 for bending in the longitudinal direction where tension developed is parallel to bed joints, provided crushing strength of masonry units is not less than 10 N/mm^2.
b) Grade M2 mortar	1)	0.05 N/mm^2 for bending in the vertical direction where tension developed is normal to bed joints.
	2)	0.10 N/mm^2 for bending in the longitudinal direction where tension developed is parallel to bed joints, provided crushing strength of masonry units is not less than 7.5 N/mm^2.

NOTES

1 No tensile stress is permitted in masonry in case of water-retaining structures in view of water in contact with masonry. Also no tensile stress is permitted in earth-retaining structures, in view of the possibility of presence of water at the back of such walls.

2 Allowable tensile stress in bending in the vertical direction may be increased to 0.1 N/mm^2 for M1 mortar and 0.07 N/mm^2 for M2 mortar in case of boundary walls/compound at the discretion of the designer, since there is not much risk to life and property in the event of failure of such walls.

5.4.3 *Permissible Shear Stress*

In case of walls built in mortar not leaner than Grade M1 (*see* Table 1) and resisting horizontal forces in the plane of the wall, permissible shear stress calculated on the area of bed joints, shall not exceed the value obtained by the formula given below, subject to a maximum of 0.5 N/mm^2:

$$f_s = 0.1 + f_d/6$$

f_d = compressive stress due to dead loads, in N/mm^2; and

f_s = permissible shear stress, in N/mm^2.

5.4.4 If there is tension in any part of a section of masonry, the area under tension shall be ignored while working out shear stress on the section.

5.5 Design Thickness/Cross-Section

5.5.1 *Walls and Columns Subjected to Vertical Loads*

Walls and columns bearing vertical loads shall be designed on the basis of permissible compressive stress. Design consists in determining thickness in case of walls and section in case of columns in relation to strength of masonry units and grade of mortar to be used, taking into consideration various factors, such as slenderness ratio, eccentricity, area of section, workmanship, quality of supervision, etc, subject further to provisions of **5.5.1.1** to **5.5.1.4**.

5.5.1.1 *Solid walls*

Thickness used for design calculation shall be the actual thickness of masonry computed as the sum of the average dimensions of the masonry units specified in the relevant standard, together with the specified joint thickness. In masonry with raked joints, thickness shall be reduced by the depth of raking of joints for plastering/pointing.

5.5.1.2 *Cavity walls*

a) Thickness of each leaf of a cavity wall shall not be less than 75 mm.

b) Where the outer leaf is half masonry unit in thickness, the uninterrupted height and length of this leaf shall be limited so as to avoid undue loosening of ties due to differential movements

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between the two leaves. The outer leaf shall, therefore, be supported at least at every third storey or at every 10 m of height, whichever is less and at every 10 m or less along the length.

c) Where the load is carried by both leaves of a wall of a cavity construction, the permissible stress shall be based on the slenderness ratio derived from the effective thickness of the wall as given in **4.5.4** or **4.5.5**. The eccentricity of the load shall be considered with respect to the centre of gravity of the cross-section of the wall.

d) Where the load is carried by one leaf only, the permissible stress shall be the greater of values calculated by the following two alternative methods:

1) The slenderness ratio is based on the effective thickness of the cavity wall as a whole as given in **4.5.4** or **4.5.5** and on the eccentricity of the load with respect to the centre of gravity of the cross-section of the whole wall (both leaves) (This is the same method as where the load is carried by both the leaves but the eccentricity will be more when the load is carried by one leaf only).

2) The slenderness ratio is based on the effective thickness of the loaded leaf only using **4.5.1** and **4.5.2**, and the eccentricity of the load will also be with respect to the centre of gravity of the loaded leaf only.

In either alternative, only the actual thickness of the load bearing leaf shall be used in arriving at the cross-sectional area resisting the load (*see* **5.5.1.1**).

5.5.1.3 *Faced wall*

The permissible load per length of wall shall be taken as the product of the total thickness of the wall and the permissible stress in the weaker of the two materials. The permissible stress shall be found by using the total thickness of the wall when calculating the slenderness ratio.

5.5.1.4 *Veneered wall*

The facing (veneer) shall be entirely ignored in calculations of strength and stability. For the purpose of determining the permissible stress in the backing, the slenderness ratio shall be based on the thickness of the backing alone.

5.5.2 *Walls and Columns Mainly Subjected to Lateral Loads*

5.5.2.1 *Free standing walls*

a) Free standing walls, subjected to wind pressure or seismic forces shall be designed on the basis of permissible tensile stress in masonry or stability as in **4.2.2.4**. However, in seismic Zones II, free-standing walls may be apportioned without making any design calculations with the help of Table 12 provided the mortar used is of grade not leaner than M1.

b) If there is a horizontal damp-proof course near the base of the wall, that is, not capable of developing tension vertically, the minimum wall thickness should be the greater of that calculated from either,

1) the appropriate height to thickness ratio given in Table 12 reduced by 25 percent, reckoning the height from the level of the damp-proof course; or

2) the appropriate height to thickness ratio given in Table 12 reckoning the height from the lower level at which the wall is restrained laterally.

Table 12 Height to Thickness Ratio of Free Standing Walls Related to Wind Speed

[*Clause* 5.5.2.1(a) *and* (b)]

Sl No.	Design Wind Pressure N/mm^2	Height to Thickness Ratio
(1)	(2)	(3)
i)	Up to 285	10
ii)	575	7
iii)	860	5
iv)	1 150	4

NOTES

1 For intermediate values, linear interpolation is permissible.

2 Height is to be reckoned from 150 mm below ground level or top of footing/foundation block, whichever is higher, and up to the top edge of the wall.

3 The thickness should be measured including the thickness of the plaster.

5.5.2.2 *Retaining walls*

Normally masonry of retaining walls shall be designed on the basis of zero-tension, and permissible compressive stress. However, in case of retaining walls for supporting horizontal thrust from dry materials, retaining walls may be designed on the basis of permissible tensile stress at the discretion of the designers.

5.5.3 *Walls and Columns Subjected to Vertical as well as Lateral Loads*

For walls and columns, stress worked out separately

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for vertical loads as in **5.5.1** and lateral loads as in **5.5.2** shall be combined and elements designed on the basis of permissible stress.

5.5.4 *Walls Subjected to In-Plane Bending and Vertical Loads (Shear Walls)*

Walls subjected to in-plane bending and vertical loads, that is, shear walls shall be designed on the basis of no tension with permissible shear stress and permissible compressive stress.

5.5.5 *Non-Load Bearing Walls*

Non-load bearing walls, such as panel walls, curtain walls and partition walls which are mainly subjected to lateral loads, according to present state of art, are not capable of precise design and only approximate methods based on some tests are available. Guidelines for approximate design of these walls are given in Annex D.

6 GENERAL REQUIREMENTS

6.1 Methods of Construction

6.1.1 *General*

Construction of the following types of load bearing and non-load bearing masonry walls shall be carried out in accordance with good practice [6-4(4)]:

a) Brickwork,
b) Stone masonry,
c) Hollow concrete block masonry,
d) Gypsum partition blocks,
e) Autoclaved cellular concrete block masonry, and
f) Lightweight concrete block masonry.

6.1.2 *Construction of Buildings in Seismic Zones*

Special features of construction for earthquake resistant masonry buildings in Seismic Zones II, III, IV and V shall be applicable according to **8**.

6.2 Minimum Thickness of Walls from Consideration other than Structural

Thickness of walls determined from consideration of strength and stability may not always be adequate in respect of other requirements, such as resistance to fire, thermal insulation, sound insulation and resistance to damp penetration for which reference may be made to the appropriate Parts/Sections of the Code, and thickness suitably increased, where found necessary.

6.3 Workmanship

6.3.1 *General*

Workmanship has considerable effect on strength of masonry and bad workmanship may reduce the strength of brick masonry to as low as half the intended strength. The basic compressive stress values for masonry as given in Table 9 holds good for commercially obtainable standards of workmanship with reasonable degree of supervision.

6.3.2 *Bedding of Masonry Units*

Masonry units shall be laid on a full bed of mortar with frog, if any, upward such that cross-joints and wall joints are completely filled with mortar. Masonry units which are moved after initial placement shall be re-laid in fresh mortar, discarding the disturbed mortar.

6.3.3 *Bond*

Cross-joints in any course of one brick thick masonry wall shall be not less than one-fourth of a masonry unit in horizontal direction from the cross-joints in the course below. In masonry walls more than one brick in thickness, bonding through the thickness of wall shall be provided by either header units or by other equivalent means in accordance with good practice [6-4(5)].

6.3.4 *Verticality and Alignment*

All masonry shall be built true and plumb within the tolerances prescribed below; care shall be taken to keep the perpends properly aligned:

a) Deviation from vertical within a storey shall not exceed 6 mm per 3 m height.
b) Deviation in verticality in total height of any wall of a building more than one storey in height shall not exceed 12.5 mm.
c) Deviation from position shown on plan of any brickwork shall not exceed 12.5 mm.
d) Relative displacement between load bearing walls in adjacent storeys intended to be in vertical alignment shall not exceed 6 mm.
e) Deviation of bed-joint from horizontal in a length of 12 m shall not exceed 6 mm subject to a maximum deviation of 12 mm.
f) Deviation from the specified thickness of bed joints, cross-joints and perpends shall not exceed one-fifth of the specified thickness.

NOTE — These tolerances have been specified from the point of view of their effect on the strength of masonry. The permissible stress recommended in **5.3** may be considered applicable only, if these tolerances are adhered to.

6.4 Joints to Control Deformation and Cracking

Special provision shall be made to control or isolate thermal and other movements so that damage to the fabric of the building is avoided and its structural sufficiency preserved. Design and installation of joints shall be done according to the appropriate

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recommendations in accordance with good practice [6-4(6)].

6.5 Chases, Recesses and Holes

6.5.1 Chases, recesses and holes are permissible in masonry only if these do not impair strength and stability of the structure.

6.5.2 In masonry, designed by structural analysis, all chases, recesses and holes shall be considered in structural design and detailed in building plans.

6.5.3 When chases, recesses and holes have not been considered in structural design and are not shown in drawings, these may be provided, subject to the constraints and precautions specified in **6.5.3.1** to **6.5.3.10**.

6.5.3.1 As far as possible, services should be planned with the help of vertical chases and use of horizontal chases should be avoided.

6.5.3.2 For load bearing walls, depth of vertical and horizontal chases shall not exceed one-third and one-sixth of the wall thickness, respectively.

6.5.3.3 Vertical chases shall not be closer than 2 m in any stretch of wall and shall not be located within 345 mm of an opening or within 230 mm of a cross wall that serves as a stiffening wall for stability. Width of a vertical chase shall not exceed thickness of wall in which it occurs.

6.5.3.4 When unavoidable horizontal chases of width not exceeding 60 mm in a wall having slenderness ratio not exceeding 15 may be provided. These shall be located in the upper or lower middle third height of wall at a distance not less than 600 mm from a lateral support. No horizontal chase shall exceed 1 m in length and there shall not be more than 2 chases in any one wall. Horizontal chases shall have minimum mutual separation distance of 500 mm. Sum of lengths of all chases and recesses in any horizontal plane shall not exceed one-fourth the length of the wall.

6.5.3.5 Holes for supporting put-logs of scaffolding shall be kept away from bearings of beams, lintels, and other concentrated loads. If unavoidable, stresses in the affected area shall be checked to ensure that these are within safe limits.

6.5.3.6 No chase, recess or hole shall be provided in any stretch of a masonry wall, the length of which is less than four times the thickness of wall, except when found safe by structural analysis.

6.5.3.7 Masonry directly above a recess or a hole, if wider than 300 mm, shall be supported on a lintel. No lintel, however, is necessary in case of a circular recess or hole exceeding 300 mm in diameter provided upper half of the recess or hole is built as a semi-circular arch of adequate thickness and there is an adequate length of masonry on the sides of openings to resist the horizontal thrust.

6.5.3.8 As far as possible, chases, recesses and holes in masonry should be left (inserting sleeves, where necessary) at the time of construction of masonry so as to obviate subsequent cutting. If cutting is unavoidable, it should be done without damage to the surrounding or residual masonry. It is desirable to use such tools for cutting which depend upon rotary and not on heavy impact for cutting action.

6.5.3.9 No chase, recess or hole shall be provided in half-brick load bearing wall, excepting the minimum number of holes needed for scaffolding.

6.5.3.10 Chases, recesses or holes shall not be cut into walls made of hollow or perforated units, after the units have been incorporated in masonry.

6.6 Corbelling

6.6.1 Where corbelling is required for the support of some structural element, maximum projection of masonry unit should not exceed one-half of the height of the unit or one-half of the built-in part of the unit and the maximum horizontal projection of the corbel should not exceed one-third of the wall thickness.

6.6.2 The load per unit length on a corbel shall not be greater than half of the load per unit length on the wall above the corbel. The load on the wall above the corbel, together with four times the load on the corbel, shall not cause the average stress in the supporting wall or leaf to exceed the permissible stresses given in **5.4**.

6.6.3 It is preferable to adopt header courses in the corbelled portion of masonry from considerations of economy and stability.

7 REINFORCED BRICK AND REINFORCED BRICK CONCRETE FLOORS AND ROOFS

The construction and design of reinforced brick and reinforced brick concrete floors and roof shall be in accordance with good practices [6-4(7)].

8 SPECIAL CONSIDERATION FROM EARTHQUAKE POINT OF VIEW

8.0 Special features of design and construction for earthquake resistant masonry buildings are given in **8.2** to **8.8.2.** However, special features of design and construction for improving earthquake resistance of low strength masonry buildings is covered in **9**.

8.1 For the purpose of **8** and **9**, the definitions given below shall apply in addition to those given in **2**.

8.1.1 *Separation Section* — A gap of specified width

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between adjacent buildings or parts of the same building either left uncovered or covered suitably to permit movement in order to avoid pounding due to earthquake.

8.1.1.1 *Crumple section* — The separation gap filled with appropriate material that crumples or factures in the event of an earthquake.

8.1.2 *Centre of Rigidity* — The point in a structure where application of lateral force produces equal deflections of its components at any level in any particular direction.

8.1.3 *Shear Wall* — A wall designed to resist lateral force in the own plane. Braced frames, subjected primarily to axial stresses, shall be considered as shear walls for the purpose of this definition.

8.1.4 *Space Frame* — A three-dimensional structural system comprised of interconnected members, without shear or bearing walls, so that to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor bracing systems.

8.1.4.1 *Vertical load carrying frame* — A space frame designed to carry all the vertical loads, the horizontal loads being resisted by shear walls.

8.1.4.2 *Moment resistant frame* — A space frame capable of carrying all vertical and horizontal loads, by developing bending moments in the members and at joints.

8.1.4.3 *Moment resistant frame with shear walls* — A space frame with moment resistant joints and strengthened by shear walls to assist in carrying horizontal loads.

8.1.5 *Box System* — A bearing wall structure without a space frame, the horizontal forces being resisted by the walls that act as shear walls.

8.1.6 *Band* — A reinforced concrete or reinforced brick runner provided in the walls to tie them together and to impart horizontal bending strength in them.

NOTE — For low strength masonry buildings, wooden runners may also be used as runner.

8.1.7 *Seismic Zone and Seismic Coefficient* — The Seismic Zones II to IV as classified in **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code and corresponding basic seismic coefficient α_o as specified in **3.4** of good practice [6-4(8)].

8.1.8 *Design Horizontal Seismic Coefficient* — The value of horizontal seismic coefficient A_h computed taking into account the soil-foundation system and the importance factor as specified in **6.4** of good practice [6-4(9)].

8.1.9 *Concrete Grades* — 28 day compressive strength of concrete cubes of 150 mm size, in MPa; for example, for Grade M20 as per good practice[6-4(10)], the characteristic compressive strength equals to 20 MPa.

8.1.10 *Zone Factor (Z)* — It is a factor to obtain the design spectrum depending on the perceived maximum seismic risk characterized by maximum considered earthquake (MCE) in the zone in which the structure is located.

8.2 General Principles

The general principles given in **8.2.1** to **8.2.9** shall be observed in construction of earthquake resistant buildings.

8.2.1 *Lightness*

Since the earthquake force is a function of mass, the weight of the building shall be as minimum as possible, consistent with structural safety and functional requirements. Roofs and upper storeys of buildings, in particular, should be designed as light as possible.

8.2.2 *Continuity of Construction*

8.2.2.1 As far as possible, the parts of the building should be tied together in such a manner that the building acts as one unit.

8.2.2.2 For parts of buildings between separation or crumple sections to expansion joints, floor slabs shall be continuous throughout as far as possible. Concrete slabs shall be rigidly connected or integrally cast with the support beams.

8.2.2.3 Additions to the structures shall be accompanied by the provision of separation or crumple sections between the new and the existing structures as far as possible, unless positive measures are taken to establish continuity between the existing and the new construction.

8.2.2.4 Alteration to the building structure shall be done by maintaining its structural stability by ensuring proper load path.

8.2.3 *Projecting and Suspended Parts*

8.2.3.1 Projecting parts shall be avoided as far as possible. If the projecting parts cannot be avoided, they shall be properly reinforced and firmly tied to the main structure, and their design shall be in accordance with good practice [6-4(8)].

8.2.3.2 Ceiling plaster shall preferably be avoided. When it is unavoidable, the plaster shall be as thin as possible.

8.2.3.3 Suspended ceiling shall be avoided as far as possible. Where provided they shall be light, adequately framed and secured to which electrical fixtures shall be fully secured.

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8.2.4 *Building Configuration*

8.2.4.1 In order to minimise torsion and stress concentration, provisions given in **8.2.4.2** to **8.2.4.4** should be complied with as relevant.

8.2.4.2 The building should have a simple rectangular plan and be symmetrical both with respect to mass and rigidity so that the centre of mass and rigidity of the building coincide with each other in which case no separation sections other than expansion joints are necessary. For provision of expansion joints reference may be made to good practice [6-4(6)].

8.2.4.3 If symmetry of the structure is not possible in plan, elevation or mass, provision shall be made for torsional and other effects due to earthquake forces in the structural design or the parts of different rigidities may be separated through crumple sections. The length of such building between separation sections shall not preferably exceed three times the width.

NOTE — As an alternative to separation section to reduce torsional moments, the centre of rigidity of the building may be brought close or coincident to the centre of mass by adjusting the locations and/or sizes of columns and walls.

8.2.4.4 Buildings having plans with shapes like L, T, E and Y shall preferably be separated into rectangular parts by providing separation sections at appropriate places. Typical examples are shown in Fig. 15.

NOTES

1 The buildings with small lengths of projections forming L, T, E or Y shapes need not be provided with separation section. In each cases the length of the projection may not exceed 15 to 20 percent of the total dimension of the building in the direction of the projection (*see* Fig. 16).

2 For buildings with minor asymmetry in plan and elevation, separation sections may be omitted.

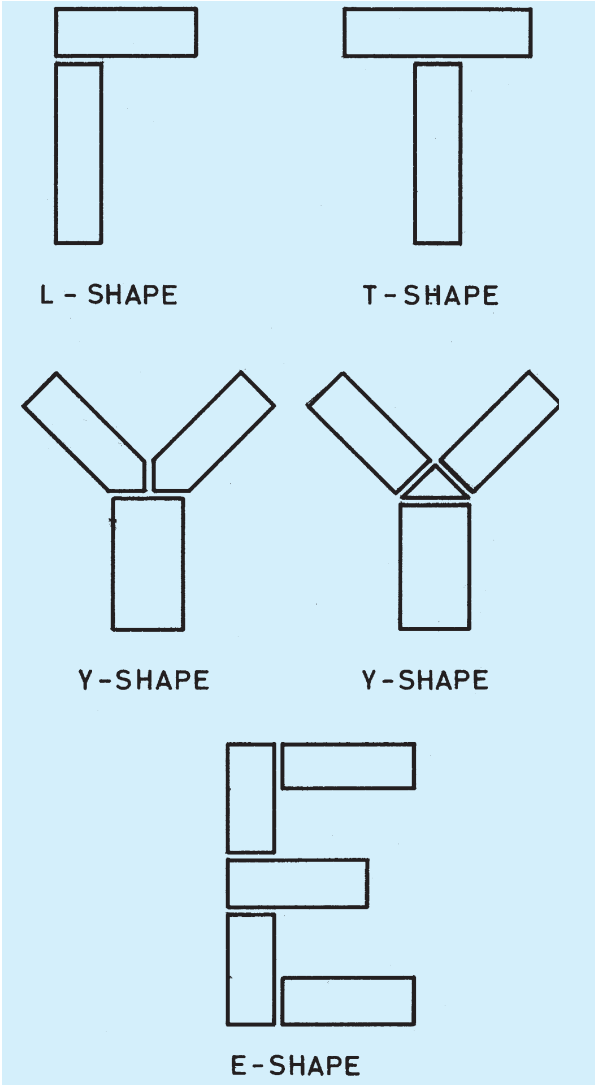


FIG. 15 TYPICAL SHAPES OF BUILDING WITH SEPARATION SECTIONS

8.2.5 *Strength in Various Directions*

The structure shall be designed to have adequate strength against earthquake effects along both the horizontal axes. The design shall also be safe considering the reversible nature of earthquake forces.

8.2.6 *Foundations*

The structure shall not be founded on such soils which shall subside or liquefy during an earthquake, resulting in large differential settlements (*see also* **8.3.3.3**).

8.2.7 *Ductility*

The main structural elements and their connection shall be designed to have a ductile failure. This shall enable the structure to absorb energy during earthquakes to avoid sudden collapse of the structure. Providing reinforcing steel in masonry at critical sections, as specified in this Section shall not only increase strength and stability but also ductility. The details for achieving ductility in reinforced concrete structures is given in good practice [6-4(11)].

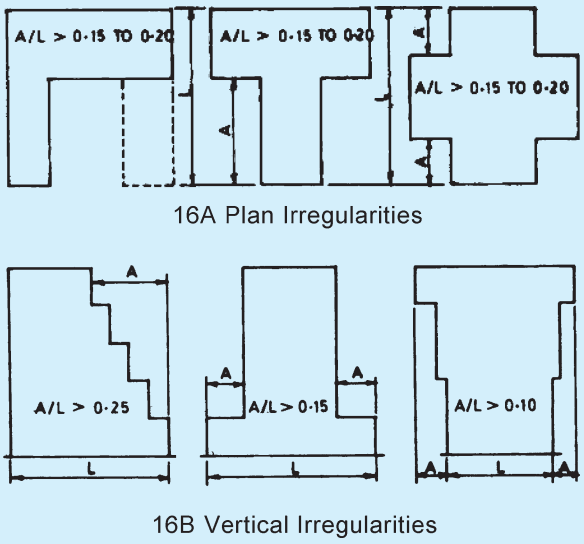


FIG. 16 PLAN AND VERTICAL IRREGULARITIES

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8.2.8 *Damage to Non-Structural Parts*

Suitable details shall be worked out to connect the non-structural parts with the structural framing so that the deformation of the structural frame leads to minimum damage of the non-structural elements.

8.2.9 *Fire Safety*

Fire frequently follows an earthquake and therefore, buildings shall be constructed to make them fire resistant in accordance with the provisions of Part 4 'Fire and Life Safety' of the Code for fire safety.

8.3 Special Construction Features

8.3.1 *Separation of Adjoining Structures*

8.3.1.1 Separation of adjoining structures or parts of the same structure is required for structures having different total heights or storey heights and different dynamic characteristics. This is to avoid collision during an earthquake.

8.3.1.2 Minimum width of separation gaps as mentioned in **8.3.1.1**, shall be as specified in Table 13. The design seismic coefficient to be used shall be in accordance with **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

8.3.1.3 Where separation is necessary, a complete separation of the parts shall be made except below the plinth level. The plinth beams, foundation beams and footings may be continuous. Where separation sections are provided in a long building, they shall take care of movement owing to temperature changes also.

Table 13 Gap Width for Adjoining Structures

(*Clause* 8.3.1.2)

Sl. No.	Buildings Categories for Earthquake Resisting Features	Gap Width per Storey for Adjoining Masonry Building mm
(1)	(2)	(3)
i)	Frames with shear walls	15
ii)	Category B[1)]	10
iii)	Category C[1)]	10
iv)	Category D[1)]	15
v)	Category E[1)]	20

[1)] *See* Table 14.

NOTE — Minimum total gap shall be 25 mm. For any other value of A_h the gap width shall be determined proportionately.

8.3.2 *Separation or Crumple Section*

8.3.2.1 In case of framed construction, members shall be duplicated on either side of the separation or crumple section. As an alternative, in certain cases, such duplication may not be provided, if the portions on either side can act as cantilevers to take the weight of the building and other relevant loads.

8.3.2.2 Typical details of separation and crumple sections are shown in Fig. 17. For other types of joint details, reference may be made to good practice [6-4(6)].

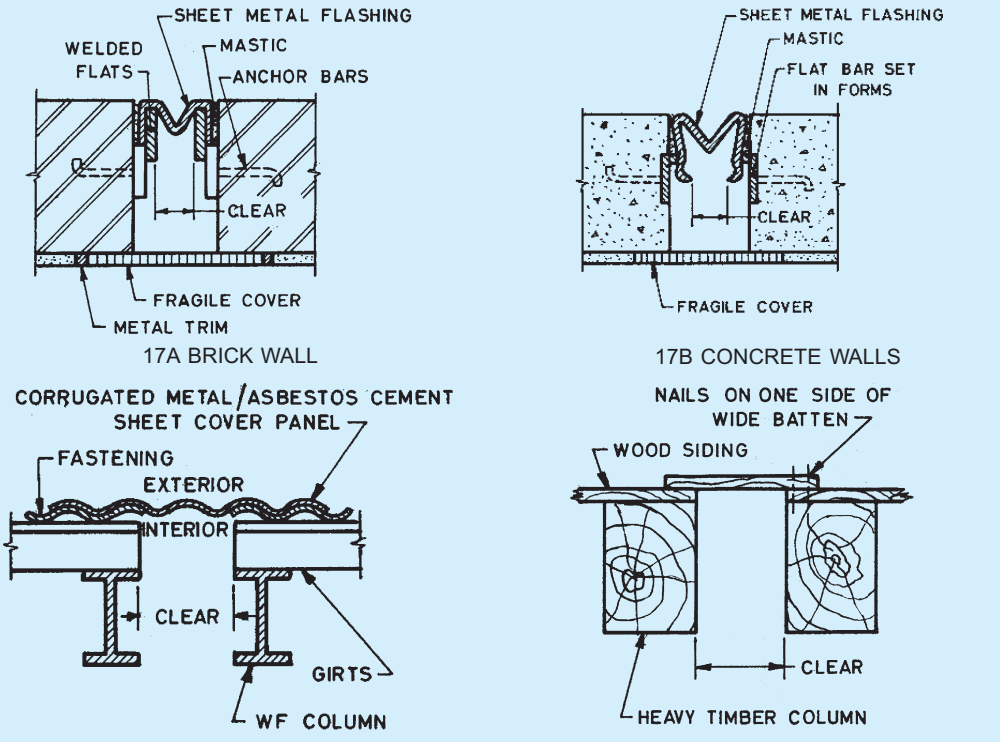
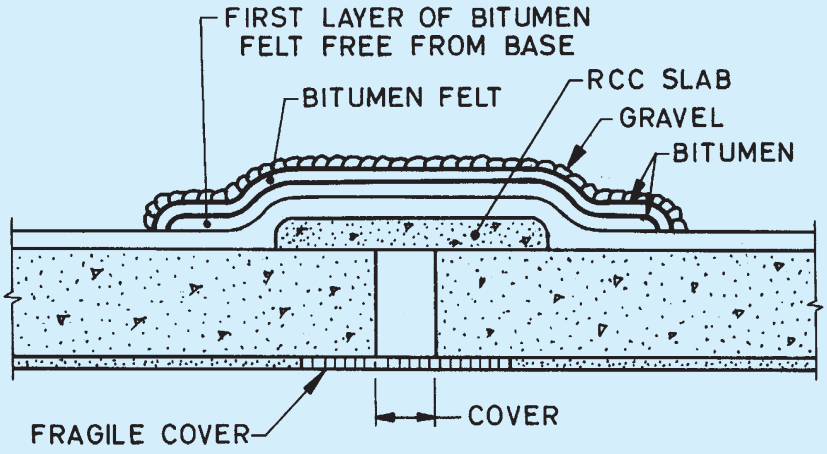
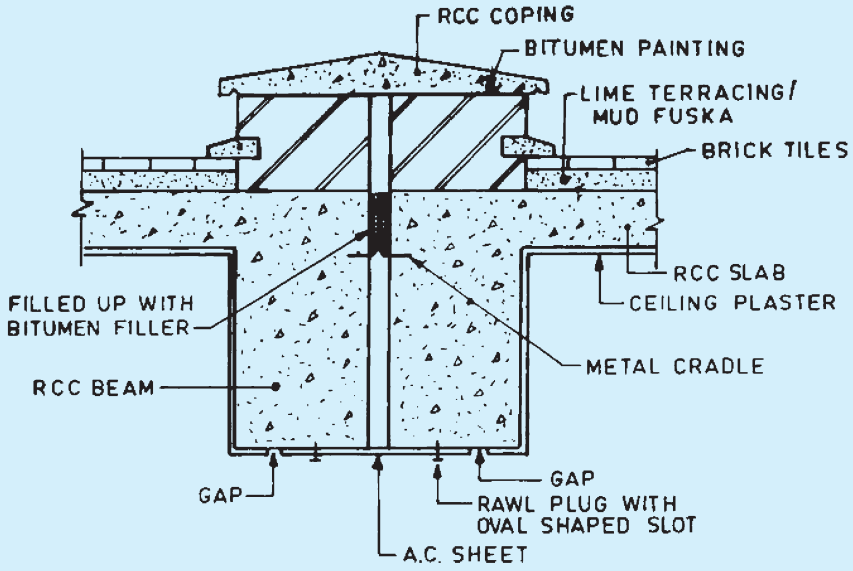


FIG. 17 TYPICAL DETAILS OF SEPARATION OR CRUMPLE SECTION (*CONTINUED*)

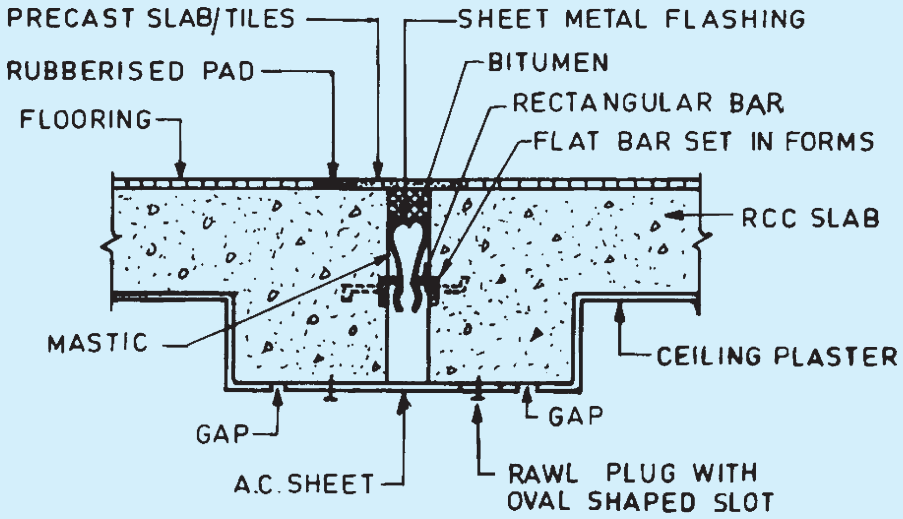
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17E RCC SLAB ON ROOF SURFACE



17F SEPARATION JOINT DETAILS AT ROOF



17G SEPARATION AT FLOOR LEVEL

NOTE — Fragile cover may consist of asbestos cement sheet, particle board and like.

FIG. 17 TYPICAL DETAILS OF SEPARATION OR CRUMPLE SECTION

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8.3.3 *Foundations*

8.3.3.1 For the design of foundations, the provisions of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' and Section 2 'Soils and Foundation' of the Code shall generally be followed.

8.3.3.2 The subgrade below the entire area of the building shall preferably be of the same type of the soil. Wherever this is not possible, a suitably located separation or crumple section shall be provided.

8.3.3.3 Loose fine sand, soft silt and expansive clays should be avoided. If unavoidable, the building shall rest either on a rigid raft foundation or on piles taken to a firm stratum. However, for light constructions the following measures may be taken to improve the soil on which the foundation of the building may rest:

a) Sand piling, and
b) Soil stabilization.

8.3.3.4 *Isolated footings for columns*

All the individual footings or pile caps where used in Type III Soft soils {Table 1 of good practice [6-4(9)]}, shall be connected by reinforced concrete ties at least in two directions approximately at right angles to each other. For buildings with no basement, the ties may be placed at or below the plinth level and for buildings with basement they may be placed at the level of basement floor. They shall need to be designed to carry the load of the panel walls also.

NOTE — The ties may not be necessary where structural floor connects the columns at or below the plinth level.

8.3.3.4.1 Where ties are used, their sections shall be designed to carry in tension as well as in compression, an axial load not less than the earthquake force in the direction the tie acting on the heavier of the columns connected, but the sections shall not be less than 200 mm × 200 mm with M20 concrete reinforced with 4 bars of 12 mm diameter plain mild steel bars or 10 mm diameter high strength deformed bars, one at each corner, bound by 8 mm diameter stirrups not more than 150 mm apart.

NOTE — In working out the buckling strength of ties, the lateral support provided by the soil may be taken into account. Calculations show that for such buried ties, lateral buckling is not a problem and the full section of the tie may be taken effective as a short column.

8.3.3.4.2 In the case of reinforced concrete slab, the thickness shall not be less than 1/50th of the clear distance between the footings, but not less than 100 mm in any case. It shall be reinforced with not less than 0.15 percent mild steel bars or 0.12 percent high strength deformed bars in each direction placed symmetrically at top and bottom.

8.3.4 *Roofs and Floors*

8.3.4.1 Flat roof or floor shall not preferably be made of tiles of ordinary bricks supported on steel, timber or reinforced concrete joists, nor they shall be of a type which in the event of an earthquake is likely to be loosened and parts or all of which may fall. If this type of construction cannot be avoided, the joists should be blocked at ends and bridged at intervals such that their spacing is not altered during an earthquake.

8.3.4.1.1 For pitched roofs, corrugated iron or asbestos sheets shall be used in preference to country, Allahabad or Mangalore tiles or other loose roofing units. All roofing materials shall be properly tied to the supporting members. Heavy roofing materials shall generally be avoided.

8.3.4.2 *Pent roofs*

8.3.4.2.1 All roof trusses shall be supported on reinforced concrete or reinforced brick band (*see* **8.6.4.3**). The holding down bolts shall have adequate size and length as required for earthquake forces in accordance with **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

Where a trussed roof adjoins a masonry gable, the ends of the purlins shall be carried on and secured to a plate or bearer which shall be adequately bolted to reinforced concrete or reinforced brick band at the top of gable end masonry (*see* **8.6.4.4**).

NOTE — Hipped roof in general have shown better structural behaviour during earthquakes than gable ended roofs.

8.3.4.2.2 At tie level all the trusses and the gable end shall be provided with diagonal braces in plan so as to transmit the lateral shear due to earthquake force to the gable walls acting as shear walls at the ends as specified in **8.6.4**.

8.3.4.3 *Jack arches*

Jack arched roofs or floors, where used shall be provided with mild steel ties in all spans along with diagonal braces in plan to ensure diaphragms actions.

8.3.5 *Staircases*

8.3.5.1 The inter-connection of the stairs with the adjacent floors should be appropriately treated by providing sliding joints at the stairs to eliminate their bracing effect on the floors. Large stair halls shall preferably be separated from the rest of the building by means of separation or crumple sections.

8.3.5.2 Three types of stair construction may be adopted as described below:

a) *Separated staircases* — One end of the staircase rests on a wall and the other end is carried by columns and beams which have no

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connection with the floors. The gap at the vertical joints between the floor and the staircase may be covered either with a tread plate attached to one side of the joint and sliding on the other side, or covered with some appropriate material which could crumple or fracture during an earthquake without causing structural damage. The supporting members, columns or walls, are isolated from the surrounding floors by means of separation or crumple sections. A typical example is shown in Fig. 18.

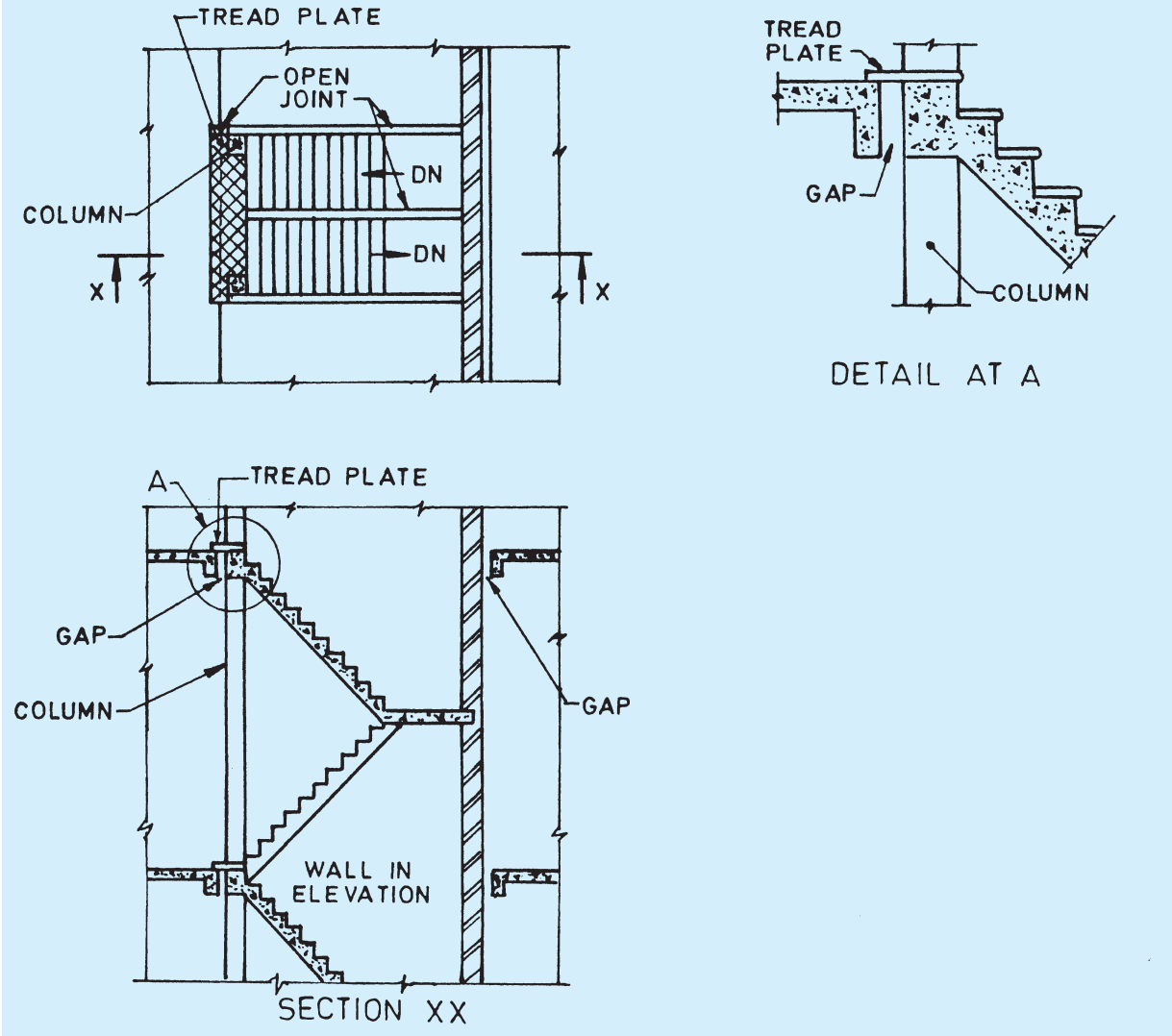


FIG. 18 SEPARATED STAIRCASE

b) *Built-in staircase* — When stairs are built monolithically with floors, they can be protected against damage by providing rigid walls at the stair opening. An arrangement, in which the staircase is enclosed by two walls, is given in Fig. 19. In such cases, the joints, as mentioned in respect of separated staircases, shall not be necessary.

The two walls mentioned above, enclosing the staircase, shall extend through the entire height of the stairs and to the building foundations.

c) *Staircases with sliding joints* — In case it is not possible to provide rigid walls around stair openings for built-in staircase or to adopt the separated staircases, the staircases shall have sliding joints so that they shall not act as diagonal bracing.

8.4 Types of Construction

8.4.1 The types of construction usually adopted in buildings are as follows:

a) Framed construction; and
b) Box type construction.

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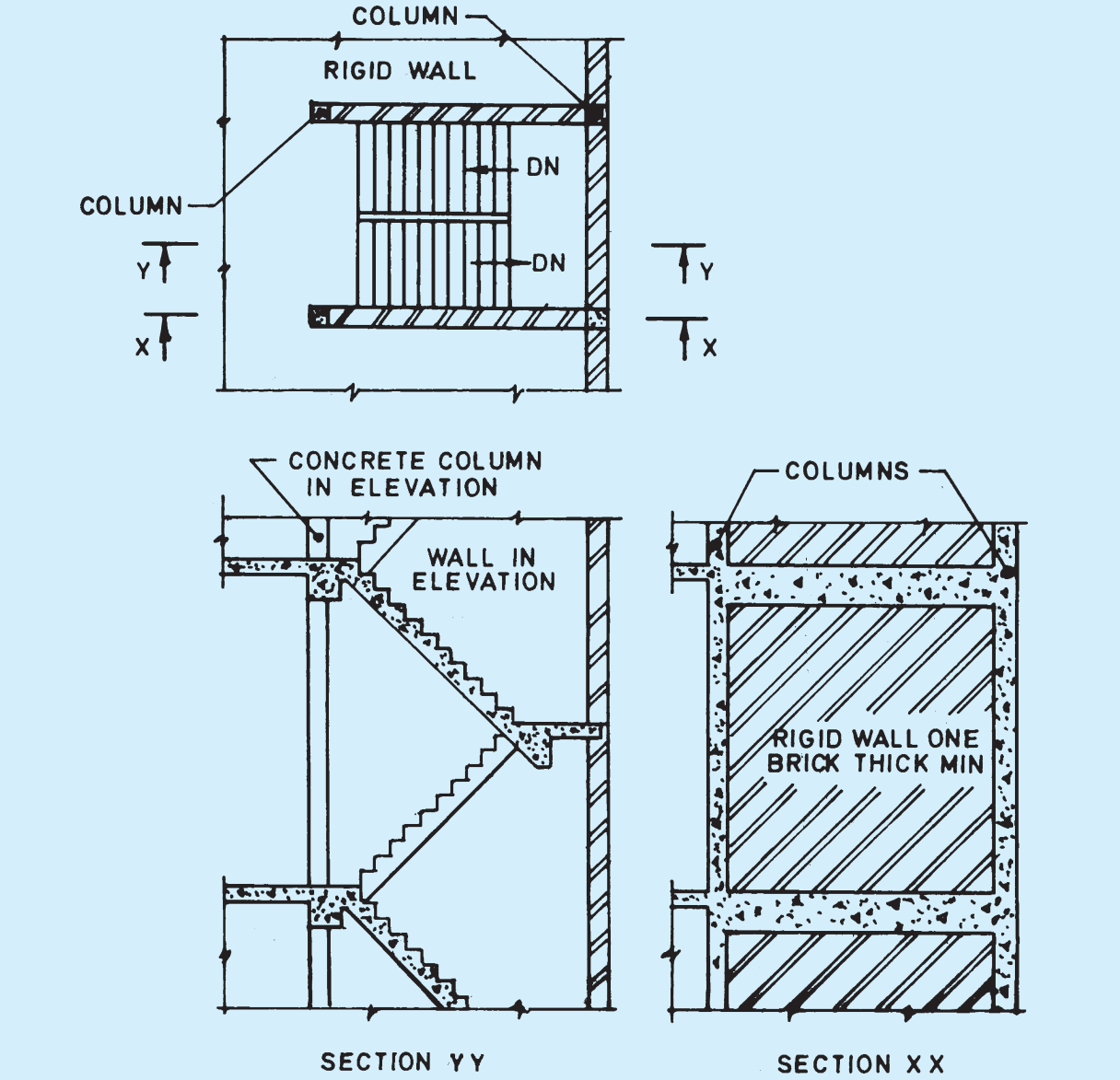


FIG. 19 RIGIDLY BUILT-IN STAIRCASE

8.4.2 *Framed Construction*

This type of construction is suitable for multi-storied and industrial buildings as described in **8.4.2.1** and **8.4.2.2**.

8.4.2.1 *Vertical load carrying frame construction*

This type of construction consists of frames with flexible (hinged) joints and bracing members. Steel multi-storied building or industrial frames and timber construction usually are of this type.

8.4.2.1.1 Such buildings shall be adequately strengthened against lateral forces by shear walls and/or other bracing systems in plan, elevation and sections such that earthquake forces shall be resisted by them in any direction.

8.4.2.2 *Moment resistant frames with shear walls*

The frames may be of reinforced concrete or steel with semi-rigid or rigid joints. The walls are rigid capable of acting as shear walls and may be of reinforced concrete or of brickwork reinforced or unreinforced bounded by framing members through shear connectors.

8.4.2.2.1 The frame and wall combinations shall be designed to carry the total lateral force due to earthquake acting on the building. The frame acting alone shall be designed to resist at least 25 percent of the total lateral force.

8.4.2.2.2 The shear walls shall preferably be distributed evenly over the whole building. When concentrated at one location, forming what is called a rigid core in the building, the design shall be checked for torsional effects and the shear connection between the core and the floors conservatively designed for the total shear transfer.

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8.4.2.2.3 The shear walls should extend from the foundation either to the top of the building or to a lesser height as required from design consideration. In design, the interaction between frame and the shear walls should be considered properly to satisfy compatibility and equilibrium conditions.

NOTE — Studies show that shear walls of height about 85 percent of total height of building are advantageous.

8.4.3 *Box Type Construction*

This type of construction consists of prefabricated or *in-situ* masonry, concrete or reinforced concrete walls along both the axes of the building. The walls support vertical loads and also act as shear walls for horizontal loads acting in any direction. All traditional masonry construction falls under this category. In prefabricated construction attention shall be paid to the connection between wall panels so that transfer of shear between them is ensured.

8.5 Categories of Buildings

8.5.1 For the purpose of specifying the earthquake resisting features in masonry and wooden buildings, the buildings have been categorized in four categories B to E based on the seismic zone and the importance of the building *I*,

where

I = Importance factor applicable to the building {as per good practice [6-4(9)]}.

8.5.1.1 The building categories are given in Table 14.

Table 14 Building Categories for Earthquake Resisting Features

(*Clause* 8.5.1.1)

Sl No.	Importance Factor	Seismic Zone			
		II	III	IV	V
(1)	(2)	(3)	(4)	(5)	(6)
i)	1.0	B	C	D	E
ii)	1.5	C	D	E	E

NOTE — Category A is now defunct as Seismic Zone I does not exist any more.

8.6 Masonry Construction with Rectangular Masonry Units

8.6.1 The design and construction of masonry walls using rectangular masonry units in general shall be governed by **3** to **7** of this Section and good practice [6-4(5)].

8.6.1.1 *Masonry units*

8.6.1.1.1 Well burnt bricks conforming to accepted standard [6-4(12)] or solid concrete blocks conforming to accepted standard [6-4(13)] and having a crushing strength not less than 3.5 MPa shall be used. The strength of masonry unit required shall depend upon number of storeys and thickness of walls (*see* **3** to **6**).

8.6.1.1.2 Squared stone masonry, stone block masonry or hollow concrete block masonry, as specified in the good practice [6-4(14)] of adequate strength, may also be used.

8.6.1.2 *Mortar*

8.6.1.2.1 Mortars, such as those given in Table 15 or of equivalent specification, shall preferably be used for masonry construction for various categories of buildings.

8.6.1.2.2 Where steel reinforcing bars are provided in masonry, the bars shall be embedded with adequate cover in cement sand mortar not leaner than 1 : 3 (minimum clear cover 10 mm) or in cement concrete of grade M20 (minimum clear cover 15 mm or bar diameter whichever is more), so as to achieve good bond and corrosion resistance.

8.6.2 *Walls*

8.6.2.1 Masonry bearing walls built in mortar, as specified in **8.6.1.2.1** unless rationally designed as reinforced masonry shall not be built of greater height than 15 m subject to a maximum of four storeys when measured from the mean ground level to the roof slab or ridge level. The masonry bearing walls shall be reinforced in accordance with **8.6.4.1**.

8.6.2.2 The bearing walls in both directions shall be straight and symmetrical in plan as far as possible.

8.6.2.3 The wall panels formed between cross walls and floors or roof shall be checked for their strength in bending as a plate or as a vertical strip subjected to the earthquake force acting on its own mass.

NOTE — For panel walls of 200 mm or larger thickness having a storey height not more than 3.5 m and laterally supported at the top, this check need not be exercised.

8.6.2.4 *Masonry bond*

For achieving full strength of masonry, the usual bonds specified for masonry should be followed so that the vertical joints are broken properly from course to course. To obtain full bond between perpendicular walls, it is necessary to make a slopping (stepped) joint by making the corners first to a height of 600 mm and then building the wall in between them. Otherwise, the

Table 15 Recommended Mortar Mixes

(*Clauses* 8.6.1.2.1 *and* 8.6.2.6)

Sl No.	Building Category	Grade of Mortar	Minimum Compressive Strength at 28 Days
			N/mm^2
(1)	(2)	(3)	(4)
i)	E	H1	10
		H2	6.0
ii)	D	M1	5.0
		M2	3.0
iii)	C	M2	3.0
iv)	B	M3	1.5

NOTE — *See* Table 1 and Table 2 for more details.

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toothed joint should be made in both the walls alternatively in lifts of about 450 mm (*see* Fig. 20).

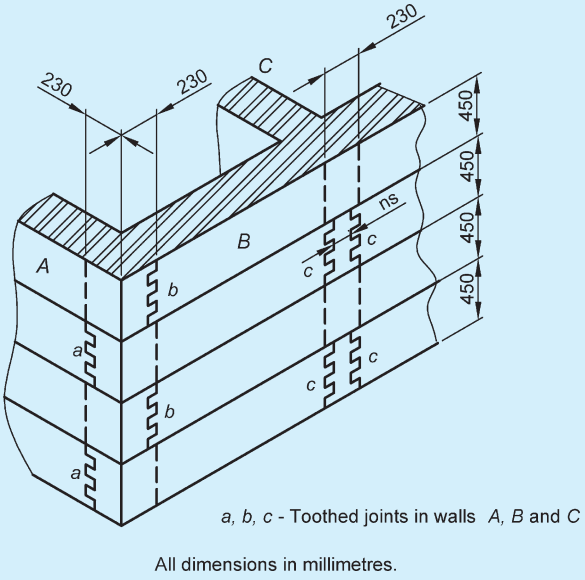


FIG. 20 ALTERNATING TOOTHED JOINTS IN WALLS AT CORNER AND T-JUNCTION

8.6.2.5 Ignoring tensile strength, free standing walls shall be checked against overturning under the action of design seismic coefficient α_h allowing for a factor safety of 1.5.

8.6.2.6 Panel or filler walls in framed buildings shall be properly bonded to surrounding framing members by means of suitable mortar (*see* Table 15) or connected through dowels. If the walls are so bonded they shall be checked according to **8.6.2.3** otherwise as in **8.6.2.5**.

8.6.3 *Openings in Bearing Walls*

8.6.3.1 Door and window openings in walls reduce their lateral load resistance and hence, should preferably be small and more centrally located. The guidelines on the size and position of opening are given in Table 16 and Fig. 21.

Table 16 Size and Position of Openings in Bearing Walls

(*Clause* 8.6.3.1)

Sl No.	Position of Opening	Details of Opening for Building Category		
		B	C	D and E
(1)	(2)	(3)	(4)	(5)
i)	Distance b_5 from the inside corner of outside wall, mm, *Min*	0	230	450
ii)	For total length of openings, the ratio $(b_1 + b_2 + b_3)/l_1$ or $(b_6 + b_7)/l_2$ shall not exceed,			
	a) one-storeyed building	0.60	0.55	0.50
	b) two-storeyed building	0.50	0.46	0.42
	c) 3 or 4 storeyed building	0.42	0.37	0.33
iii)	Pier width between consecutive openings b_4, mm, *Min*	340	450	560
iv)	Vertical distance between two openings one above the other h_3, mm, *Min*	600	600	600
v)	Width of opening of ventilator b_8, mm, *Max*	900	900	900

NOTE — Four storeys buildings not allowed in Category E.

8.6.3.2 Openings in any storey shall preferably have their top at the same level so that a continuous band could be provided over them, including the lintels throughout the building.

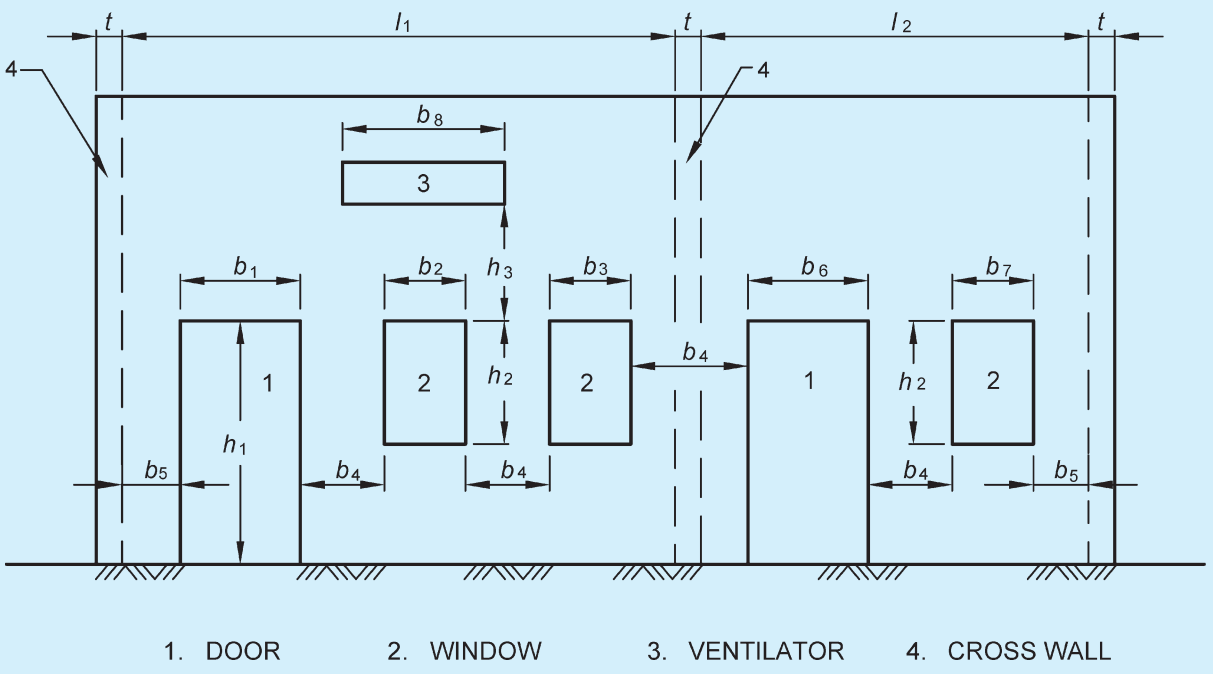
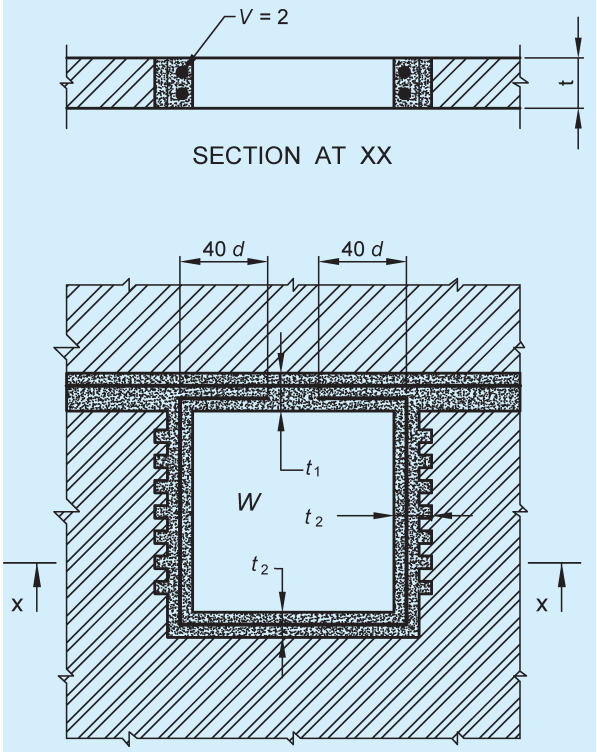


FIG. 21 RECOMMENDED DIMENSIONS OF OPENINGS AND PIERS (*SEE* TABLE 16)

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8.6.3.3 Where openings do not comply with the guidelines of Table 15, they should be strengthened by providing reinforced concrete or reinforcing the brickwork, as shown in Fig. 22 with high strength deformed (HSD) bars of 8 mm diameter but the quantity of steel shall be increased at the jambs to comply with **8.6.4.9**, if so required.



W = WINDOW
t = WALL THICKNESS
t_1 = LINTEL THICKNESS
t_2 = THICKNESS OF CONCRETE IN JAMB
V = VERTICAL BAR
d = DIAMETER OF REINFORCING BARS

FIG. 22 STRENGTHENING MASONRY AROUND OPENINGS

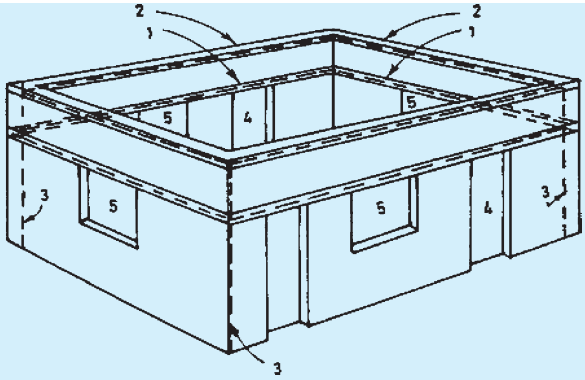
8.6.3.4 If a window or ventilator is to be projected out, the projection shall be in reinforced masonry or concrete and well anchored.

8.6.3.5 If an opening is tall from bottom to almost top of a storey, thus dividing the wall into two portions, these portions shall be reinforced with horizontal reinforcement of 6 mm diameter bars at not more than 450 mm intervals, one on inner and one on outer face, properly tied to vertical steel at jambs, corners or junction of walls, where used.

8.6.3.6 The use of arches to span over the openings is a source of weakness and shall be avoided. Otherwise, steel ties should be provided.

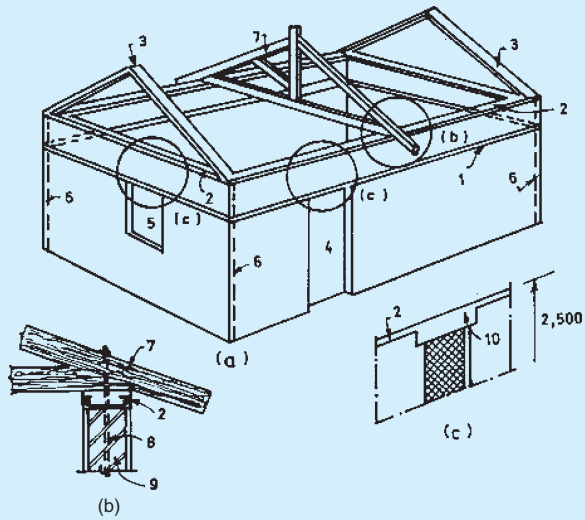
8.6.4 *Seismic Strengthening Arrangements*

8.6.4.1 All masonry buildings shall be strengthened by the methods, as specified for various categories of buildings, as listed in Table 17, and detailed in subsequent clauses. Figures 23 and 24 show, schematically, the overall strengthening arrangements to be adopted for category D and E buildings which consist of horizontal bands of reinforcement at critical levels, vertical reinforcing bars at corners, junctions of walls and jambs of openings.



1 — LINTEL BAND
2 — ROOF/FLOOR BAND
3 — VERTICAL BAR
4 — DOOR
5 — WINDOW

FIG. 23 OVERALL ARRANGEMENT OF REINFORCING LOW STRENGTH MASONRY BUILDINGS



1 — LINTEL BAND
2 — EAVES LEVEL (ROOF) BAND
3 — GABLE BAND
4 — DOOR
5 — WINDOW
6 — VERTICAL STEEL BAR
7 — RAFTER
8 — HOLDING DOWN BOLT
9 — BRICK/STONE WALL
10 — DOOR LINTEL INTEGRATED WITH ROOF BAND:
a) PERSPECTIVE VIEW
b) DETAILS OF TRUSS CONNECTION WITH WALL
c) DETAIL OF INTEGRATING DOOR LINTEL WITH ROOF BAND

FIG. 24 OVERALL ARRANGEMENT OF REINFORCING LOW STRENGTH MASONRY BUILDING HAVING PITCHED ROOF

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8.6.4.2 Lintel band is a band (*see* **8.1.6**) provided at lintel level on all load bearing internal, external longitudinal and cross walls. The specifications of the band are given in **8.6.4.5**.

NOTE — Lintel band, if provided in panel or partition walls also shall improve their stability during severe earthquake.

8.6.4.3 Roof band is a band (*see* **8.1.6**) provided immediately below the roof or floors. The specifications of the band are given in **8.6.4.5**. Such a band need not be provided underneath reinforced concrete or brick-work slabs resting on bearing walls, provided that the slabs are continuous over the intermediate wall up to the crumple sections, if any, and cover the width of end walls, fully or at least ¾ of the wall thickness.

Table 17 Strengthening Arrangements Recommended for Masonry Buildings (Rectangular Masonry Units)

(*Clause* 8.6.4.1)

Sl No.	Building Category	Number of Storeys	Strengthening to be Provided in All Storeys
(1)	(2)	(3)	(4)
i)	B	1) 1 to 3	a, b, c, f, g
		2) 4	a, b, c, d, f, g
ii)	C	1) 1 and 2	a, b, c, f, g
		2) 3 and 4	a to g
iii)	D	1) 1 and 2	a to g
		2) 3 and 4	a to h
iv)	E	1 to 3[1)]	a to h

[1)] 4th storey not allowed in category E.

where

a = masonry mortar (*see* **8.6.1.2**);

b = lintel band (*see* **8.6.4.2**);

c = roof band and gable band where necessary (*see* **8.6.4.3** and **8.6.4.4**);

d = vertical steel at corners and junctions of walls (*see* **8.6.4.8**);

e = vertical steel at jambs of openings (*see* **8.6.4.9**);

f = bracing in plan at tie level of roofs (*see* **8.3.4.2.2**);

g = plinth band where necessary (*see* **8.6.4.6**); and

h = dowel bars (*see* **8.6.4.7**).

NOTE — In case of four storey buildings of category B, the requirements of vertical steel may be checked through a seismic analysis using a design seismic co-efficient equal to four times the one given in **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code (this is because the brittle behaviour of masonry in the absence of a vertical steel results in much higher effective seismic force than that envisaged in the seismic coefficient, provided in the Code). If this analysis shows that vertical steel is not required the designer may take the decision accordingly.

8.6.4.4 Gable band is a band provided at the top of gable masonry below the purlins. The specifications of the band are given in **8.6.4.5**. This band shall be made continuous with the roof band at the eaves level.

8.6.4.5 *Section and reinforcement of band*

The band shall be made of reinforced concrete of grade not leaner than M20 or reinforced brickwork in cement mortar not leaner than 1 : 3 (H1). The bands shall be of the full width of the wall not less than 75 mm in depth and reinforced with steel, as indicated in Table 18.

NOTE — In coastal areas, the concrete grade shall be M30 concrete and the filling mortar of 1 : 3 (H1) (cement-sand with water proofing admixture).

Table 18 Recommended Longitudinal Steel in Reinforced Concrete Bands

(*Clause* 8.6.4.5)

Sl No.	Span	Building Category B		Building Category C		Building Category D		Building Category E	
		No. of Bars	Dia mm	No. of Bars	Dia mm	No. of Bars	Dia mm	No. of Bars	Dia mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	5 or less	2	8	2	8	2	8	2	10
ii)	6	2	8	2	8	2	10	2	12
iii)	7	2	8	2	10	2	12	4	10
iv)	8	2	10	2	12	4	10	4	12

NOTES

1 Span of wall shall be the distance between centre lines of its cross walls or buttresses. For spans greater than 8 m, it shall be desirable to insert pilasters or buttresses to reduce the span or special calculation shall be made to determine the strength of wall and section of band.

2 The number and diameter of bars given above pertain to high strength deformed bars.

3 Width of R.C. band is assumed same as the thickness of the wall. Wall thickness shall be 200 mm minimum. A clear cover of 20 mm from face of wall shall be maintained.

4 The vertical thickness of R.C. band be kept 75 mm minimum, where two longitudinal bars are specified, one on each face; and 150 mm, where four bars are specified.

5 Concrete mix shall be of grade M20 of good practice [6-4(10)].

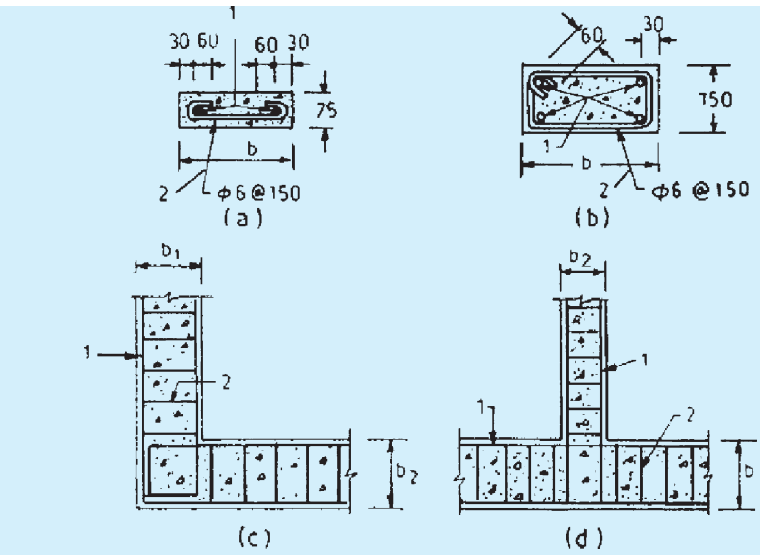
6 The longitudinal steel bars shall be held in position by steel links or stirrups 6 mm diameter spaced at 150 mm apart.

8.6.4.5.1 In case of reinforced brickwork, the thickness of joints containing steel bars shall be increased so as to have a minimum mortar cover of 15 mm around the bar. In bands of reinforced brickwork the area of steel provided shall not be less than either as per **10.7.2.2** or specified above for reinforced concrete bands.

8.6.4.5.2 For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands continuity of reinforcement is essential. The details as shown in Fig. 25 are recommended.

8.6.4.6 Plinth band is a band provided at plinth level of walls on top of the foundation wall. This is to be provided where strip footings of masonry (other than

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1 — LONGITUDINAL BARS
2 — LATERAL TIES
b_1, b_2 — WALL THICKNESS

a) SECTION OF BAND WITH TWO BARS
b) SECTION OF BAND WITH FOUR BARS
c) STRUCTURAL PLAN AT CORNER JUNCTION
d) SECTION PLAN AT T-JUNCTION OF WALLS

All dimensions in millimetres.

FIG. 25 REINFORCEMENT AND BENDING DETAIL IN R.C. BAND

reinforced concrete or reinforced masonry) are used and the soil is either soft or uneven in its properties, as frequently happens in hill tracts. Where used, its section may be kept same as in **8.6.4.5**. This band shall serve as damp proof course as well.

8.6.4.7 In category D and E buildings, to further enhance the box action of walls, steel dowel bars may be used at corners and T-junctions of walls at the sill level of windows to length of 900 mm from the inside corner in each wall. Such dowel may be in the form of U stirrups 8 mm diameter. Where used, such bars shall be laid in 1 : 3 cement-sand-mortar with a minimum clear cover of 20 mm on all sides to minimise corrosion.

8.6.4.8 *Vertical reinforcement*

Vertical steel at corners and junctions of walls, which are up to 340 mm (1½ brick) thick, shall be provided as specified in Table 19. For walls thicker than 340 mm the area of the bars shall be proportionately increased. For earthquake resistant framed wall construction, *see* **8.6.5**.

8.6.4.8.1 The vertical reinforcement shall be properly embedded in the plinth masonry of foundations and roof slab or roof band so as to develop its tensile strength in bond. It shall be passing through the lintel bands and floor slabs or floor level bands in all storeys.

Bars in different storeys may be welded {*see* good practices [6-4(15)] and [6-4(16)], as relevant} or suitably lapped.

NOTE — Typical details of providing vertical steel in brickwork masonry with rectangular solid units at corners and T-junctions are shown in Fig. 26.

8.6.4.9 Vertical reinforcement at jambs of window and door openings shall be provided as per Table 19. It

Table 19 Vertical Steel Reinforcement in Masonry Walls with Rectangular Masonry Units

(*Clause* 8.6.4.8)

Sl No.	No. of Storeys	Storey	Diameter of HSD Single Bar at Each Critical Section mm			
			Category B	Category C	Category D	Category E
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	One	—	Nil	Nil	10	12
ii)	Two	a) Top	Nil	Nil	10	12
		b) Bottom	Nil	Nil	12	16
iii)	Three	a) Top	Nil	10	10	12
		b) Middle	Nil	10	12	16
		c) Bottom	Nil	12	12	16
iv)	Four	a) Top	10	10	10	Four storied building not permitted
		b) Third	10	10	12	
		c) Second	10	12	16	
		d) Bottom	12	12	20	

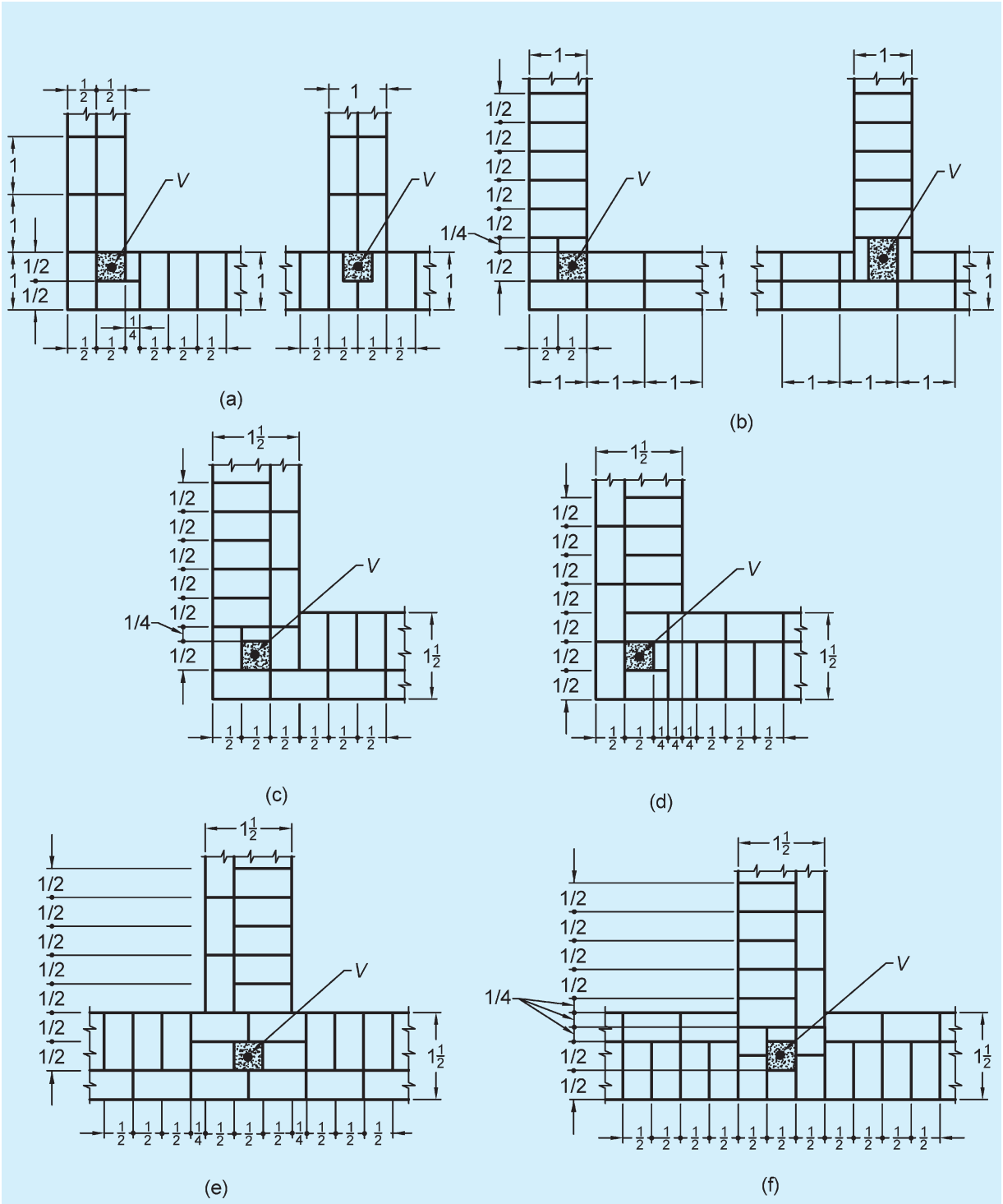
NOTES

1 The diameters given above are for HSD bars.

2 The vertical bars shall be covered with concrete M20 or mortar 1:3 grade in suitably created pockets around the bars (*see* Fig. 26). This shall ensure their safety from corrosion and good bond with masonry.

3 In case of floors/roofs with small precast components, *see also* **8.7.2.3** for floor/roof band details.

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1- One-brick length , $\frac{1}{2}$ - Half - brick length , *V* - Vertical steel bar with mortar/ concrete filling in pocket

(a) and (b) - Alternate courses in one brick

(c) and (d) - Alternate courses at corner junction of $1\frac{1}{2}$ - brick wall

(e) and (f) - Alternate courses at T- junction of $1\frac{1}{2}$ - brick wall

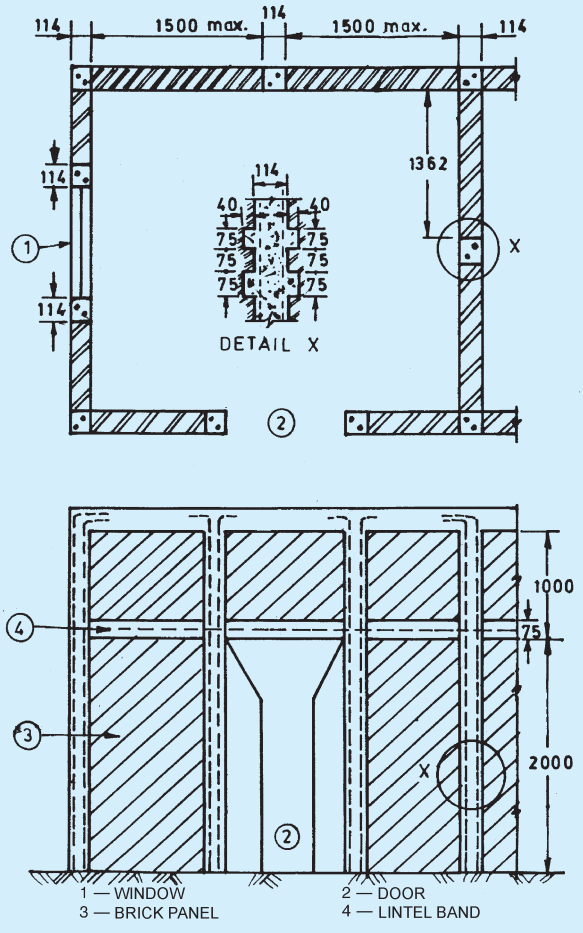
FIG. 26 TYPICAL DETAILS OF PROVIDING VERTICAL STEEL BARS IN BRICK MASONRY

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may start from foundation of floor and terminate in lintel band (*see* Fig. 22).

8.6.5 *Framing of Thin Load Bearing Walls* (*see* Fig. 27)

Load bearing walls can be made thinner than 200 mm say 150 mm inclusive of plastering on both sides. Reinforced concrete framing columns and collar beams shall be necessary to be constructed to have full bond with the walls. Columns are to be located at all corners and junctions of walls and spaced not more than 1.5 m apart but so located as to frame up the doors and windows. The horizontal bands or ring beams are located at all floors, roof as well as lintel levels of the openings. The sequence of construction between walls and columns shall be first to build the wall up to 4 to 6 courses height leaving toothed gaps (tooth projection being about 40 mm only) for the columns and second to pour M20 (1 : 1½ : 3) concrete to fill the columns against the walls using wood forms only on two sides. The columns steel should be accurately held in position all along. The band concrete should be cast on the wall masonry directly so as to develop full bond with it.



All dimensions in millimetres.

NOTES

1 Detailing of steel around the window openings will be same as for door openings with additional 75 mm band at sill level.

2 Figures are for just explanation purposes and the same shall not be used as design guide.

FIG. 27 FRAMING OF THIN LOAD-BEARING BRICK WALL

Such construction may be limited to only two storeys maximum in view of its vertical load carrying capacity. The horizontal length of walls between cross walls shall be restricted to 7 m and the storey height to 3 m.

8.6.6 *Reinforcing Details for Hollow Block Masonry*

The following details may be followed in placing the horizontal and vertical steel in hollow block masonry using cement-sand or cement-concrete blocks.

8.6.6.1 *Horizontal band*

U-shaped blocks may be used for construction of horizontal bands at various levels of the storeys as shown in Fig. 28, where the amount of horizontal reinforcement shall be taken 25 percent more than that given in Table 18 and provided by using four bars and 6 mm diameter stirrups. Other continuity details shall be followed, as shown in Fig. 25.

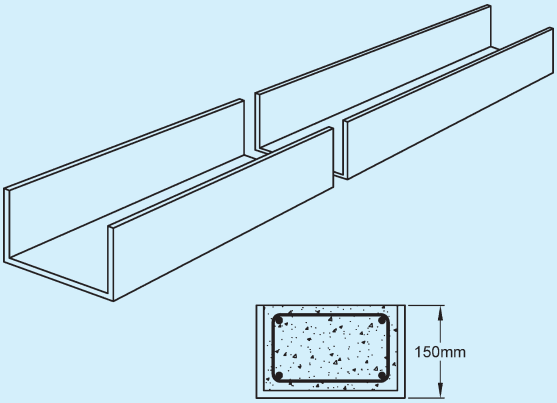
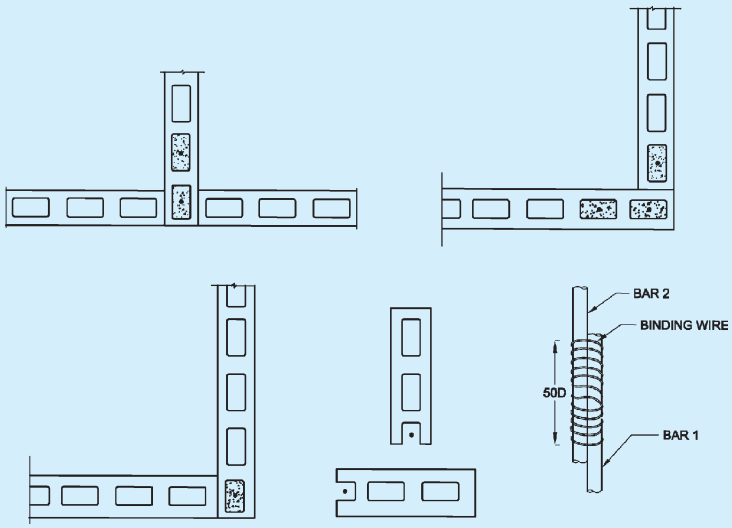


FIG. 28 U-BLOCKS FOR HORIZONTAL BANDS

8.6.6.2 *Vertical reinforcement*

Bars, as specified in Table 19 shall be located inside the cavities of the hollow blocks, one bar in each cavity (*see* Fig. 29). Where more than one bar is planned these can be located in two or three consecutive cavities. The cavities containing bars are to be filled by using micro-concrete 1 : 2 : 3 or cement coarse sand mortar 1 : 3, and properly rodded for compaction. The vertical bars should be spliced by welding or overlapping for developing full tensile strength. For proper bonding, the overlapped bars should be tied together by winding the binding wire over the lapped length. To reduce the number of overlaps, the blocks may be made U-shaped as shown in Fig. 29 which shall avoid lifting and threading of bars into the hollows.

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NOTE—OVERLAPPING OF VERTICAL REINFORCEMENT = 50D, AND
D = DIAMETER OF THE REINFORCEMENT.

FIG. 29 VERTICAL REINFORCEMENT IN CAVITIES

8.7 Floors/Roofs with Small Precast Components

8.7.1 *Types of Precast Floors/Roofs*

Earthquake resistance measures for floors and roofs with small precast components, as covered in this Section, have been dealt with as typical examples.

8.7.1.1 *Precast reinforced concrete unit roof/floor*

The unit is a precast reinforced concrete component, channel (inverted trough) shaped in section (*see* Fig. 30). The nominal width of the unit varies from 300 to 600 mm, its height from 150 to 200 mm and a minimum flange thickness of 30 mm. Length of unit shall vary according to room dimensions, but the maximum length is restricted to 4.2 m from stiffness considerations. Horizontal corrugations are provided on the two longitudinal faces of the units so that the structural roof/floor acts monolithic after concrete grouted in the joints between the units attains strength (*see* Fig. 31).

8.7.1.2 *Precast reinforced concrete cored unit roof/floor*

The unit is a reinforced concrete component having a nominal width of 300 to 600 mm and thickness of 130 to 150 mm having two circular hollows 90 mm diameter, throughout the length of the unit (*see* Fig. 32). The minimum flange/web thickness of the unit shall be 20 mm. Length of unit varies according to room dimensions, but the maximum length shall be restricted to 4.2 m from stiffness considerations. Horizontal corrugations are provided on the two longitudinal faces of the units so that the structural roof/floor acts monolithic after concrete grouted in the joints between the units attains strength (*see* Fig. 33).

8.7.1.3 *Precast reinforced concrete plank and joist scheme for roof/floor*

The scheme consists of precast reinforced concrete planks supported on partially precast reinforced concrete joists. The reinforced concrete planks are 300 mm wide and the length varies according to the spacing of the joists, but it shall not exceed 1.5 m (*see* Fig. 34). To provide monolithic property to the roof/floor and to have T-beam effect with the joists, the planks shall be made partially 30 mm thick and the partially 60 mm thick and *in-situ* concrete shall be filled in the depressed portions to complete the roof/floor structurally (*see* Fig. 35).

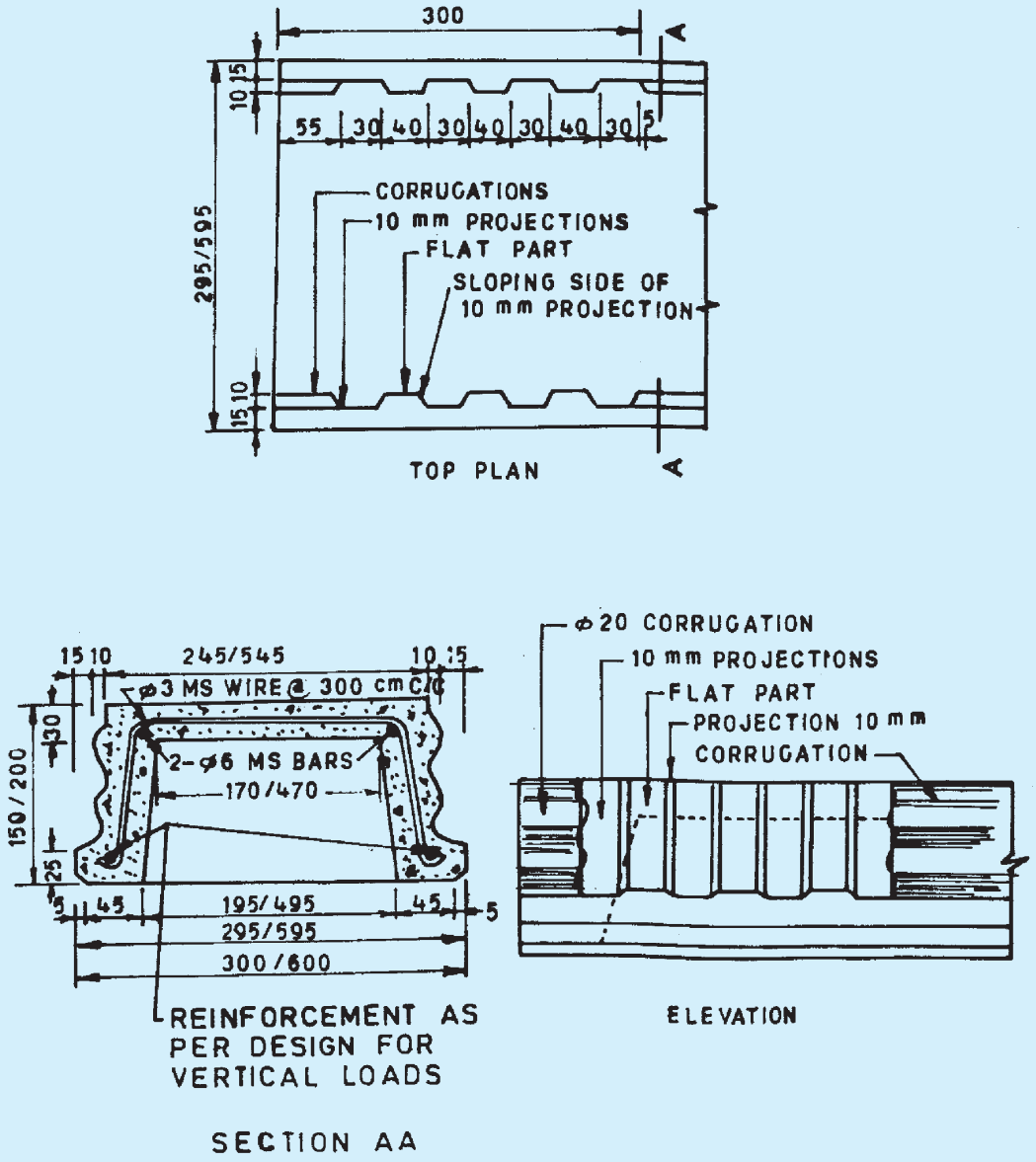
8.7.1.4 *Prefabricated brick panel system for roof/floor*

It consists of prefabricated reinforced brick panels (*see* Fig. 36) supported on Precast reinforced concrete joists with nominal reinforced 35 mm thick structural deck concrete over the brick panels and joists (*see* Fig. 37). The width of the brick panels shall be 530 mm for panels made of bricks of conventional size and 450 mm for panels made of bricks of modular size. The thickness of the panels shall be 75 mm or 90 mm, respectively depending upon whether conventional or modular bricks are used. The length of the panels shall vary depending upon the spacing of the joists, but the maximum length shall not exceed 1.2 m.

8.7.1.5 *Precast reinforced concrete waffle unit roof/floor*

Waffle units are of the shape of inverted troughs, square or rectangular in plan, having lateral dimensions up to 1.2 m and depth depending upon the span of the roof/floor to be covered (*see* Fig. 38 and Fig. 39). The

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All dimensions in millimetres.

FIG. 30 CHANNEL UNITS

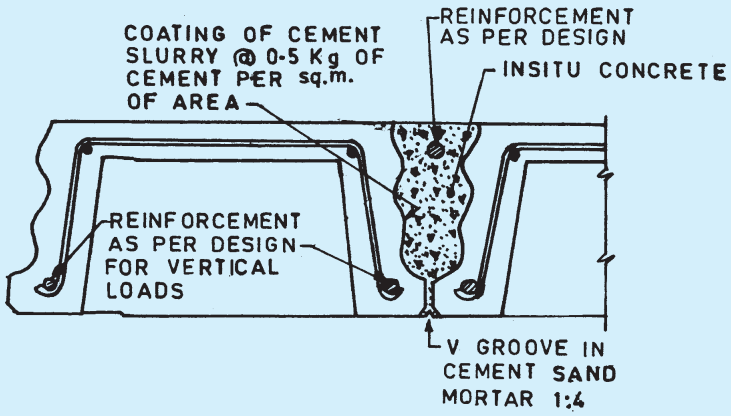
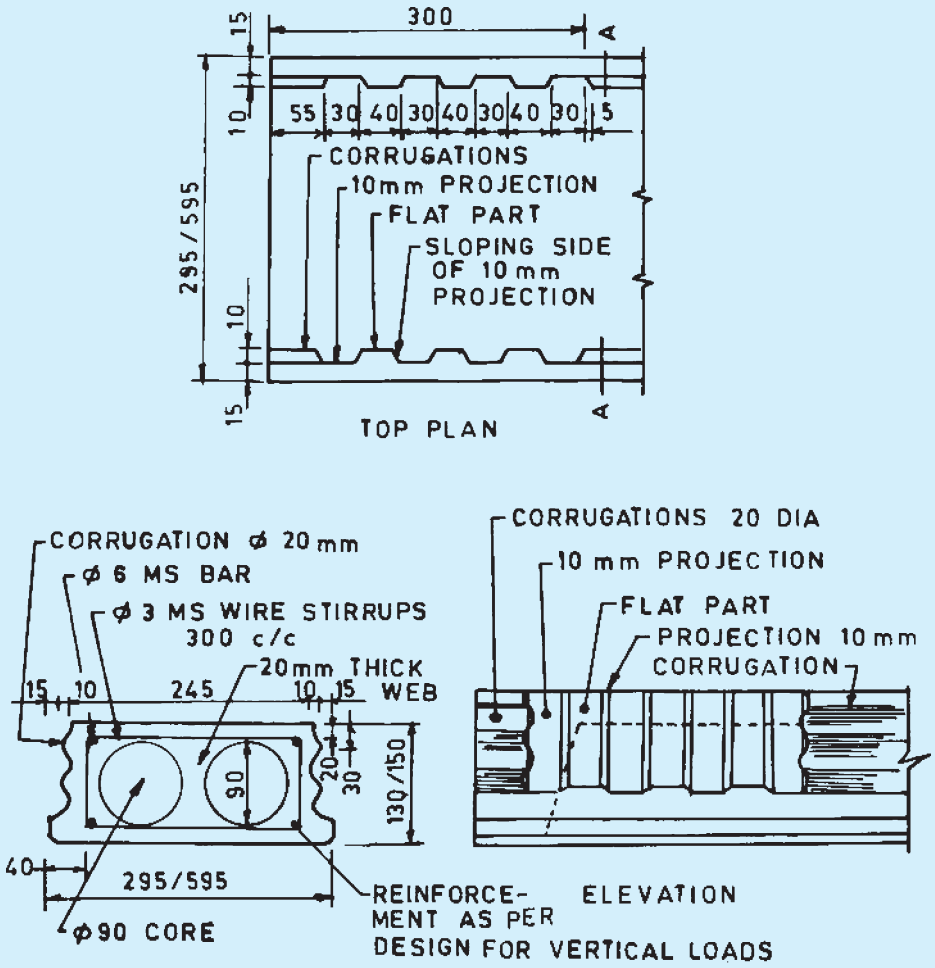


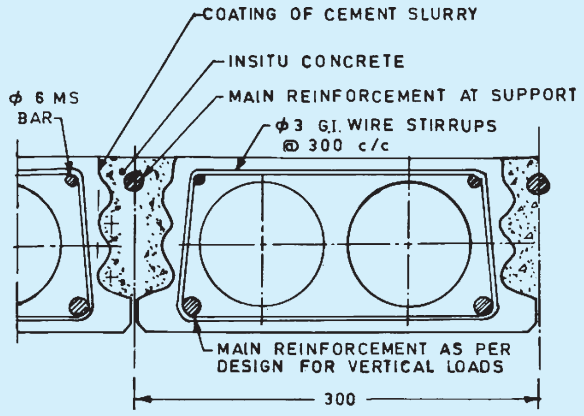
FIG. 31 CHANNEL UNITS

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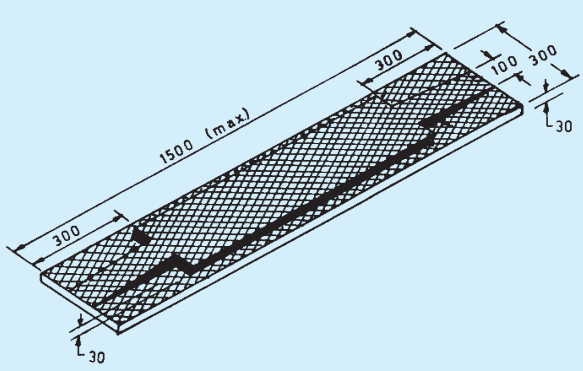
All dimensions in millimetres.

FIG. 32 CORE UNITS



All dimensions in millimetres.

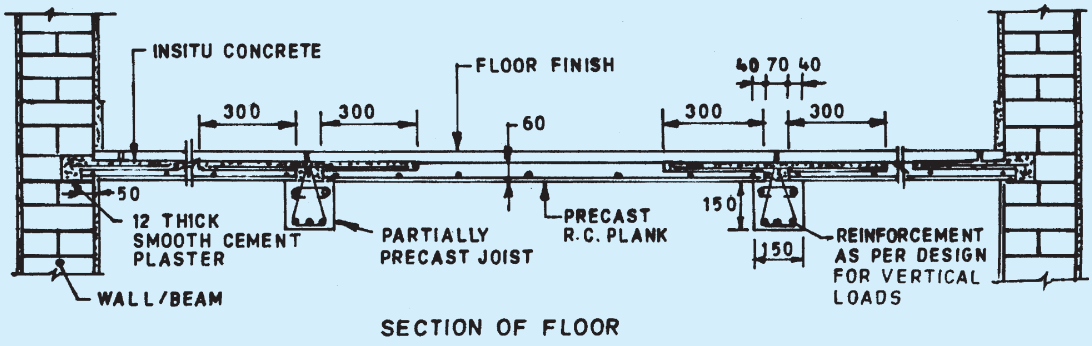
FIG. 33 CORED, UNIT FLOOR



All dimensions in millimetres.

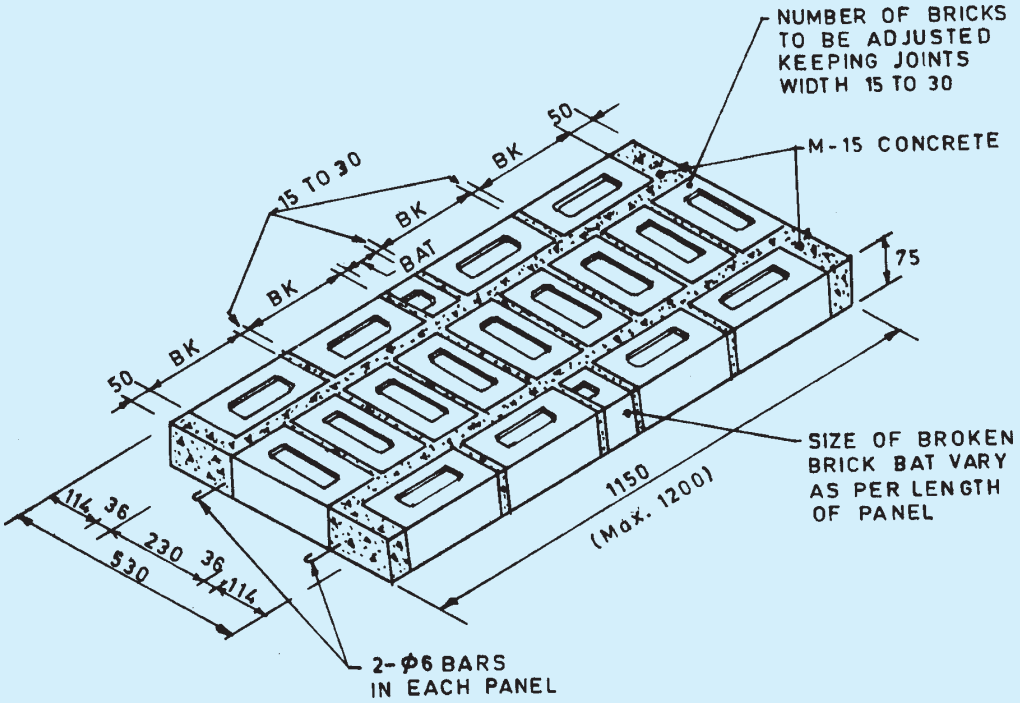
FIG. 34 PRECAST REINFORCED CONCRETE PLANK

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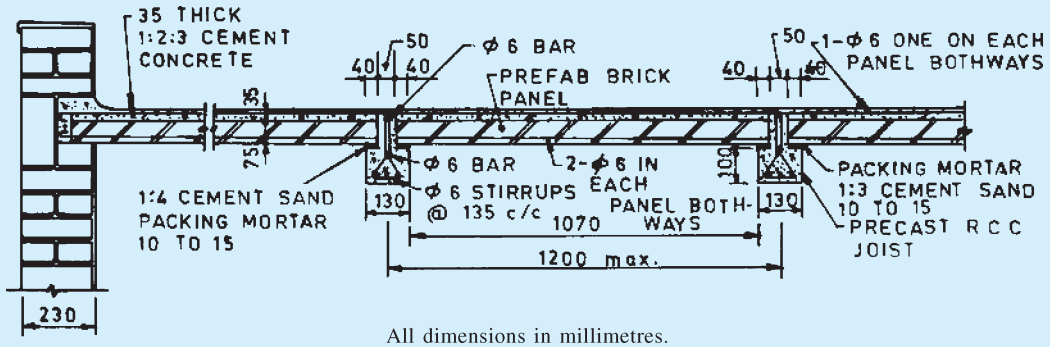
All dimensions in millimetres.

FIG. 35 PRECAST REINFORCED CONCRETE PLANK FLOOR



All dimensions in millimetres.

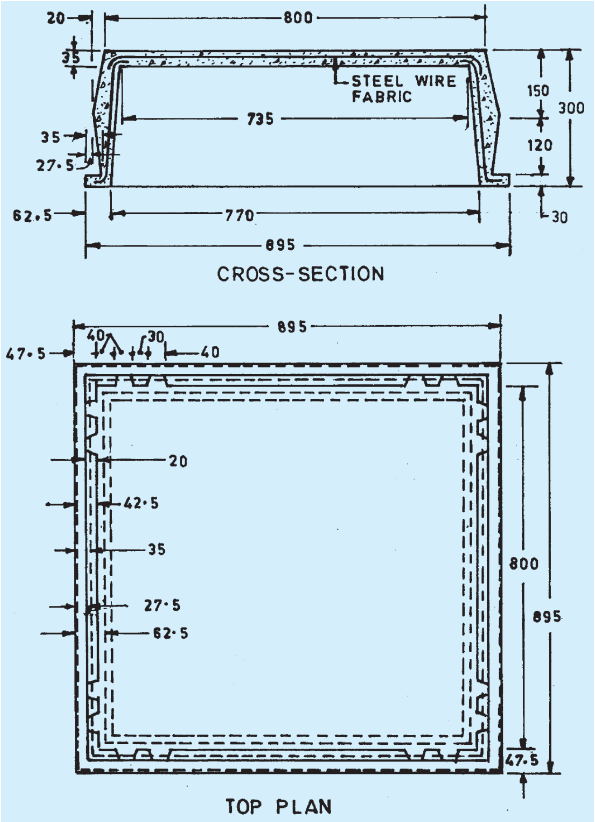
FIG. 36 PREFAB BRICK PANEL



All dimensions in millimetres.

FIG. 37 BRICK PANEL FLOOR

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All dimensions in millimetres.

FIG. 38 WAFFLE UNITS

minimum thickness of flange/web shall be 35 mm. Horizontal projections may be provided on all the four external faces of the unit and the unit shall be so shaped that it shall act monolithic with *in-situ* concrete to ensure load transfer. Vertical castellation, called shear keys, shall be provided on all the four external faces of the precast units to enable them to transfer horizontal shear force from one unit to adjacent unit through *in-situ* concrete filled in the joints between the units. The waffle units shall be laid in a grid pattern with gaps between two adjacent units, and reinforcement, as per design, and structural concrete shall be provided in the gaps between the units in both the directions. The scheme is suitable for two way spanning roofs and floors of buildings having large spans.

8.7.2 *Seismic Resistance Measures*

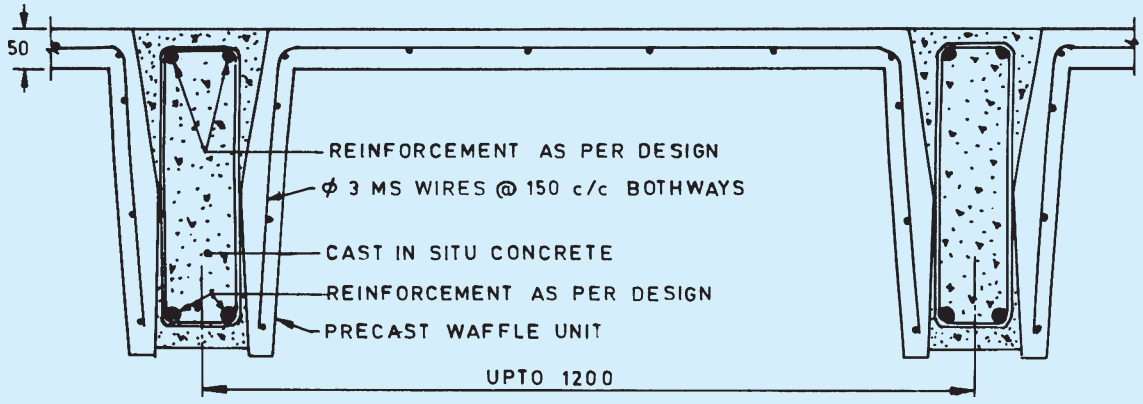
8.7.2.1 All floors and roofs to be constructed with small precast components shall be strengthened as specified for various categories of buildings in Table 20. The strengthening measures are detailed in **8.7.2.3** and **8.7.2.8**.

8.7.2.2 Vertical castellation, called shear keys, shall be provided on the longitudinal faces of the channel, cored and waffle units to enable them to transfer horizontal shear force from one unit to the adjacent unit through the *in-situ* concrete filled in the joints between the units. The minimum percentage of area of shear keys as calculated below, on each face of the unit, shall be 15.

Shear keys shall have a minimum width of 40 mm at its root with the body of the component and shall be to the full height of the component and preferably at uniform spacing. Percentage of area of shear keys shall be calculated as:

$$\frac{\text{No. of shear keys on one face of the component} \times 40}{\text{Length of the face of the component, in mm}} \times 100$$

8.7.2.3 Tie beam (*see* Table 20) is a beam provided all round the floor or roof to bind together all the precast components to make it a diaphragm. The beams shall be to the full width of the supporting wall or beam less the bearing of the precast components. The depth of the beam shall be equal to the depth of the precast components plus the thickness of structural deck concrete, where used over the components. The beam shall be made of cement concrete of grade not leaner



All dimensions in millimetres.

FIG. 39 WAFFLE UNIT FLOOR

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Table 20 Strengthening Measures for Floors/ Roofs with Small Precast Components

(*Clauses* 8.7.2.1 *and* 8.7.2.8)

Sl No.	Building Category	Number of Storeys	Strengthening to be Provided in Floor/Roof with			
			Channel/ Cored Unit	R.C. Planks and Joists	Brick Panels and Joists	Waffle Units
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	B	1 to 3 4	a a, c	a a, c	a a, d	a a
ii)	C	1 and 2 3 and 4	a, b a, b, c	a a, c	a a, d	a a, e
iii)	D	1 - 4	a, b c	a, c	a, d	a, c, e
iv)	E	1 - 3	a, b, c	a, c	a, d	a, c, e

NOTE

a — Tie beam as per **8.7.2.3**;

b — Reinforcing bars of precast unit and tied to tie beam reinforcement as per **8.7.2.4**;

c — Reinforced deck concrete as per **8.7.2.5**;

d — Reinforced deck concrete as per **8.7.2.6**; and

e — Reinforced bars in joint between precast waffle units tied to tie beam reinforcement as per **8.7.2.7**.

than M15 and shall be reinforced as indicated in Table 18. If depth of tie is more than 75 mm, equivalent reinforcement shall be provided with one bar of minimum diameter 8 mm at each corner. Tie beams shall be provided on all longitudinal and cross walls. Typical details of the beams are shown in Fig. 40 to Fig. 44.

NOTE — Adequate edge support say 60 mm, shall be provided to precast element on the wall so as to avert its slippage during seismic ground motion.

8.7.2.4 Top reinforcement in the channel or cored units (*see* Table 20) shall be projected out at both the ends for anchorage length and tied to tie beam reinforcement.

8.7.2.5 Structural deck concrete (*see* Table 20) of grade not leaner than M15 shall be provided over precast components or act monolithic. Wherever, deck concrete is to be provided, the top surface of the components shall be finished rough. Cement slurry with 0.5 kg of cement/m^2 of the surface area shall be applied over the components immediately before laying the deck concrete and the concrete shall be compacted using plate vibrators. The minimum thickness of deck concrete shall be 35 mm or 40 mm reinforced with 6 mm diameter bars and 150 mm apart both ways and anchored into the tie beam placed all round. The maximum size of coarse aggregate used in deck concrete shall not exceed 12 mm.

NOTE — Under conditions of economic constraints, the deck concrete itself could serve as floor finish. The concrete is laid in one operation (*see* Fig. 44) without joints.

8.7.2.6 The deck concrete normally used over the brick panel with joist floor shall be reinforced with 6 mm diameter bars spaced 150 mm apart both ways (*see* Table 20)

8.7.2.7 For floors/roofs with precast waffle units, two 16 mm diameter high strength deformed bars shall be provided as top reinforcement in the joints between waffle units, in addition to reinforcement required for taking bending moment for vertical loads. This reinforcement (*see* Table 20) shall be fixed to tie beam reinforcement.

8.7.2.8 In case of floors/roofs with precast components other than those indicated in Table 20, the buildings shall be analysed for maximum expected seismic forces and the floor/roof shall be designed to act as diaphragm and take care of the resulting forces.

8.8 Timber Construction

8.8.1 Timber has higher strength per unit weight and is, therefore, very suitable for earthquake resistant construction. Materials, design and construction in timber shall generally conform to good practice [6-4(17)].

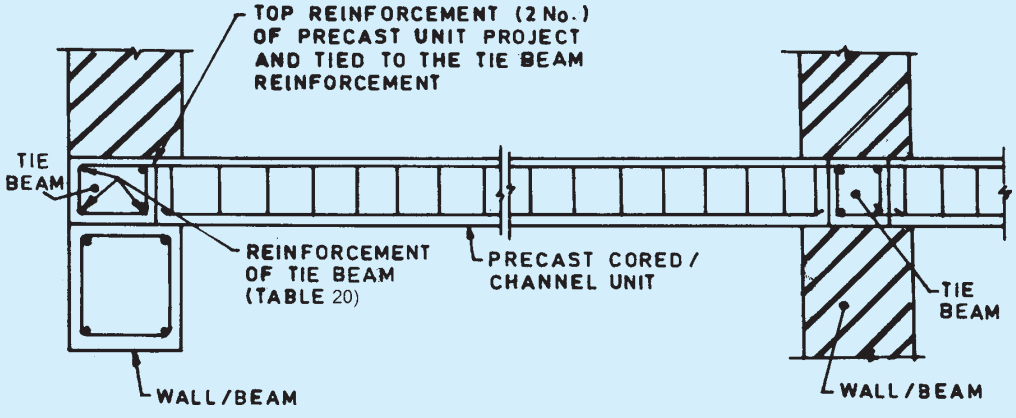
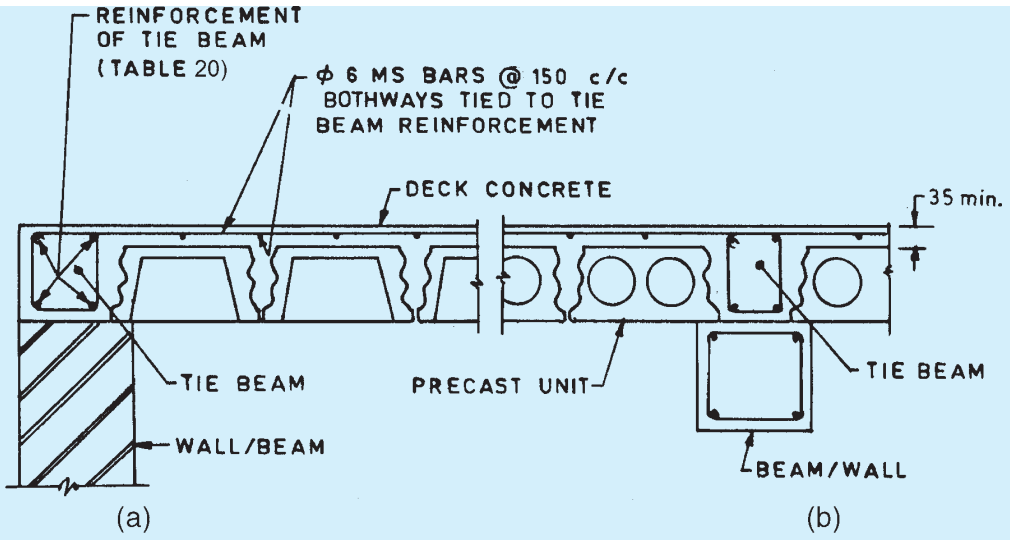


FIG. 40 CONNECTION OF PRECAST CORED/CHANNEL UNIT WITH TIE BEAM

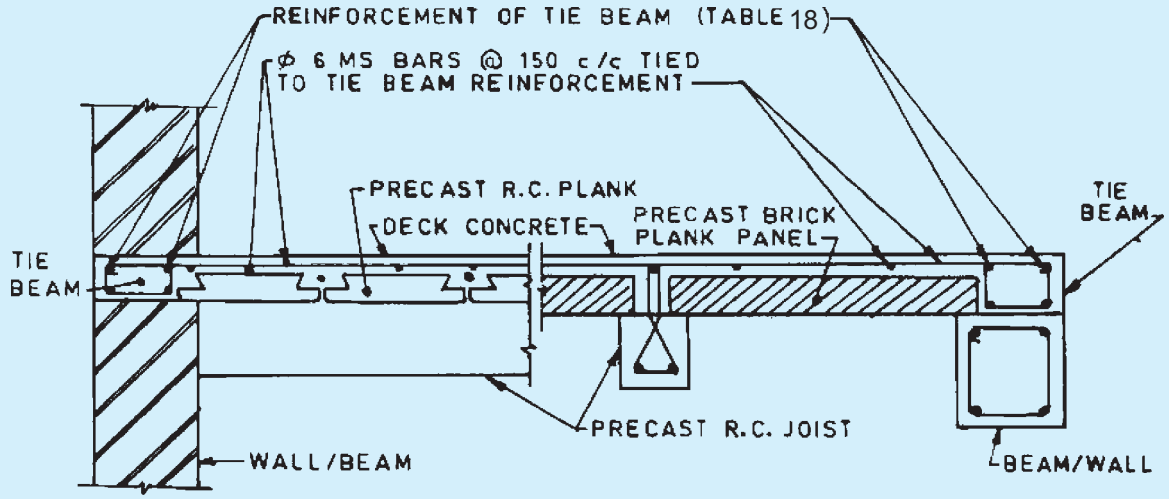
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a) CHANNEL UNIT FLOOR/ROOF.
b) CORED UNIT FLOOR/ROOF.

All dimensions in millimetres.

FIG. 41 CONNECTION OF CHANNEL/CORED UNIT FLOOR/ROOF (WITH DECK CONCRETE) WITH TIE BEAM



All dimensions in millimetres.

FIG. 42 CONNECTION OF PRECAST REINFORCED CONCRETE PLANK AND PRECAST BRICK PANEL FLOOR/ROOF (WITH DECK CONCRETE) WITH TIE BEAM

8.8.2 Timber (with masonry in-fill) construction shall generally be restricted to two storeys with or without the attic floor.

8.8.3 In timber (with masonry in-fill) construction attention shall be paid to fire safety against electric short circuiting, kitchen fire, etc.

8.8.4 The superstructure of timber buildings shall be made rigid against deformations by adopting suitable construction details at the junctions of the framing members and in wall panels as given in **8.8.6** to **8.8.10** so that the construction as a whole behaves as one unit against earthquake forces.

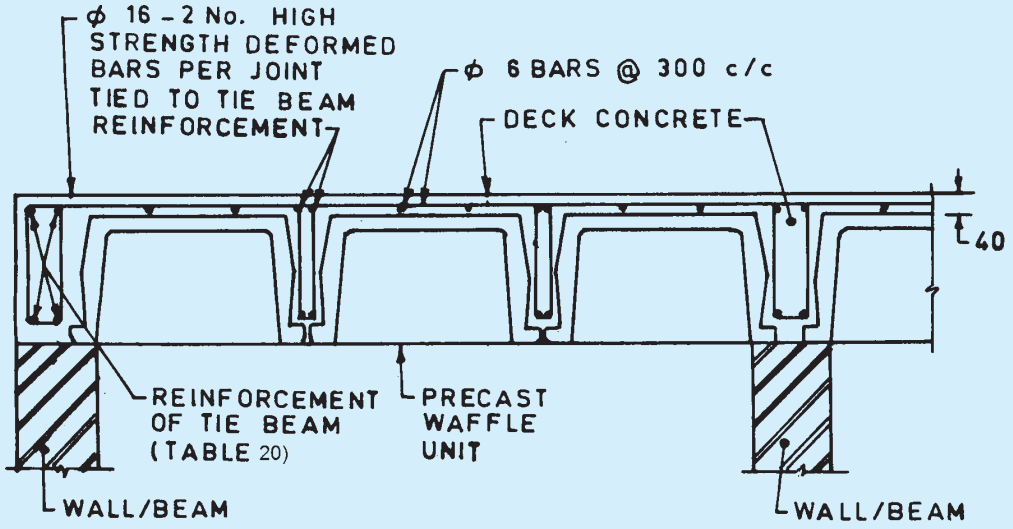
8.8.5 *Foundations*

8.8.5.1 Timber construction shall preferably start above the plinth level, the portion below shall be in masonry or concrete.

8.8.5.2 The superstructure may be connected with the foundation in one of the two ways as given below:

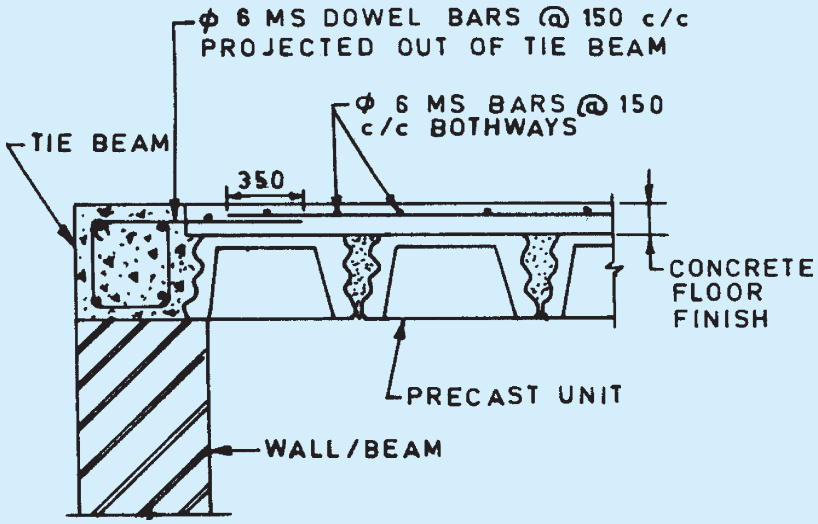
a) The superstructure may simply rest on the

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All dimensions in millimetres.

FIG. 43 CONNECTION OF PRECAST WAFFLE UNIT FLOOR/ROOF (WITH DECK CONCRETE) WITH TIE BEAM



All dimensions in millimetres.

FIG. 44 PROVISION OF REINFORCEMENT IN CONCRETE FLOOR FINISH

plinth masonry, or in the case of small buildings of one storey having plan area less than about 50 m^2, it may rest on firm plane ground so that the building is free to slide laterally during ground motion.

NOTES

1 Past experience has shown that superstructure of the buildings not fixed with the foundation escaped collapse even in a severe earthquake although they were shifted sideways.

2 Where fittings for water supply or water borne sanitation from the house are to be installed, proper attention should be given to permit movement so as to avoid fracture of damage to pipes.

b) The superstructure may be rigidly fixed into the plinth masonry or concrete foundation as given in Fig. 45 or in case of small building having plan area less than 50 m^2, it may be fixed to vertical poles embedded into the ground. In each case the building is likely to move along with its foundation. Therefore, the superstructure shall be designed to carry the resulting earthquake shears.

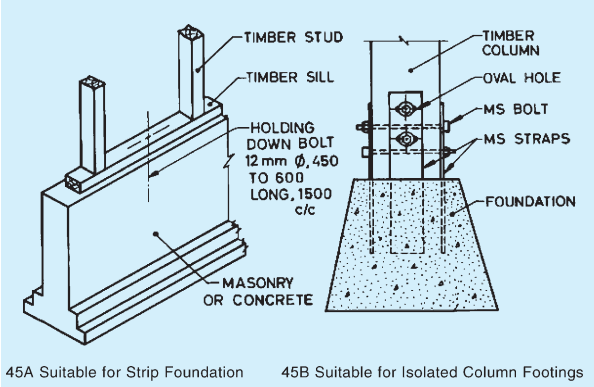
8.8.6 *Types of Framing*

The types of construction usually adopted in timber building are as follows:

a) Stud wall construction; and

b) Brick nogged timber frame construction.

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45A Suitable for Strip Foundation 45B Suitable for Isolated Column Footings

All dimensions in millimetres.

FIG. 45 DETAILS OF CONNECTION OF COLUMN WITH FOUNDATION

8.8.7 *Stud Wall Construction*

8.8.7.1 The stud wall construction consists of timber studs and corner posts framed into sills, top plates and wall plates. Horizontal struts and diagonal braces are used to stiffen the frame against lateral loads. The wall covering may consist of *EKRA*, timber or like. Typical details of stud walls are shown in Fig. 46. Minimum sizes and spacing of various members used are specified in **8.8.7.2** to **8.8.7.10**.

8.8.7.2 The timber studs for use in load bearing walls shall have a minimum finished size of 40 × 90 mm and their spacing shall not exceed those given in Table 21.

8.8.7.3 The timber studs in non-load bearing walls shall not be less than 40 × 70 mm in finished cross section. Their spacing shall not exceed 1 m.

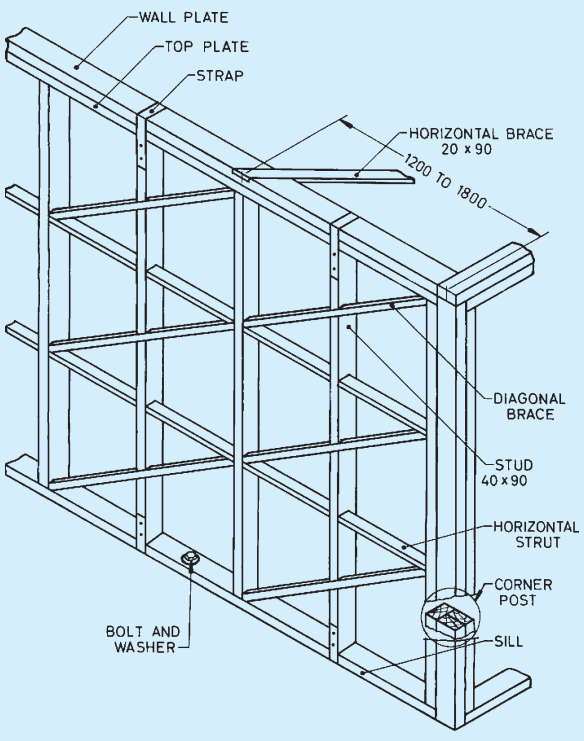
8.8.7.4 There shall be at least one diagonal brace for every 1.6 m × 1 m area of load bearing walls. Their minimum finished sizes shall be in accordance with Table 22.

8.8.7.5 The horizontal struts shall be spaced not more than 1 m apart. They shall have a minimum size of 30 × 40 mm for all locations.

8.8.7.6 The finished sizes of the sill, the wall plate and top plate shall not be less than the size of the studs used in the wall.

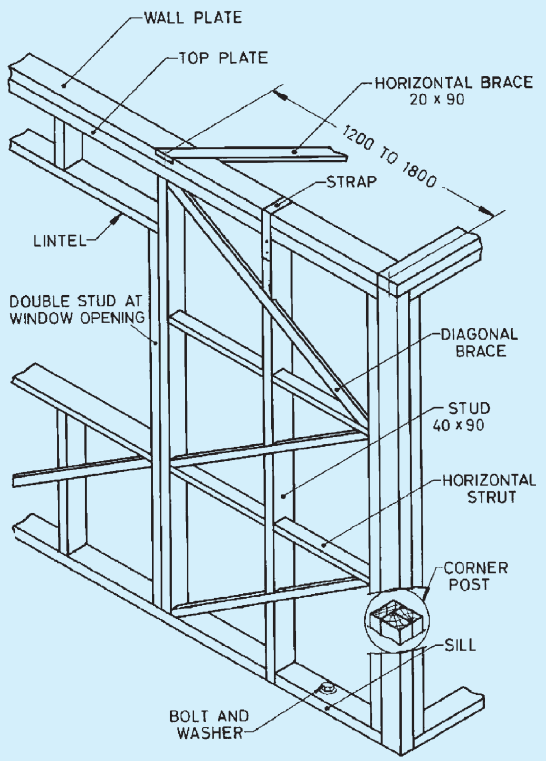
8.8.7.7 The corner posts shall consists of three timbers, two being equal in size to the studs used in the walls meeting at the corner and the third timber being of a size to fit so as to make a rectangular section (*see* Fig. 46).

8.8.7.8 The diagonal braces shall be connected at their ends with the stud wall members by means of wire nails having 6 gauge (4.88 mm diameter) and 100 mm length. Their minimum number shall be 4 nails



All dimensions in millimetres.

46A Timber Framing in Stud Wall Construction without Opening in Wall



All dimensions in millimetres.

46B Timber Framing in Stud Wall Construction with Opening in Wall

FIG. 46 STUD WALL CONSTRUCTION

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Table 21 Maximum Spacing of 40 mm × 90 mm Finished Size Studs in Stud Wall Construction

(*Clause* 8.7.2)

Sl No.	Group of Timber [Grade I[1)]]	Single Storeyed or First Floor of the Double Storeyed Buildings		Ground Floor of Double Storeyed Buildings	
		Exterior Wall	Interior Wall	Exterior Wall	Interior Wall
		mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	Group A, B	1 000	800	500	400
ii)	Group C	1 000	1 000	500	500

[1)]Grade I timbers as defined in Table 5 of good practice [6-4(17)].

Table 22 Minimum Finished Sizes of Diagonal Braces

(*Clause* 8.7.4)

Sl No.	Building Category (*see* Table 2)	Group of Timber [Grade I[1)]]	Single Storeyed or First Floor of Double Storeyed Buildings		Ground Floor of Double Storeyed Buildings	
			Exterior Wall	Interior Wall	Exterior Wall	Interior Wall
			mm × mm	mm × mm	mm × mm	mm × mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	B, C	All	20 × 40	20 × 40	20 × 40	20 × 40
ii)	D and E	Group A and Group B	20 × 40	20 × 40	20 × 40	30 × 40
		Group C	20 × 40	30 × 40	30 × 40	30 × 40

[1)] Grade I timber as defined in Table 5 of good practice [6-4(17)].

for 20 mm × 40 mm braces and 6 nails for 30 mm × 40 mm braces. The far end of nails may be clutched as far as possible.

8.8.7.9 Horizontal bracing shall be provided at corners of T-junctions of walls at sill, first floor and eaves levels. The bracing members shall have a minimum finished size of 20 mm × 90 mm and shall be connected by means of wire nails to the wall plates at a distance between 1.2 m and 1.8 m measured from the junction of the walls. There shall be a minimum number of six nails of 6 gauge (4.88 mm diameter) and 100 mm length with clutching as far ends.

8.8.7.10 Unsheathed studding shall not be used adjacent to the wall of another building. The studding shall be sheathed with close jointed 20 mm or thicker boards.

8.8.8 *Brick Nogged Timber Frame Construction*

8.8.8.1 The brick nogged timber frame consists of intermediate verticals, columns, sills, wall plates, horizontal nogging members and diagonal braces framed into each other and the space between framing members filled with tight-fitting brick masonry in stretcher bond. Typical details of brick nogged timber frame construction are shown in Fig. 47. Minimum sizes and spacing of various elements used are specified in **8.8.8.2** to **8.8.8.9**.

8.8.8.2 The vertical framing members in brick nogged load bearing walls shall have minimum finished sizes as specified in Table 22.

8.8.8.3 The minimum finished size of the vertical members in non-load bearing walls shall be 40 mm × 100 mm spaced not more than 1.5 m apart.

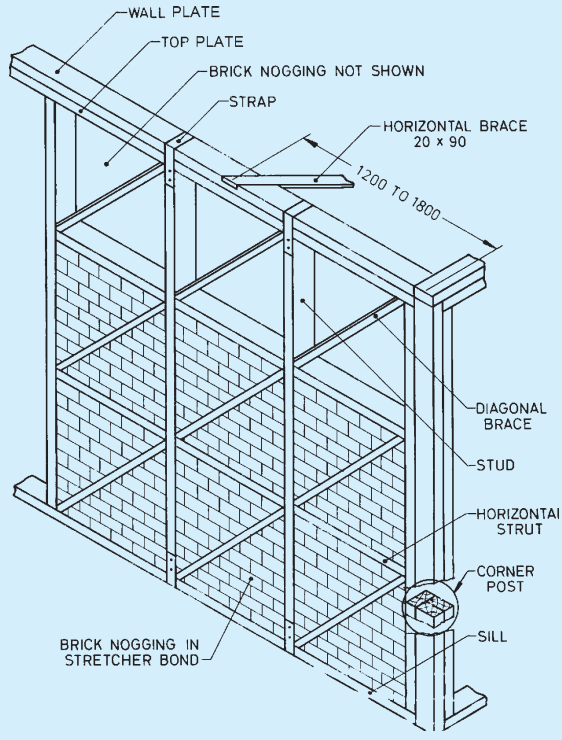
8.8.8.4 The sizes of diagonal bracing members shall be the same as in Table 22.

8.8.8.5 The horizontal framing members in brick-nogged construction shall be spaced not more than 1 m apart. Their minimum finished sizes shall be in accordance with Table 23 and Table 24.

8.8.8.6 The finished sizes of the sill, wall plate and top plate shall be not less than the size of the vertical members used in the wall.

8.8.8.7 Corner posts shall consist of three vertical timbers as described in **8.8.7.7**.

8.8.8.8 The diagonal braces shall be connected of their ends with the other members of the wall by means of wire nails as specified in **8.8.7.8**.



All dimensions in millimetres.

FIG. 47 BRICK NOGGED TIMBER FRAME CONSTRUCTION

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Table 23 Minimum Finished Sizes of Vertical in Brick Nogged Timber Frame Construction

(*Clauses* 8.8.8.5)

Sl No.	Spacing	Group of Timber [Grade I[1)]]	Single Storeyed or First Floor of Double Storeyed Buildings		Ground Floor of Double Storeyed Buildings	
			Exterior Wall	Interior Wall	Exterior Wall	Interior Wall
	m		mm × mm	mm × mm	mm × mm	mm × mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	1	Group A,B	50 × 100	50 × 100	50 × 100	50 × 100
		Group C	50 × 100	70 × 100	70 × 100	90 × 100
ii)	1.5	Group A,B	50 × 100	70 × 100	70 × 100	80 × 100
		Group C	70 × 100	80 × 100	80 × 100	100 × 100

[1)] Grade I timber as defined in Table 5 of good practice [6-4(17)].

Table 24 Minimum Finished Size of Horizontal Nogging Members

(*Clause* 8.8.8.5)

Sl No.	Spacing of Verticals	Size
	m	mm
(1)	(2)	(3)
i)	1.5	70 × 100
ii)	1	50 × 100
iii)	0.5	25 × 100

8.8.8.9 Horizontal bracing members of corners of T-junctions of wall shall be as specified in **8.8.7.9**.

8.8.9 *Notching and Cutting*

8.8.9.1 Timber framing frequently requires notching and cutting of the vertical members. The notching or cutting should in general be limited to 20 mm in depth unless steel strips are provided to strengthen the notched face of the members. Such steel strips, where necessary shall be at least 1.5 mm thick and 35 mm wide extending at least 150 mm beyond each side of the notch or cut and attached to the vertical member by means of bolts or screws at each end.

8.8.9.2 The top plate, the wall plate or the sill of a wall may be notched or cut, if reinforcing strip of iron is provided as specified in **8.8.9.1**. In case the member is notched or cut not to exceed 40 mm in depth, such reinforcing strip may be placed along the notched edge only. Where the notch or cut is more than 40 mm in depth or the member is completely cut through, such reinforcing strips shall be placed on both edges of the member. The details of notching and cutting are shown in Fig. 48.

8.8.9.3 Joints in timber shall preferably be bound by metallic fasteners.

8.8.10 *Bridging and Blocking*

8.8.10.1 All wooden joists shall have at least one row of cross bridging for every 3.5 m length of span. The cross-section of the bridging member shall be a minimum of 40 × 70 mm and the member shall be screwed or nailed to the joists.

8.8.10.2 All spaces between joists shall be blocked at all bearing with solid blocks not less than 40 mm thick and the full depth of the joists. The block shall be screwed or nailed to the joists as well as to the bearings.

8.9 *Confined Masonry Building Construction*

For the provisions relating to confined masonry building construction (*see* Annex E).

9 GUIDELINES FOR IMPROVING EARTHQUAKE RESISTANCE OF LOW STRENGTH MASONRY BUILDINGS

9.0 The term 'low strength masonry' includes fired brickwork laid in clay mud mortar and random rubble; uncoursed, undressed or semi-dressed stone masonry in weak mortars; such as cement sand, lime sand and clay mud. Special features of design and construction for improving earthquake resistance of buildings of low strength masonry are given in **9.1** to **9.6.5.7.**

9.1 For the purpose of this clause, the terminology given in **8.1** shall apply.

9.2 General Principles

The general principles given in **9.2.1** to **9.2.5** shall be observed in construction of earthquake resistant buildings.

9.2.1 *Lightness*

Since the earthquake force is a function of mass, the weight of the building shall be as minimum as possible, consistent with structural safety and functional requirements. Roofs and upper storeys of buildings, in particular, should be designed as light as possible.

9.2.2 *Continuity of Construction*

9.2.2.1 As far as possible, the parts of the building should be tied together in such a manner that the building acts as one unit.

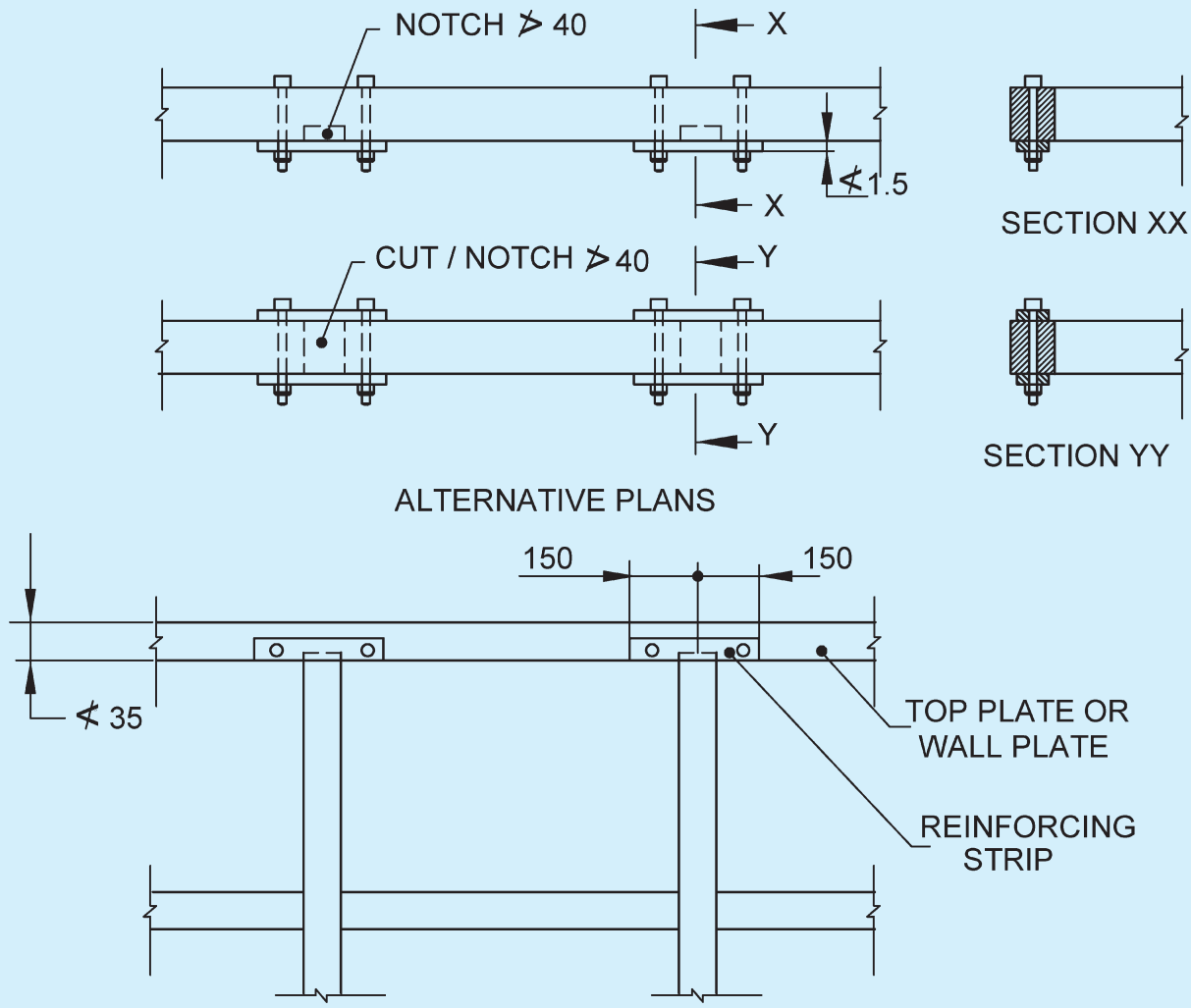
9.2.2.2 For integral action of building, roof and floor slabs should be continuous throughout as far as possible.

9.2.2.3 Additions and alterations to the structures should be accompanied by the provision of positive measures to establish continuity between the existing and the new construction.

9.2.3 *Projecting and Suspended Parts*

9.2.3.1 Projecting parts should be avoided as far as

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All dmensions in millimetres.

FIG. 48 NOTCHING AND CUTTING

possible. If the projecting parts cannot be avoided, they should be properly reinforced and firmly tied to the main structure, and their design should be in accordance with good practice [6-4(7)].

NOTE — In cases where stability of projecting parts against overturning is achieved by counterweight in the form of wall, slab, etc, the overturning should be checked by increasing the weight of projecting part and decreasing the weight of stabilizing mass simultaneously in accordance with the vertical seismic coefficient specified in **4.4.2** of good practice [6-4(7)].

9.2.3.2 Ceiling plaster shall preferably be avoided. When it is unavoidable, the plaster shall be as thin as possible.

9.2.3.3 Suspended ceiling shall be avoided as far as possible. Where provided they shall be light, adequately framed and secured.

9.2.4 *Building Configuration*

9.2.4.1 In order to minimise torsion, the building should have a simple rectangular plan and be symmetrical both with respect to mass and rigidity so that the centre of mass and rigidity of the building coincide with each other. It will be desirable to use separate blocks of rectangular shape particularly in Seismic Zone V and Seismic Zone IV.

NOTE — For small buildings, minor asymmetry in plan and elevation may be ignored. Designing such buildings against torsion may be difficult and uncertain.

9.2.5 *Fire Safety*

Fire frequently follows an earthquake and therefore, buildings shall be constructed to make them fire resistant in accordance with the provisions of Part 4 ‘Fire and Life Safety’ of the Code for fire safety, as relevant.

9.3 Special Construction Features

9.3.1 *Foundations*

9.3.1.1 For the design of foundations, the provisions of Part 6 ‘Structural Design, Section 2 Soils and Foundation’ of the Code in conjunction with **5** of Part

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6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code shall generally be followed.

9.3.1.2 The subgrade below the entire area of the building shall preferably be of the same type of the soil. Wherever this is not possible, the buildings should preferably be separated into units and then the units should be located separately.

9.3.1.3 Loose fine sand, soft silt and expansive clays should be avoided. If unavoidable, the following measures may be taken to improve the soil on which the foundation of the building may rest:

a) Sand piling/under-reamed piling/stone columns, etc; and
b) Soil stabilization.

9.3.2 *Roofs and Floors*

9.3.2.1 Flat roof or floor should not preferably be made of tiles or ordinary bricks supported on steel, timber or reinforced concrete joists, nor they shall be of a type which in the event of an earthquake is likely to be loosened and parts or all of which may fall. If this type of construction cannot be avoided, the joists should be blocked at ends and bridged at intervals such that their spacing is not altered during an earthquake.

9.3.2.1.1 For pitched roofs, corrugated iron or asbestos sheets should be used in preference to country, Allahabad or Mangalore tiles or other loose roofing units. All roofing materials shall be properly tied to the supporting members. Heavy roofing materials shall generally be avoided.

9.3.2.2 *Pent roofs*

9.3.2.2.1 All roof trusses should be supported on and fixed to timber band, reinforced concrete, or reinforced brick band. The holding down bolts should have adequate size and length as required for earthquake and wind forces.

Where a trussed roof adjoins a masonry gable, the ends of the purlins should be carried on and secured to a plate or bearer which shall be adequately bolted to reinforced concrete or reinforced brick band at the top of gable end masonry.

9.3.2.2.2 At tie level all the trusses and the gable end should be provided with diagonal braces in plan so as to transmit the lateral shear due to earthquake force to the gable walls acting as shear walls.

9.3.2.3 *Jack arches*

Jack arched roofs or floors, where used should be provided with mild steel ties in all spans along with diagonal braces in plan to ensure diaphragm actions.

9.3.3 *Staircases*

9.3.3.1 The inter-connection of the stairs with the adjacent floors should be appropriately treated by providing sliding joints at the stairs to eliminate their bracing effect on the floors. Ladders may be made fixed at one end and freely resting at the other.

9.3.3.2 *Built-in staircase*

When stairs are built monolithically with floors, they can be protected against damage by providing rigid walls at the stair opening. The walls enclosing the staircase, should extend through the entire height of the stairs and to the building foundations.

9.4 Box Type Construction

This type of construction consists of prefabricated or *in-situ* masonry walls along both the axes of the building. The walls support vertical loads and also act as shear walls for horizontal loads acting in any direction. All traditional masonry construction falls under this category. In prefabricated construction attention shall be paid to the connection between wall panels so that transfer of shear between them is ensured.

9.5 Categories of Buildings

For the purpose of specifying the earthquake resisting features in masonry and wooden buildings, the buildings have been categorized in four categories B to E based on the seismic zone and the importance of building I, where I – importance factor applicable to the building [*see* **6.4.2** and Table 6 of good practice [6-4(8)], the classification as given in **8.5** shall be applicable. The building categories are given in Table 14.

9.6 Low Strength Masonry Construction

9.6.1 Two types of construction are included herein, namely:

a) Brick construction using weak mortar, and
b) Random rubble and half-dressed stone masonry construction using different mortars such as clay mud, lime-sand and cement sand.

9.6.1.1 These constructions should not be permitted for important buildings and should preferably be avoided for building category D and shall not be used for category E (*see* Table 14).

9.6.1.2 It will be useful to provide damp-proof course at plinth level to stop the rise of pore water into the superstructure.

9.6.1.3 Precautions should be taken to keep the rain water away from soaking into the wall so that the mortar is not softened due to wetness. An effective way is to take out roof projections beyond the walls by about 500 mm.

9.6.1.4 Use of a water-proof plaster on outside face of walls will enhance the life of the building and maintain its strength at the time of earthquake as well.

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9.6.1.5 Ignoring tensile strength, free standing walls should be checked against overturning under the action of design seismic coefficient, α_h, allowing for a factor of safety of 1.5.

9.6.2 *Brickwork in Weak Mortars*

9.6.2.1 The fired bricks should have a compressive strength not less than 3.5 MPa. Strength of bricks and wall thickness should be selected for the total building height.

9.6.2.2 The mortar should be lime-sand (1:3) or clay mud of good quality. Where horizontal steel is used between courses, cement-sand mortar (1:3) should be used with thickness so as to cover the steel with 6 mm mortar above and below it. Where vertical steel is used, the surrounding brickwork of 1x1 or 1½ × 1½ brick size depending on wall thickness should preferably be built using 1:6 cement-sand mortar.

9.6.2.3 The minimum wall thickness shall be one brick in one storey construction, and one brick in top storey and 1½ brick in bottom storeys of up to three storey construction. It should also not be less than 1/16 of the length of wall between two consecutive perpendicular walls.

9.6.2.4 The height of the building shall be restricted to the following, where each storey height shall not exceed 3.0 m :

For Categories B: and C	three storeys with flat roof; and two storeys plus attic for pitched roof.
For Category D:	two storeys with flat roof; and one storey plus attic for pitched roof.

9.6.2.5 *Special bond in brick walls*

For achieving full strength of masonry, the usual bonds specified for masonry should be followed so that the vertical joints are broken properly from course to course. To obtain full bond between perpendicular walls, it is necessary to make a sloping (stepped) joint by making the corners first to a height of 600 mm and then building the wall in between them. Otherwise the toothed joint should be made in both the walls, alternatively in lifts of about 450 mm (*see* Fig. 20).

9.6.3 *Stone Masonry (Random Rubble or Half-Dressed)*

9.6.3.1 The construction of stone masonry of random rubble or dressed stone type should generally follow good practice [6-4(14)].

9.6.3.2 The mortar should be cement-sand (1:6), lime sand (1:3) or clay mud of good quality.

9.6.3.3 The wall thickness '*t*' should not be larger than 450 mm. Preferably it should be about 350 mm, and the stones on the inner and outer wythes should be interlocked with each other.

NOTE — If the two wythes are not interlocked, they tend to delaminate during ground shaking, bulge apart (*see* Fig. 49) and buckle separately under vertical load leading to complete collapse of the wall and the building.

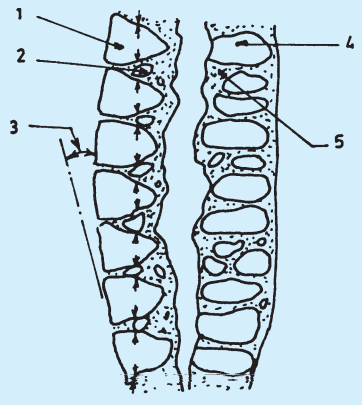
9.6.3.4 The masonry should preferably be brought to courses at not more than 600 mm lift.

9.6.3.5 'Through' stones of full length equal to wall thickness should be used in every 600 mm lift at not more than 1.2 m apart horizontally. If full length stones are not available, stones in pairs each of about ¾ of the wall thickness may be used in place of one full length stone so as to provide an overlap between them (*see* Fig. 50).

9.6.3.6 In place of 'through' stones, 'bonding elements' of steel bars 8 mm to 10 mm diameter bent to S-shape or as hooked links may be used with a cover of 25 mm from each face of the wall (*see* Fig. 50). Alternatively, wood bars of 38 mm × 38 mm cross-section or concrete bars of 50 mm × 50 mm section with an 8 mm diameter rod placed centrally may be used in place of 'through' stones. The wood should be well treated with preservative so that it is durable against weathering and insect action.

9.6.3.7 Use of 'bonding' elements of adequate length should also be made at corners and junctions of walls to break the vertical joints and provide bonding between perpendicular walls.

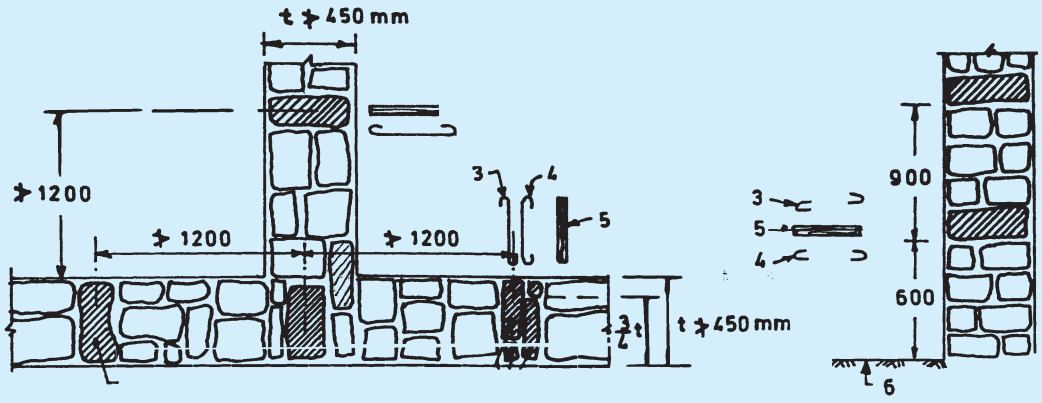
9.6.3.8 Height of the stone masonry walls (random rubble or half-dressed) should be restricted as follows, with storey height to be kept 3.0 m maximum, and span of walls between cross walls to be limited to 5.0 m:



1. HALF-DRESSED CONICAL STONE
2. SMALL ALIGNMENT
3. ROTATION OF WYTHE
4. RANDOM RUBBLE
5. MUD OR WEAK LIME MORTARY

FIG. 49 WALL DELAMINATED WITH BUCKLED WYTHES

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50A SECTIONAL PLAN OF WALL

50B CROSS-SECTION OF WALL

1. THROUGH STONE
2. PAIR OF OVERLAPPING STONE
3. S-SHAPE TIE
4. HOOKED TIE
5. WOOD PLANK
6. FLOOR LEVEL

FIG. 50 THROUGH STONE AND BAND ELEMENTS

a) *For category B* — Two storeys with flat roof or one storey plus attic, if walls are built in lime-sand or mud mortar; and one storey higher if walls are built in cement-sand 1:6 mortar.

b) *For categories C and D* — Two storeys with flat roof or two storeys plus attic for pitched roof, if walls are built in 1:6 cement mortar; and one storey with flat roof or one storey plus attic, if walls are built in lime-sand or mud mortar, respectively.

9.6.3.9 If walls longer than 5 m are needed, buttresses may be used at intermediate points not farther apart than 4.0 m. The size of the buttress be kept of uniform thickness. Top width should be equal to the thickness of main wall, *t*, and the base width equal to one sixth of wall height.

9.6.4 *Opening in Bearing Walls*

9.6.4.1 Door and window openings in walls reduce their lateral load resistance and hence should preferably, be small and more centrally located. The size and position of openings shall be as given in Table 25 and Fig. 21.

9.6.4.2 Openings in any storey shall preferably have their top at the same level so that a continuous band could be provided over them including the lintels throughout the building.

9.6.4.3 Where openings do not comply with the guidelines of Table 25, they should be strengthened by providing reinforced concrete lining as shown in Fig. 22 with 2 high strength deformed steel bars of 8 mm diameter.

9.6.4.4 The use of arches to span over the openings is a source of weakness and shall be avoided, otherwise, steel ties should be provided.

Table 25 Size and Position of Openings in Bearing Walls (*see* Fig. 21)

(*Clauses* 9.6.4.1 *and* 9.6.4.3)

Sl No.	Description	Building Category	
		B and C	*D*
(1)	(2)	(3)	(4)
i)	Distance b_5 from the inside corner of outside wall, *Min,* mm	230	600
ii)	Total length of openings, ratio; *Max* : $(b_1 + b_2 + b_3)/l_1$ or $(b_6 + b_7)/l_2$ shall not exceed:		
	a) one storeyed building	0.46	0.42
	b) 2 and 3 storeyed building	0.37	0.33
iii)	Pier width between consecutive openings, b_4, mm	450	560
iv)	Vertical distance between two openings one above the other, h_3, *Min*, mm	600	600
v)	Width of opening of ventilator, b_8, *Max*, mm	750	750

9.6.5 *Seismic Strengthening Arrangements*

9.6.5.1 All buildings to be constructed of masonry shall be strengthened by the methods as specified for various categories of buildings, listed in Table 26 and detailed in subsequent clauses. Figure 23 and Fig. 24 show, schematically, the overall strengthening arrangements to be adopted for category *D* buildings, which consist of horizontal bands of reinforcement at critical levels and vertical reinforcing bars at corners and junctions of walls.

9.6.5.2 Lintel band is a band provided at lintel level on all internal and external longitudinal as well as cross walls except partition walls. The details of the band are given in **9.6.5.5**.

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Table 26 Strengthening Arrangements Recommended for Low Strength Masonry Buildings

(*Clause* 9.6.5.1)

Sl No.	Building Category	Number of Storeys	Strengthening to be Provided
(1)	(2)	(3)	(4)
i)	B	1 and 2	b,c,f,g
		3	b,c,d,f,g
ii)	C	1	b,c,f,g
		2 and 3	b,c,d,f,g
iii)	D	1 and 2	b,c,d,f,g

where

b = Lintel band (*see* **9.6.5.2**).

c = Roof band and gable band where necessary (*see* **9.6.5.3** *and* **9.6.5.4**).

d = Vertical steel at corners and junctions of walls (*see* **9.6.5.7**).

f = Bracing in plan at tie level of pitched roofs (*see* **9.3.2.2.2**).

g = Plinth band, where necessary (*see* **9.6.5.6**).

NOTE — For building of category *B* in two storeys constructed with stone masonry in weak mortar, it will be desirable to provide vertical steel of 10 mm dia in both storeys.

9.6.5.3 Roof band is a band provided immediately below the roof or floors. The details of the band are given in **9.6.5.5**. Such a band need not be provided underneath reinforced concrete or reinforced brick slabs resting on bearing walls, provided that the slabs cover the width of end walls fully.

9.6.5.4 Gable band is a band provided at the top of gable masonry below the purlins. The details of the band are given in **9.6.5.5**. This band shall be made continuous with the roof band at the eaves level.

9.6.5.5 *Details of band*

9.6.5.5.1 *Reinforced band*

The band should be made of reinforced concrete of grade not leaner than M15 or reinforced brickwork in cement mortar not leaner than 1:3. The bands should be of full width of the wall, not less than 75 mm in depth and should be reinforced with 2 high strength deformed steel bars of 8 mm diameter and held in position by 6 mm diameter bar links, installed at 150 mm apart as shown in Fig. 25.

NOTES

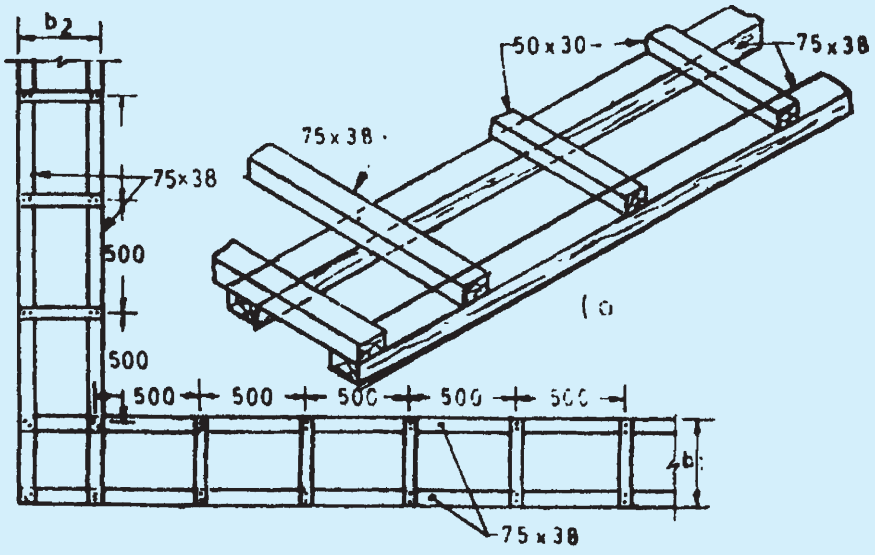
1 In coastal areas, the concrete grade shall be of grade in accordance with Part 6 'Structural Design, Section 5 Concrete' of the Code and the filling mortar of 1:3 ratio (cement-sand) with water proofing admixture.

2 In case of reinforced brickwork, the thickness of joints containing steel bars should be increased to 20 mm so as to have a minimum mortar cover of 6 mm around the bar. In bands of reinforced brickwork, the area of steel provided should be equal to that specified above for reinforced concrete bands.

3 For full integrity of walls at corners and junctions of walls and effective horizontal bending resistance of bands, continuity of reinforcement is essential. The details as shown in Fig. 25 are recommended.

9.6.5.5.2 *Wooden band*

As an alternative to reinforced band, the lintel band could be provided using wood beams in one or two parallel pieces with cross elements as shown in Fig. 51.



All dimensions in millimetres.

FIG. 51 WOODEN BAND FOR LOW-STRENGTH MASONRY BUILDINGS

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9.6.5.6 Plinth band is a band provided at plinth level of walls on top of the foundation wall. This is to be provided where strip footings of masonry (other than reinforced concrete or reinforced masonry) are used and the soil is either soft or uneven in its properties as frequently happens in hill tracts. Where used, its section may be kept same as in **9.6.5.5.1**. This band serves as damp proof course as well.

9.6.5.7 *Vertical reinforcement*

Vertical steel at corners and junctions of walls which are up to 350 mm thick should be provided as specified in Table 27. For walls thicker than 350 mm, the area of the bars should be proportionately increased.

9.6.5.7.1 The vertical reinforcement should be properly embedded in the plinth masonry of foundations and roof slab or roof band so as to develop its tensile strength in bond. It should pass through the lintel bands and floor slabs or floor level bands in all storeys. Bars in different storeys may be welded or suitably lapped.

NOTES

1 Typical details of providing vertical steel in brickwork at corners and T-junctions are shown in Fig. 26.

2 For providing vertical bar in stone masonry, use of a casing pipe is recommended around which masonry be built to height of 600 mm (*see* Fig. 52). The pipe is kept loose by rotating it during masonry construction. It is then raised and the cavity below is filled with M15 (or 1:2:4) grade of concrete mix and rodded to compact it.

Table 27 Vertical Steel Reinforcement in Low Strength Masonry Walls

(*Clause* 9.6.5.7)

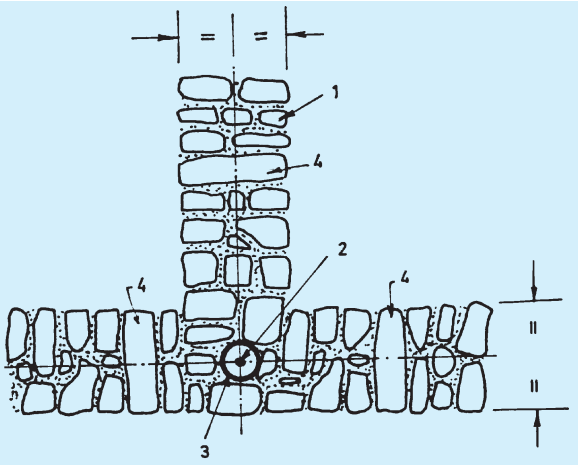
Sl No.	No. of Storeys	Storey	Diameter of HSD Single Bar; in mm, at Each Critical Section for		
			Category B	Category C	Category D
(1)	(2)	(3)	(4)	(5)	(6)
i)	One	—	Nil	Nil	10
ii)	Two	a) Top	Nil	10	10
		b) Bottom	Nil	10	12
iii)	Three	a) Top	10	10	10
		b) Middle	10	10	12
		c) Bottom	12	12	12

NOTES

1 The diameters given above are for high strength deformed bars with yield strength 415 MPa. For mild-steel plain bars, use equivalent diameters.

2 The vertical bars should be covered with concrete of M15 grade or with mortar 1:3 (cement-sand) in suitably created pockets around the bars (*see* Fig. 26 and Fig. 52). This will ensure their safety from corrosion and good bond with masonry.

3 For category *B* two storey stone masonry buildings, *see* Note under Table 25.



1. STONE WALL
2. VERTICAL STEEL BAR
3. CASING PIPE
4. THROUGH STONE OR BONDING ELEMENT

FIG. 52 TYPICAL CONSTRUCTION DETAIL FOR INSTALLING VERTICAL STEEL BAR IN RANDOM RUBBLE STONE MASONRY

10 REINFORCED MASONRY

10.1 General

This Section gives the recommendations for structural design aspect of reinforced load bearing and non-load bearing walls, constructed with solid or perforated burnt clay bricks, sand-lime bricks, stones, concrete blocks, lime based blocks or burnt clay hollow blocks in regard to the materials to be used, maximum permissible stresses and methods of design.

10.2 Terminology

For the purpose of **10**, the definitions given below shall apply.

10.2.1 *Cross-Sectional Area of Masonry Unit* — Net cross-sectional area of a masonry unit shall be taken as the gross cross-sectional area minus the area of cellular space. Gross cross-sectional area of cored units shall be determined to the outside of the coring but cross-sectional area of grooves shall not be deducted from the gross cross-sectional area to obtain the net cross-sectional area

10.2.2 *Grout* — A mixture of cement, sand and water of pourable consistency for filling small voids.

10.2.3 *Grouted Masonry*

10.2.3.1 *Grouted hollow-unit masonry* — That form of grouted masonry construction in which certain designated cells of hollow units are continuously filled with grout.

10.2.3.2 *Grouted multi-wythe masonry* — That form of grouted masonry construction in which the space

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between the wythes is solidly or periodically filled with grout.

10.2.4 *Joint Reinforcement* — A prefabricated reinforcement in the form of lattice truss which has been hot dip galvanized after fabrication and is to be laid in the mortar bed joint.

10.2.5 *Pier* — It is an isolated vertical member whose horizontal dimension measured at right angles to its thickness is not less than 4 times its thickness and whose height is less than 5 times its length.

10.2.6 *Prism* — An assemblage of masonry units bonded by mortar with or without grout used as a test specimen for determining properties of masonry.

10.2.7 *Reinforced Masonry* — Masonry which is reinforced to the minimum requirements of this Section and grouted so that the two materials act together in resisting forces.

10.2.8 *Grouted Cavity Reinforced Masonry* — Two parallel single leaf walls spaced at least 50 mm apart, effectively tied together with wall ties. The intervening cavity contains steel reinforcement and is filled with infill concrete so as to result in common action with masonry under load.

10.2.9 *Pocket Type Reinforced Masonry* — Masonry reinforced primarily to resist lateral loading where the main reinforcement is concentrated in vertical pockets formed in the tension face of the masonry and is surrounded by in situ concrete.

10.2.10 *Quetta Bond Reinforced Masonry* — Masonry at least one and half units thick in which vertical pockets containing reinforcement and mortar or concrete infill occur at intervals along its length.

10.2.11 *Specified Compressive Strength of Masonry* — Minimum Compressive strength, expressed as force per unit of net cross-section area, required of the masonry used in construction by the contract document, and upon the project design is based. Whenever the quantity f_m is under the radical sign, the square root of numerical value only is intended and the result has units of MPa.

10.2.12 *Wall Tie* — A metal fastener which connects wythes of masonry to each other or to other materials.

10.2.13 *Wythe* — A continuous vertical tie of masonry one unit in thickness.

10.3 Materials

10.3.1 *Masonry Units*

10.3.1.1 Masonry units shall be bricks, blocks or stones conforming to relevant Indian Standards. Masonry units that have been previously used shall not be reused in brickwork or block work construction, unless they have been thoroughly cleaned and conform to the code for similar new masonry units. The minimum compressive strength of masonry units used for reinforced masonry shall be 7 MPa.

10.3.1.2 The shape and dimension of masonry units, construction practices, including methods of positioning of reinforcement, placing and compacting of grout, as well as design and detailing should be such as to promote homogeneity of structural members, development of the bond of the grout to both reinforcement and masonry units and avoidance of corrosion of reinforcement.

10.3.2 *Concrete*

For reinforced masonry M20 grade of cement concrete (minimum cover 15 mm at top and bottom and 20 mm side cover) shall be used to ensure transfer of internal forces from steel reinforcement to masonry.

NOTE — In case cover is less or mortar is put in mortar bed, necessary precaution against corrosion shall be provided as per **10.5.10.2**. High strength mortars (H1 and H2) shall be used in mortar bed.

10.3.3 *Reinforcement*

Steel reinforcement of grade Fe 415 or less only shall be used (*see also* Note under **10.5.2.1**). Deformed bar shall be used.

10.3.4 *Material Properties*

10.3.4.1 *General*

Unless otherwise determined by test, the following modulus shall be used in determining the effects of elasticity.

10.3.4.2 *Elastic modulus*

For steel reinforcement, $E_s = 200$ GPa $= 2.0 \times 10^5$ MPa

For clay masonry and concrete masonry, $E_m = 550\, f_m$

or the chord modulus of elasticity taken between 0.05 and 0.33 of the maximum compressive strength of each prism determined by test in accordance with Annex B.

10.3.4.3 *Shear modulus*

For clay and concrete masonry, the shear modulus is 0.4 times the elastic modulus.

10.4 Design Considerations

10.4.1 *General*

Design considerations shall be as per **4** along with the following provisions.

10.4.2 *Structural Continuity*

Intersecting structural elements intended to act as a unit shall be joined together to resist the design forces. Walls shall be joined together to all floors, roofs or other

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elements which provide lateral support for the wall. Where floors or roofs are designed to transmit horizontal forces to walls, the anchorages to the walls shall be designed to resist the horizontal forces.

10.4.3 *Effective Span*

10.4.3.1 The effective span of simply supported/ continuous members may be taken as the smaller of the following:

a) Distance between centres of supports.
b) Clear distance between supports plus an effective depth, d.

10.4.3.2 Effective span of a cantilever shall be taken as,

a) distance between the end of cantilever and the centre of its support; and
b) distance between the end of cantilever and the face of support plus half its effective depth, whichever is greater.

10.4.4.1 *Wall*

Slenderness ratio (ratio of effective height h_{ef} to effective thickness t_{ef}) should not exceed 27 for vertically loaded reinforced masonry walls in their plane.

For reinforced masonry members such as walls subjected to out-of-plane bending and for beams as a part of wall subjected to bending in the plane of the wall, the maximum effective span to effective depth shall be as given in Table 28.

Table 28 Maximum Effective Span to Effective Depth for Walls Subjected to Out-of-Plane Bending

(*Clause* 10.4.4.1)

Sl No.	Boundary Conditions	Maximum Effective Span to Effective Depth (l_{ef}/d) or Effective Thickness Ratios (l_{ef}/t_{ef})	
		Wall Subjected to Out-of-Plane Bending	Beam Part of Wall Subjected to In-Plane Bending
(1)	(2)	(3)	(4)
i)	Simply-supported	35	20
ii)	Continuous	45	26
iii)	Spanning in two directions	45	—
iv)	Cantilevered	18	7

10.4.4.2 *Columns*

For a column, slenderness ratio shall be taken to be the greater of the ratios of effective heights to the respective effective thickness in the two principal directions. Slenderness ratio for a load bearing unreinforced column shall not exceed 15 whereas for reinforced column the slenderness ratio should be limited to 20.

10.4.5 *Minimum Design Dimensions*

10.4.5.1 *Minimum thickness of load bearing walls columns*

The nominal thickness of masonry bearing walls in building shall not be less than 230 mm.

10.4.5.2 *Parapet wall*

Parapet walls shall be at least 200 mm thick and height shall not exceed 3 times the thickness. The parapet wall shall not be thinner than the wall below.

10.4.6 *Eccentricity in Columns*

Columns shall be designed for a minimum eccentricity of 10 percent of side dimension for each axis in addition to applied loads.

10.5 Requirements Governing Reinforcement and Detailing

10.5.1 *General*

This section provides requirements for the working (allowable) stress design of masonry structure neglecting the contribution of tensile strength of masonry.

10.5.1.1 Members are designed for composite action, stresses shall be computed using transformed area concept of linear elastic analysis as follows:

$$A_t = A_b + m\,A_s$$

where

A_t = total transformed cross-sectional area of the member,
A_b = cross-sectional area of brick,
A_s = cross-sectional area of reinforcement, and
m = modular ratio of steel reinforcement and brick.

10.5.1.2 Stiffness calculation shall be based on un-cracked section properties.

10.5.2 *Steel Reinforcement-Allowable Stresses*

10.5.2.1 *Tension*

Tensile stress in reinforcement shall not exceed the following:

a) MS bars confirming to accepted standard [6-4(18)]
   1) 140 MPa for diameter ≤ 20 mm
   2) 130 MPa for diameter > 20 mm
b) HYSD bars confirming to accepted standard [6-4(19)] 230 MPa

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NOTE — For high yield strength deformed bars of Grade Fe 500 the permissible stress shall be 0.55 f_y; where f_y= characteristics strength of steel.

10.5.2.2 *Compression*

Compressive stress in reinforcement shall not exceed the following:

a) MS bars confirming to confirming to accepted standard [6-4(18)] : 130 MPa
b) HYSD bars confirming to accepted standard [6-4(19)] : 190 MPa

10.5.3 *Size of Reinforcement*

a) The maximum size of reinforcement used in masonry shall be 25 mm diameter bars and minimum size shall not be less than 8 mm.
b) The diameter of reinforcement shall not exceed one-half the least clear dimension of the cell, bond beam, or collar joint in which it is placed.

10.5.4 *Spacing of Reinforcement*

a) Clear distance between parallel bars shall not be less than the diameter of the bars, or less than 25 mm.
b) In columns and pilasters, clear distance between vertical bars shall not be less than 1.5 times the bar diameter, nor less than 35 mm.

10.5.5 *Anchorage*

10.5.5.1 *Development length of bars*

The development length L_d for deformed bars conforming to accepted standard [6-4(19)] shall be given by the following equation but shall not be less than 300 mm:

$$L_d = 0.25\, d_b F_s$$

where

d_b = nominal diameter of bar (mm), and
F_s = permissible tensile/compressive stress in steel (MPa).

10.5.5.2 For MS bars and epoxy coated bars L_d shall be increased by 60 percent.

10.5.5.3 *Standard hooks*

a) Standard hooks shall be formed by one of the following methods (*see* Fig. 53):
   1) 180° turn plus extension of at least 4 bar diameters but not less than 64 mm at free end of bar.
   2) A 90° turn plus extension of at least 10 bar diameters at free end of bar.

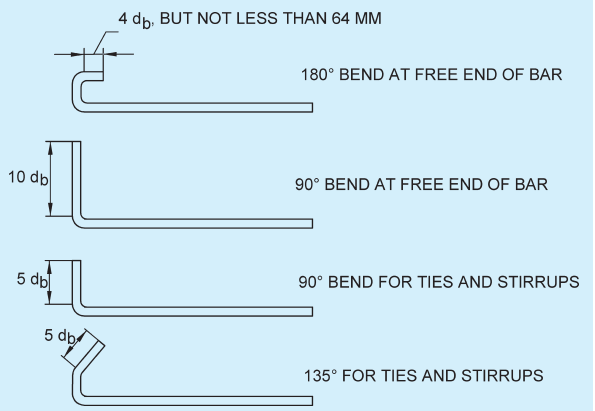


FIG. 53 STANDARD HOOK

   3) For stirrup and tie anchorage only a 90° or a 135° turn plus an extension of at least 5 bar diameters at the free end of the bar.

b) The diameter of bend, measured to the inside of the bar other than stirrups and ties, shall not be less than 5 bar diameters for 6 mm through 20 mm diameter bars. For 25 mm bars through 40 mm, a minimum bend diameter of 6 times bar diameters shall be used.
c) Inside diameter of bend for 12 mm diameter or smaller stirrups and ties shall not be less than 4 bar diameters. Inside diameter of bend for 16 mm diameter or larger stirrups and ties shall not be less than that given in (b).
d) Hooks shall not be permitted in the tension portion of any beam, except at the ends of simple or cantilever beams or at the freely supported ends of continuous or restrained beams.

10.5.5.4 *Anchorage of reinforcing bars*

a) Deformed bars may be used without end anchorages provided development length requirement is satisfied. Hooks should normally be provided for plain bars in tension.
b) Bends and hooks shall conform to accepted standard [6-4(20)] and shall be provided as follows :
   1) *Bends* — The anchorage value of bend shall be taken as 4 times the diameter of the bar for each 45° bend subject to a maximum of 16 times the diameter of the bar.
   2) *Hooks* — The anchorage value of a standard U-type hook shall be equal to 16 times the diameter of the bar.
c) For stirrups and transverse ties complete development length and anchorage shall be deemed to have been provided when the bar is provided with standard hook as described in **10.5.5.3.**

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10.5.6 *Lap Splices*

10.5.6.1 Where splices are provided in the reinforcing bars, they shall as far as possible be away from the sections of maximum stress and be staggered. It is recommended that splices in flexural members should not be at sections where the bending moment is more than 50 percent of the moment of resistance; and not more than half the bars shall be spliced at a section. Where more than one-half of the bars are spliced at a section or where splices are made at points of maximum stress, special precautions shall be taken, such as increasing the length of lap and/or using spirals or closely-spaced stirrups around the length of the splice.

10.5.6.2 Lap length including anchorage value of hooks for bars in flexural tension shall be L_d (see **10.5.5.1**) or $30d_b$, whichever is greater and for direct tension shall be $2L_d$ or $30d_b$, whichever is greater. The straight length of the lap shall not be less than $15d_b$ or 200 mm.

The following provisions shall also apply:

a) Where lap occurs for a tension bar located at:
   1) Top of a section as cast and the minimum cover is less than twice the diameter of the lapped bar, the lap length shall be increased by a factor of 1.4.
   2) Corner of a section and the minimum cover to either face is less than twice the diameter of the lapped bar or where the clear distance between adjacent laps is less than 75 mm or 6 times the diameter of lapped bar, whichever is greater, the lap length should be increased by a factor of 1.4.

b) Where both condition (1) and (2) apply, the lap length should be increased by a factor of 2.0.

NOTE — Splices in tension members shall been enclosed in spirals made of bars not less than 6 mm diameter with pitch not more than 100 mm.

10.5.7 *Curtailment of Tension Reinforcement*

In any member subjected to bending, every reinforcing bar should extend, except at end supports, beyond the point at which it is no longer needed, for a distance equal to the effective depth of the member or 12 times the diameter of the bar, whichever is the greater. The point at which reinforcement is theoretically no longer needed is where the design resistance moment of the section, considering only the continuing bars, is equal to the applied design moment. However, reinforcement should not be curtailed in a tension zone unless at least one of the following conditions is satisfied for all arrangements of design load considered:

a) Reinforcing bars extend at least the anchorage length appropriate to their design strength from the point at which they are no longer required to resist bending;

b) Design shear capacity at the section where the reinforcement stops is greater than twice the shear force due to design loads, at that section;

c) Continuing reinforcing bars at the section where the reinforcement stops provide double the area required to resist the bending moment at that section.

Where there is little or no end fixity for a member in bending, at least 25 percent of the area of the tension reinforcement required at mid-span should be carried through to the support. This reinforcement may be anchored in accordance with **10.5.5.4**, or by providing,

1) an effective anchorage length equivalent to 12 times the bar diameter beyond the centre line of the support, where no bend or hook begins before the centre of the support, or

2) an effective anchorage equivalent to 12 times the bar diameter plus $d/2$ from the face of the support, where d is the effective depth of the member, and no bend begins before $d/2$ inside the face of the support.

Where the distance from the face of a support to the nearer edges of a principal load is less than twice the effective depth, all the main reinforcement in a member subjected to bending should continue to the support and be provided with an anchorage equivalent to 20 times the bar diameter.

10.5.8 *Members Subjected to Flexure and Axial Forces*

10.5.8.1 A member which is subjected to axial stress less than $0.1 f_m$, may be designed for bending only.

10.5.8.2 *Beams*

Reinforcement in masonry designed as beam should be provided over a support where the masonry is continuous, whether the beam has been designed as continuous or not. Where this occurs, an area of steel not less than 50 percent of the area of the tension reinforcement required at mid-span should be provided in the top of the masonry over the support and anchored in accordance with **10.5.5.4**. In all cases at least one quarter of the reinforcement required at mid-span should be carried through to the support and similarly anchored.

10.5.8.3 *Columns*

Design of reinforced column shall meet the requirements of this Section.

10.5.8.3.1 Vertical reinforcement shall not be less than 0.25 percent nor exceed 4 percent of the net area of column cross-section. The minimum number of bars shall be four.

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10.5.8.3.2 *Lateral ties*

Lateral ties shall be provided in the column as per the following:

a) Longitudinal reinforcement shall be enclosed by lateral ties of at least 6 mm diameter. Vertical spacing of ties along the length of column shall be lesser of,

   1) 16 times diameter of longitudinal bar,

   2) 48 times diameter of lateral tie, and

   3) Least dimension of the column.

b) Arrangement of lateral ties is such that every corner and alternate longitudinal bar shall have lateral support provided by the corner of a lateral tie with an included angle of not more than 135°.

10.5.9 *Members Subjected to Shear*

10.5.9.1 Reinforced masonry walls may be designed taking contribution of shear reinforcement.

10.5.9.2 Where contribution of shear reinforcement is considered in resisting shear force the minimum area of shear reinforcement in the direction of force shall be determined by the following:

$$A_{v,min} = \frac{V_s}{F_s d}$$

where

V = total applied shear force,

s = spacing of the shear reinforcement,

d = distance from extreme compression fibre to centroid of tension reinforcement, and

F_s = permissible stress in steel reinforcement as defined in **10.5.2**.

10.5.9.3 The maximum spacing of shear reinforcement shall not be greater than 0.5d or 1.2 m, whichever is lesser.

10.5.9.4 In cantilever beams maximum shear shall be used whereas for members subjected to uniformly distributed load it may be assumed that maximum shear load occurs at a distance of 0.5d from the face of support when the following conditions are met:

a) Support reaction causes compression in the end region of the member, and

b) No concentrated load between face of support and a distance of 0.5d from it.

10.5.10 *Reinforcement Detailing*

10.5.10.1 *General*

Reinforcement shall be located such that it acts compositely with the masonry and various ways in which it can be used in reinforced masonry are shown in Fig. 54.

10.5.10.2 *Protection of reinforcement*

Where steel reinforcing bars are embedded in filled cavity (or pockets) or special bond construction, the bars shall have the minimum clear cover of 10 mm in mortar or a minimum clear cover 15 mm or bar diameter, whichever is more in cement concrete (grout) so as to achieve good bond and corrosion resistance.

For the reinforcement steel placed in mortar bed joint, the minimum depth of mortar cover from the reinforcing steel to the face of masonry should be 15 mm. Also mortar cover above and below reinforcement placed in bed joints should not be less than 2 mm.

Reinforcing steel shall be corrosion resistant or protected adequately against corrosion. Reinforcement shall be stainless steel or hot-dipped galvanized or epoxy coated steel reinforcement for protection against corrosion. As an alternative to solid stainless steel, normal steel reinforcing bar can be coated with at least 1mm thickness of austenitic stainless steel.

10.6 Structural Design

10.6.1 *Permissible Compressive Force*

Compressive force in reinforced masonry due to axial load shall not exceed that given by following equation:

$$P_o = (0.25 f_m A_n + 0.65 A_{st} F_s) k_s$$

where

A_n = net area,

A_{st} = area of steel,

F_s = permissible steel tensile stress, and

k_s = stress reduction factor as given in Table 10.

10.6.1.1 *Effective compressive width for locally concentrated reinforcement* (*see* Fig. 55)

When the reinforcement in masonry is concentrated locally such that it cannot be treated as a flanged member, the reinforced section shall be considered as having a width of not more than,

a) centre-to-centre bar spacing, and

b) 6 times the wall thickness.

10.6.1.2 *Combined permissible axial and flexural compressive stress*

For reinforced members subjected to combined axial load and flexure, the compressive stress in masonry due to combine action of axial load and bending shall not exceed 1.25 F_a and compressive stress in masonry due to axial load only shall not exceed F_a. *See* Annex F.

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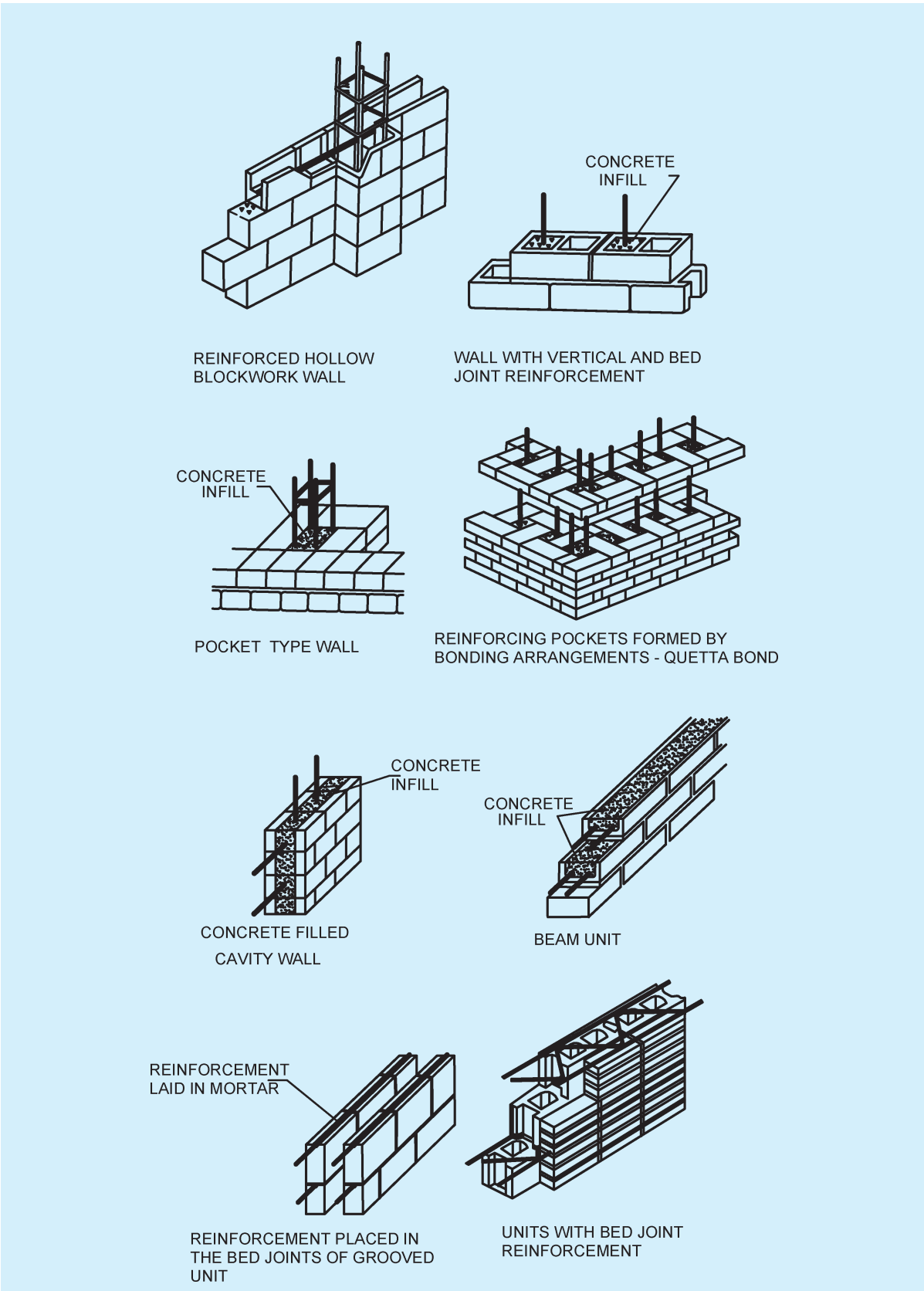


FIG. 54 REINFORCEMENT DETAILS

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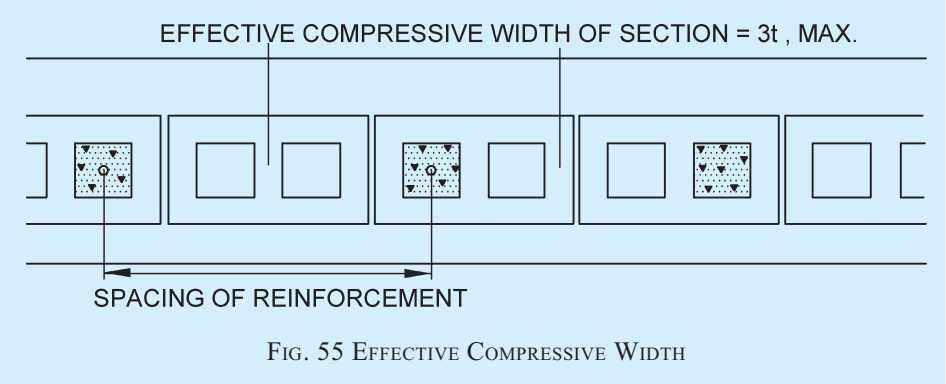


FIG. 55 EFFECTIVE COMPRESSIVE WIDTH

10.6.1.3 *Permissible tensile stress*

Provisions of **5.4.2** shall apply.

10.6.1.4 *Permissible shear stress*

For reinforced masonry members:

a) *For flexural members*

i) Without web reinforcement:

$F_v = 0.083\sqrt{f_m}$ but not greater than 0.25 MPa

ii) With web reinforcement:

$F_v = 0.25\sqrt{f_m}$ but not greater than 0.75 MPa

b) *For walls* — The allowable shear stress for reinforced masonry walls shall be according to Table 29.

Table 29 Allowable Shear Stress for Reinforced Masonry Shear Walls, F_v

[*Clause* 10.6.1.4(b)]

Sl No.	Type of Wall	M/Vd	F_v MPa	Maximum Allowable MPa
(1)	(2)	(3)	(4)	(5)
i)	Without web reinforcement	a) <1	$\frac{1}{36}\left(4-\frac{M}{Vd}\right)\sqrt{f_m}$	$\left(0.4-0.2\frac{M}{Vd}\right)$
		b) >1	$0.083\sqrt{f_m}$	0.2
ii)	With web reinforcement	<1	$\frac{1}{24}\left(4-\frac{M}{Vd}\right)\sqrt{f_m}$	$\left(0.6-0.2\frac{M}{Vd}\right)$

10.6.1.5 If there is tension in any part of a section of masonry, the area under tension shall be ignored while working out shear stress on the section.

10.7 Seismic Design Requirements

10.7.1 The requirements of this Section shall apply to the design and construction of reinforced masonry to improve its performance when subjected to earthquake loads. These provisions are in addition to general requirements of good practice [6-4(9)]. *See* Annex G.

10.7.2 *Different Performance Levels of Masonry Shear Walls*

Masonry buildings rely on masonry shear walls for the lateral load resistance and can be detailed for the following three levels of seismic performance, which can be appropriately chosen for a building considering its importance, location and acceptable degree of damage, etc. Table 30 summarizes the requirement for these shear walls and recommended *R*-values for use with good practice [6-4(9)].

Table 30 Reinforcement and *R*-Values for Different Wall Types in Various Seismic Zones

(*Clause* 10.7.2)

Sl No.	Type of Wall	Description	Reinforcement	Seismic Zone	R-Value
1)	(2)	(3)	(4)	(5)	(6)
i)	A	URM with minimum reinforcement	As per **10.7.2.1** (a) to (c)	II and III	2.5
ii)	B	RM with minimum reinforcement	As per **10.7.2.1** (a) to (c) and requirements of ordinary reinforced masonry	IV and V	3.0
iii)	C	RM with minimum reinforcement and special reinforcement	As per **10.7.2.1** (a) to (c) and requirements of special reinforced masonry	IV and V	3.0

NOTE — *R*-value is given as per provision of good practice [6-4(9)].

10.7.2.1 *Detailed Unreinforced Masonry Shear Walls (Type A wall)*

Design of detailed unreinforced masonry shear walls shall comply with requirements of unreinforced masonry wall as per **4** and **5** and shall comply with the following requirements.

a) *Minimum reinforcement requirements* (*see* Fig. 56)

Vertical reinforcement of at least 100 mm^2 in cross-

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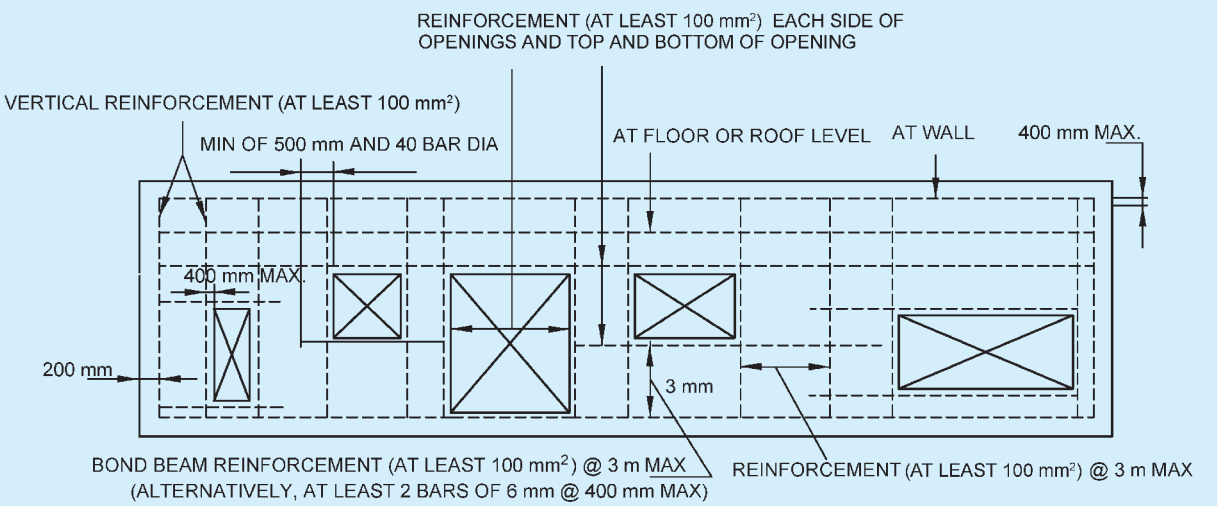


FIG. 56 PROVISION OF MINIMUM REINFORCEMENT

sectional area shall be provided at a maximum spacing of 3 m on centre at critical sections namely,

1) Corners,
2) Within 400 mm of each side of openings, and
3) Within 200 mm of the end of the walls.

b) Reinforcement around openings need not be provided for opening smaller than 400 mm in either direction.

c) Horizontal reinforcement shall consist of at least two bars of 6 mm spaced not more than 400 mm; or bond beam reinforcement shall be provided of at least 100 mm^2 in cross-sectional area spaced not more than 3 m. Horizontal reinforcement shall be provided at the bottom and top of wall openings and shall extend at least 500 mm or 40 bar diameters past the openings; continuously at structurally connected roof and floor levels and within 400 mm of the top of the walls.

10.7.2.2 *Ordinary reinforced masonry shear wall (Type B wall)*

Design of ordinary reinforced masonry shear walls shall comply with requirements of reinforced masonry wall as outlined in this document and shall comply with the requirements of section **10.7.2.1** (a) to (c).

10.7.2.3 *Special reinforced masonry shear wall (Type C wall)*

Design of special reinforced masonry shear wall shall comply with the requirement of reinforced masonry as outlined in this Section and the following.

a) The masonry shall be uniformly reinforced in both horizontal and vertical direction such that the sum of reinforcement area in both directions shall be at least 0.2 percent of the gross cross-sectional area of the wall and minimum reinforcement area in each direction shall be not less than 0.07 percent of the gross cross-sectional area of the wall.

b) Maximum spacing of horizontal and vertical reinforcement shall be lesser of,
   1) one-third length of shear wall,
   2) one-third height of shear wall, and
   3) 1.2 m.

c) Minimum cross-sectional area of reinforcement in vertical direction shall be one-third of the required shear reinforcement.

d) Shear reinforcement shall be anchored around vertical reinforcing bars with a 135° or 180° standard hook.

11 MASONRY WALLS USING RAT-TRAP BOND TECHNOLOGY

This type of masonry shall be applicable for masonry structures of not more than 2 storeys constructed in Seismic Zones II and III. For buildings in other Seismic Zones, this type of masonry wall shall be used only in non-load bearing applications such as partition walls. The provisions for this type of masonry shall be as given in Annex H.

12 NOTATIONS AND SYMBOLS

The various notations and letter symbols used in the text of the Section shall have the meaning as given in Annex J.

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ANNEX A

(*Clause* 4.7)

SOME GUIDELINES FOR ASSESSMENT OF ECCENTRICITY OF LOADING ON WALLS

A-1 Where a reinforced concrete roof and floor slab of normal span (not exceeding 30 times the thickness of wall) bear on external masonry walls, the point of application of the vertical loading shall be taken to be at the centre of the bearing on the wall. When the span is more than 30 times the thickness of wall, the point of application of the load shall be considered to be displaced from the centre of bearing towards the span of the floor to an extent of one-sixth the bearing width.

A-2 In case of a reinforced concrete slab of normal span (that is, less than 30 times the thickness of the wall), which does not bear on the full width of the wall and 'cover tiles or bricks' are provided on the external face, there is some eccentricity of load. The eccentricity may be assumed to be one-twelfth of the thickness of the wall.

A-3 Eccentricity of load from the roof/floor increases with the increase in flexibility and thus deflection of the slabs. Also, eccentricity of loading increases with the increase in fixity of slabs/beams at supports. Precast RCC slabs are better than *in-situ* slabs in this regard because of very little fixity. If supports are released before further construction on top, fixity is reduced.

A-4 Interior walls carrying continuous floors are assumed to be axially loaded except when carrying very flexible floor or roof systems. The assumption is valid also for interior walls carrying independent slabs spanning from both sides, provided the span of the floor on one side does not exceed that on the other by more than 15 percent. Where the difference is greater, the displacement of the point of application of each floor load shall be taken as one-sixth of its bearing width on the wall and the resultant eccentricity calculated therefrom.

A-5 For timber and other lightweight floors, even for full width bearing on wall, an eccentricity of about one-sixth may be assumed due to deflection. For timber floors with larger spans, that is, more than 30 times the thickness of the wall, eccentricity of one-third the thickness of the wall may be assumed.

A-6 In multi-storeyed buildings, fixity and eccentricity have normally purely local effect and are not cumulative. They just form a constant ripple on the downward increasing axial stress. If the ripple is large, it is likely to be more serious at upper levels where it can cause cracking of walls than lower down where it may or may not cause local over-stressing.

NOTE — The resultant eccentricity of the total loads on a wall at any level may be calculated on the assumption that immediately above a horizontal lateral support, the resultant eccentricity of all the vertical loads above that level is zero.

A-7 For a wall corbel to support some load, the point of application of the load shall be assumed to be at the centre of the bearing on the corbel.

ANNEX B

(*Clause* 5.4.1)

CALCULATION OF BASIC COMPRESSIVE STRESS OF MASONRY BY PRISM TEST

B-1 DETERMINATION OF COMPRESSIVE STRENGTH OF MASONRY BY PRISM TEST

When compressive strength of masonry (f_m) is to be established by tests, it shall be done in advance of the construction, using prisms built of similar materials under the same conditions with the same bonding arrangement as for the structure. In building the prisms, moisture content of the units at the time of laying, the consistency of the mortar, the thickness of mortar joints and workmanship shall be the same as will be used in the structure. Assembled specimen shall be at least 400 mm high and shall have a height to thickness ratio (h/t) of at least 2 but not more than 5. If the h/t ratio of the prisms tested is less than 5 in case of brickwork and more than 2 in case of blockwork, compressive strength values indicated by the tests shall be corrected by multiplying with the factor indicated in Table 31.

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Table 31 Correction Factors for Different *h*/*t* Ratios

(*Clause* B-1)

Ratio of Height to Thickness (*h/t*)	2.0	2.5	3.0	3.5	4.0	5.0
Correction Factors for Brickwork[1)]	0.73	0.80	0.86	0.91	0.95	1.00
Correction Factors for Blockwork[1)]	1.00	—	1.20	—	1.30	1.37

[1)] Interpolation is valid for intermediate values.

Prisms shall be tested after 28 days between sheets of nominal 4 mm plywood, slightly longer than the bed area of the prism, in a testing machine, the upper platform of which is spherically seated. The load shall be evenly distributed over the whole top and bottom surfaces of the specimen and shall be applied at the rate of 350 kN/m to 700 kN/m. The load at failure should be recorded.

B-2 CALCULATION OF BASIC COMPRESSIVE STRESS

Basic compressive stress of masonry shall be taken to be equal to $0.25 f_m$ where f_m is the value of compressive strength of masonry as obtained from prism test.

ANNEX C

(*Clauses* 5.3.3 *and* 5.4.1.5)

GUIDELINES FOR DESIGN OF MASONRY SUBJECTED TO CONCENTRATED LOADS

C-1 EXTENT OF DISPERSAL OF CONCENTRATED LOAD

For concentric loading, maximum spread of a concentrated load on a wall may be taken to be equal to $b + 4t$ (b is width of bearing and t is thickness of wall), or stretch of wall supporting the load, or centre-to-centre distance between loads, whichever is less.

C-2 INCREASE IN PERMISSIBLE STRESS

C-2.1 When a concentrated load bears on a central strip of wall, not wider than half the thickness of the wall and is concentric, bearing stress in masonry may exceed the permissible compressive stress by 50 percent, provided the area of supporting wall is not less than three times the bearing area.

C-2.2 If the load bears on full thickness of wall and is concentric, 25 percent increase in stress may be allowed.

C-2.3 For loading on central strip wider than half the thickness of the wall but less than full thickness, increase in stress may be worked out by interpolation between values of increase in stresses as given in **C-2.1** and **C-2.2**.

C-2.4 In case concentrated load is from a lintel over an opening, an increase of 50 percent in permissible stress may be taken, provided the supporting area is not less than 3 times the bearing area.

C-3 CRITERIA OF PROVIDING BED BLOCK

C-3.1 If a concentrated load bears on one end of a wall, there is a possibility of masonry in the upper region developing tension. In such a situation, the load should be supported on an RCC bed block (of M20 Grade) capable of taking tension.

C-3.2 When any section of masonry wall is subjected to concentrated as well as uniformly distributed load and resultant stress, computed by making due allowance for increase in stress on account of concentrated load, exceeds the permissible stress in masonry, a concrete bed block (of M20 Grade) should be provided under the load in order to relieve stress in masonry. In concrete, angle of dispersion of concentrated load is taken to be 45° to the vertical.

C-3.3 In case of cantilevers and long span beams supported on masonry walls, indeterminate but very high edge stresses occur at the supports and in such cases it is necessary to relieve stress on masonry by providing concrete bed block of M20 Grade concrete. Similarly when a wall is subjected to a concentrated load from a beam which is not sensibly rigid (for example, a timber beam or an RS joist), a concrete bed block should be provided below the beam in order to avoid high edge stress in the wall because of excessive deflection of the beam.

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ANNEX D

(*Clause* 5.5.5)

GUIDELINES FOR APPROXIMATE DESIGN OF NON-LOAD BEARING WALL

D-1 PANEL WALLS

A panel wall may be designed approximately as under, depending upon its support conditions and certain assumptions:

a) When there are narrow tall windows on either side of panel, the panel spans in the vertical direction. Such a panel may be designed for a bending moment of $PH/8$, where P is the total horizontal load on the panel and H is the height between the centres of supports. Panel wall is assumed to be simply supported in the vertical direction.

b) When there are long horizontal windows between top support and the panel, the top edge of the panel is free. In this case, the panel should be considered to be supported on sides and at the bottom, and the bending moment should depend upon height to length ratio of panel and flexural strength of masonry. Approximate values of bending moments in the horizontal direction for this support condition, when ratio (μ) of flexural strength of wall in the vertical direction to that in horizontal direction is assumed to be 0.5, are given in Table 32.

Table 32 Bending Moments in Laterally Loaded Panel Walls, Free at Top Edge and Supported on Other Three Edges

[*Clause* D-1(b)]

Height of Panel, H / Length of Panel, L	0.30	0.50	0.75	1.00	1.25	1.50	1.75
Bending Moment	$\frac{P.L}{25}$	$\frac{P.L}{18}$	$\frac{P.L}{14}$	$\frac{P.L}{12}$	$\frac{P.L}{11}$	$\frac{P.L}{10.5}$	$\frac{P.L}{10}$

NOTE — For H/L ratio less than 0.30, the panel should be designed as a free-standing wall and for H/L ratio exceeding 1.75, it should be designed as a horizontally spanning member for a bending moment value of $PL/8$.

c) When either there are no window openings or windows are of 'hole-in-wall' type, the panel is considered to be simply supported on all four edges. In this case also, amount of maximum bending moment depends on height to length ratio of panel and ratio (μ) of flexural strength of masonry in vertical direction to that in the horizontal direction. Approximate values for maximum bending moment in the horizontal direction for masonry with $\mu = 0.50$, are given in Table 33.

Table 33 Bending Moments in Laterally Loaded Panel Walls Supported on All Four Edges

[*Clause* D-1(c)]

Height of Panel, H / Length of Panel, L	0.30	0.50	0.75	1.00	1.25	1.50	1.75
Bending Moment	$\frac{P.L}{72}$	$\frac{P.L}{36}$	$\frac{P.L}{24}$	$\frac{P.L}{18}$	$\frac{P.L}{15}$	$\frac{P.L}{13}$	$\frac{P.L}{12}$

NOTE — When H/L is less than 0.30, value of bending moment in the horizontal direction may be taken as nil and panel wall may be designed for a bending moment value of $PH/8$ in the vertical direction; when H/L exceeds 1.75, panel may be assumed to be spanning in the horizontal direction and designed for bending moment of $PL/8$.

D-2 CURTAIN WALLS

Curtain walls may be designed as panel walls taking into consideration the actual supporting conditions.

D-3 PARTITION WALLS

D-3.1 These are internal walls usually subjected to much smaller lateral forces. Behaviour of such wall is similar to that of panel wall and these could, therefore, be designed on similar lines. However, in view of smaller lateral loads, ordinarily these could be apportioned empirically as follows:

a) Walls with adequate lateral restraint at both ends but not at the top :
   1) The panel may be of any height, provided the length does not exceed 40 times the thickness; or
   2) The panel may be of any length, provided the height does not exceed 15 times the thickness (that is, it may be considered as a free-standing wall); or
   3) Where the length of the panel is over 40 times and less than 60 times the thickness, the height plus twice the length may not exceed 135 times the thickness;

b) Walls with adequate lateral restraint at both ends at the top :
   1) The panel may be of any height, provided the length does not exceed 40 times the thickness; or
   2) The panel may be of any length, provided the height does not exceed 30 times the thickness; or
   3) Where the length of the panel is over 40 times and less than 110 times the thickness,

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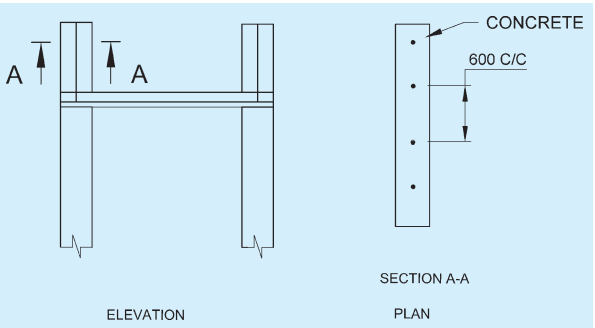
the length plus three times the height should not exceed 200 times the thickness; and

c) When walls have adequate lateral resistant at the top but not at the ends, the panel may be of any length, provided the height does not exceed 30 times the thickness.

D-3.2 Strength of bricks used in partition walls should not be less than 3.5 N/mm^2 or the strength of masonry units used in adjoining masonry, whichever is less. Grade of mortar should not be leaner than M2.

D-4 CANTILEVER PROJECTIONS

The provisions given under **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code shall be applicable. As a general guide, the details of connection between parapets and slabs for existing structures shall be as given in Fig. 57.



NOTES

1 Hole shall be made in bricks in advance to accommodate the reinforcement bars of slab.

2 Bottom bar of slab continued in the parapet at spacing of 600 mm c/c.

FIG. 57 PARAPET WALLS

ANNEX E

(*Clause* 8.9)

CONFINED MASONRY BUILDING CONSTRUCTION

E-1 UNDERSTANDING CONFINED MASONRY CONSTRUCTION

E-1.1 Confined masonry construction is a building technology that offers an alternative to 'minimally reinforced masonry' with 'RC bands and vertical Bars' and the 'RC frame construction'. It consists of masonry walls (made either of clay brick or concrete block units) and horizontal and vertical RC 'confining members' built on all four sides of the masonry wall panels. Vertical members are called 'tie columns' or 'practical columns' 'practical columns' and though they resemble columns in RC frame construction but are of much smaller cross-section. Horizontal elements, called 'tie beams', resemble beams in RC frame construction, but of much smaller section. It shall be understood that the confining elements are not beams and columns the way these are used in RC frames but rather in the nature of horizontal and vertical ties or bands for resisting tensile stresses and may better be termed as such.

The structural components of a building using confined masonry walls are as follows (*see* Fig. 58):

a) *Masonry walls,* are load bearing elements, and transmit the gravity loading from the slab(s) and walls above down to the foundation. The walls also work as bracing panels acting along with the confining tie elements which resist the horizontal earthquake forces.

b) *Confining elements,* horizontal and vertical tie elements provide the necessary tensile strength and ductility to the masonry wall panels and protect them from disintegration in the specified major earthquakes.

c) *Floor and roof slabs,* transmit both vertical gravity and lateral loads to the confined masonry walls. In an earthquake the slabs behave like rigid horizontal diaphragms.

d) *Plinth band or tie beam*, shall transmit the vertical and horizontal loads from the walls down to the foundation. It also protects the ground floor walls from settlement in soft soil conditions.

e) *Foundation,* transmits the loads from the structure to the ground.

The masonry wall construction shall follow all detailed specifications given in this Section except those to be modified as per this annex.

Confined masonry walls can be constructed using different types of masonry units, such as hollow clay tiles, burnt clay bricks, concrete blocks of hollow or solid types or dressed rectangularized stones. In confined masonry, the reinforcement is concentrated in vertical and horizontal confining elements whereas

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the masonry walls are usually free of reinforcement, but may be connected with the confining elements using steel dowels.

E-1.2 Difference Between Confined Masonry and RC Frame Construction

The appearance of finished confined masonry construction and a RC frame construction with masonry infills may look alike but in load carrying scheme they are very different. The main differences are related to the construction sequence, as well as to the manner in which these structures resist gravity and lateral loads (*see* Fig. 59). Whereas in RC Frames, the RC columns and beams carry the vertical gravity as well as the lateral loads from earthquakes or wind storms unaided by the masonry infills, in the case of confined masonry buildings, the wall panels are the main load carrying elements (both vertical and horizontal) aided by the confining elements for resisting tensile forces.

E-2 GUIDE TO EARTHQUAKE-RESISTANT CONFINED MASONRY CONSTRUCTION

The satisfactory earthquake performance of confined masonry is due to the joint action of masonry walls and the reinforced concrete confining elements. Properly designed and built confined masonry buildings are expected to exhibit good performance even in maximum considered earthquake (MCE) wherein, moderate cracking in the elements is not ruled out, but collapse of building will be highly improbable. Depending on the crushing strength of the building unit, confined masonry buildings may be constructed up to five storeys in height for various building categories as suggested below:

a) Categories B and C : Up to 5 storeys
b) Categories D and E : Up to 4 storeys

E-2.1 Building Configuration

The architectural configuration concepts as highlighted in **8.2.4** are necessary in confined masonry construction also.

E-2.2 Confining Elements

The tie-beams should be placed at plinth and every floor level. Vertical spacing of tie-beams should not exceed 3 m. The tie columns should be placed at a maximum spacing of 4 m in 200 mm or thicker walls and 3 m in 100-114 mm thick walls, as well as at the following locations:

a) At the corners of rooms and all wall-to-wall intersections,
b) At the free end of a wall, and
c) At the jambs of doors/windows of 900 mm or wider openings.

E-2.3 Walls

The wall thickness may be kept 100 or 114 mm in the case of one to two storey high residential buildings. But for all important {*see* **6.4.2** of good practice [6-4(9)]} buildings and those of more than two storeys height, the thickness should be 200 or 230 mm, and the mortar shall be as per **8.1.2**. At least two fully confined panels should be provided in each direction of the building. The earthquake performance of a confined masonry building depends on the shear resistance of masonry walls. Therefore, it is essential to provide an adequate number of walls in each direction. The walls should be placed preferably at the periphery so as to minimise torsion of the building in an earthquake.

E-2.4 Wall Density

Wall density can be defined as the total cross-sectional areas of all confined wall panels in one direction divided by the sum of the floor plan areas of all floors in a building. Wall density of at least 2 percent in each of two orthogonal directions is required to ensure good earthquake performance of confined masonry building in Seismic Zone III of India. For the aim of achieving adequate earthquake performance in the higher seismic zones, the wall density of 3 percent in Seismic Zone IV and 4.5 percent in Seismic Zone V should at least be used.

E-3 CONSTRUCTION DETAILS OF CONFINED MASONRY

E-3.1 Construction of Walls

The aim should be to use good quality building materials, that is, the build units and the mortar; as well as good quality workmanship as follows:

a) Minimum wall thickness is 100 or 114 mm. Wall panel height to thickness ratio should not exceed 30.
b) Toothed edges should be left on each side of the wall; the tooth projection may be kept ≤ 40 mm to achieve full concrete filling in the teeth space. Use of horizontal dowels instead or in addition to teething could be made at the wall-to-column interface.
c) Concrete is to be poured in the tie columns upon completion of desirable wall height (*see* Fig. 59B). Bricks shall be wetted before casting of concrete.
d) Formwork support shall be provided on two sides of the wall (*see* Fig. 60). The concrete needs to be vibrated to fill the teeth space thoroughly.

E-3.2 Tie-Columns

a) The minimum tie column cross-sectional

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dimensions are 100 mm × 100 mm or 114 mm × 114 mm in 100 or 114 mm thick walls, respectively and 150 × 200 or 150 × 230 in 200 or 230 mm thick walls at intermediate points but of square section of 200 or 230 mm side at the corners.

b) Reinforcement for the ground storey tie columns should be assembled before the foundation construction takes place (*see* Fig. 61).

c) The reinforcement in tie columns at the corners should consist of four high strength deformed bars (HSD/TOR) for longitudinal reinforcement, and 6 mm ties at 100 mm spacing in the end 500 mm height at top and bottom of column and 200 mm apart in the remaining height. Vertical bars should be lapped by a minimum of 50 times the longitudinal bar diameter. The longitudinal bar may be positioned as follows:

1) Categories B and C : 8 mm diameter up to four storeys and 10 mm diameter in 5 storeyed building
2) Categories D and E : 10 mm diameter up to 3 storeys and 12 mm diameter in 4 storeyed building

d) The tie columns at jambs of windows / doors may be 100 mm thickness of wall in size and have only two longitudinal bars each of same dia as in corner columns with 6 mm link ties spaced as in the corner columns.

E-3.3 Tie-Beams

a) The minimum tie beam cross-sectional dimensions are 100 mm × 100 mm in 100 mm thick walls; 150 mm × 200 mm in 200 mm thick walls and 150 mm × 230 mm in 230 mm thick walls.

b) Tie beams are constructed on top of the walls at each floor level.

c) The tie beam reinforcement should consist of four high strength deformed bars (HSD/TOR) for longitudinal reinforcement, and 6 mm stirrups at 200 mm spacing. The tie beam reinforcement needs to be continuous, with longitudinal reinforcement bars lapped by at least 50 times the bar diameter. The following bar diameter may be adopted:

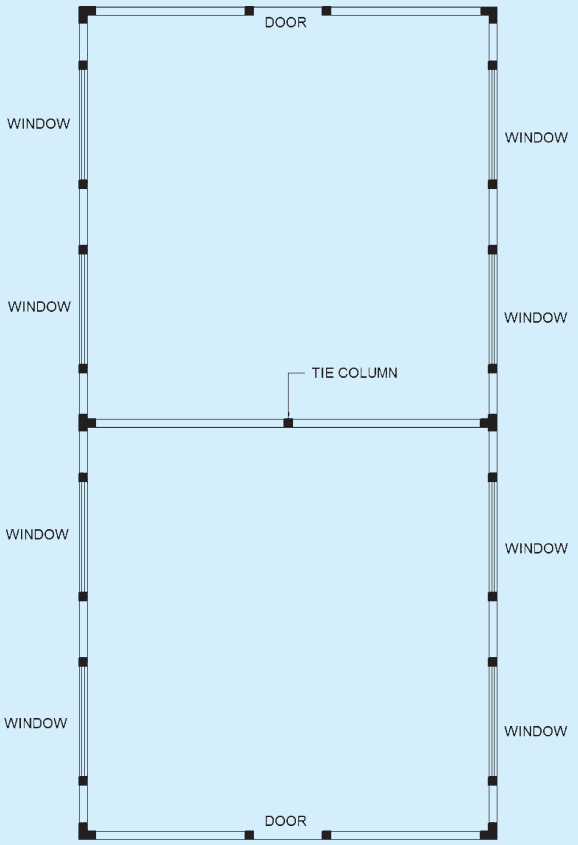
1) Building Categories B : 8 mm diameter and C
2) Building Categories D : 10 mm diameter and E

d) The lintel level bands may be provided as per **8.6.4.5**. Very wide windows may require stronger lintels.

e) Proper detailing of the tie beam and its connection to tie column is necessary for satisfactory earthquake performance (*see* Fig. 62).

E-3.4 Foundation and Plinth Construction

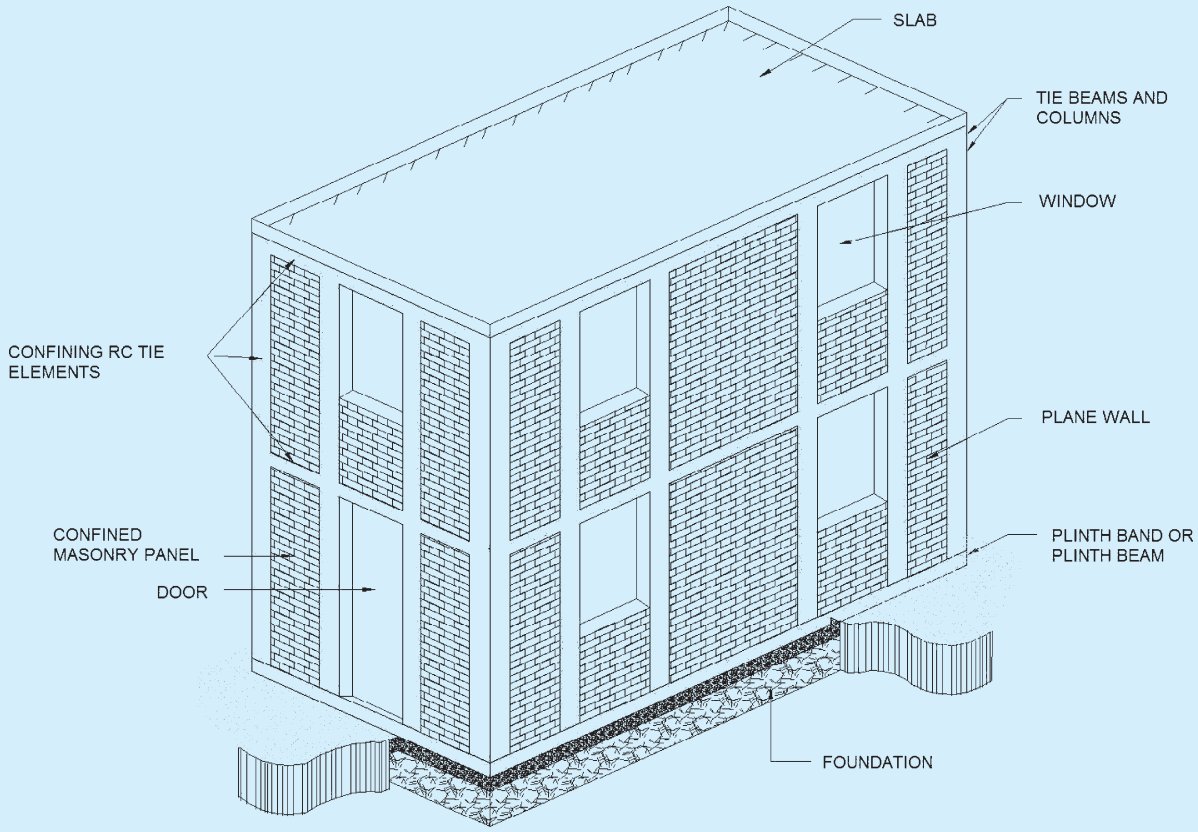
A plinth band should be constructed on top of the foundation (same as in **8.6.4.6**). Instead of the specified band in this Section, a tie beam as specified in **E-3.3** above shall be preferable for proper confinement of masonry panel above it.



58A Typical Confined Masonry Building Plan

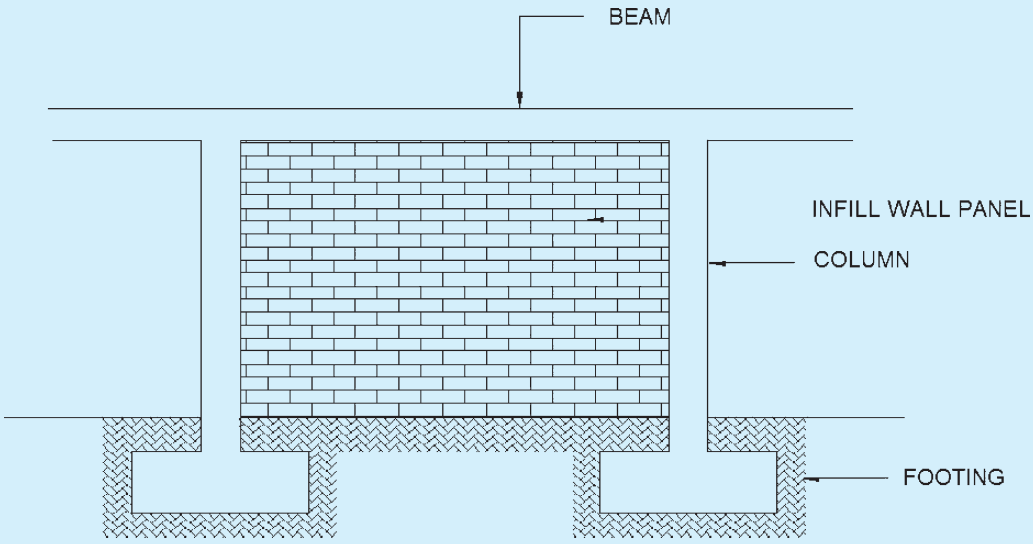
Fig. 58 Confined Masonry Building (*Continued*)

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58B TYPICAL 2-STOREY CONFINED MASONRY BUILDING

FIG. 58 CONFINED MASONRY BUILDING



59A RC FRAME CONSTRUCTION

FIG. 59 RC FRAME AND CONFINED MASONRY CONSTRUCTION (*Continued*)

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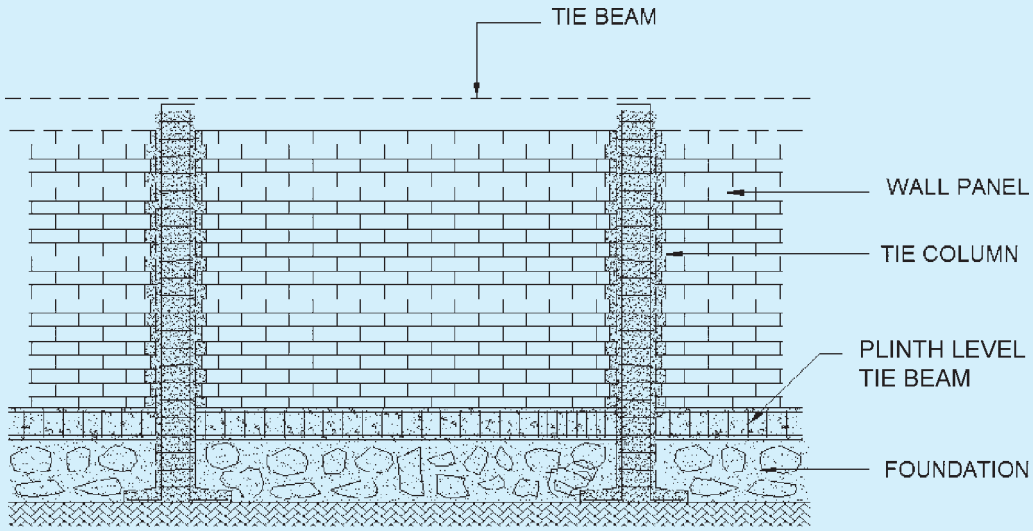


FIG. 59 RC FRAME AND CONFINED MASONRY CONSTRUCTION

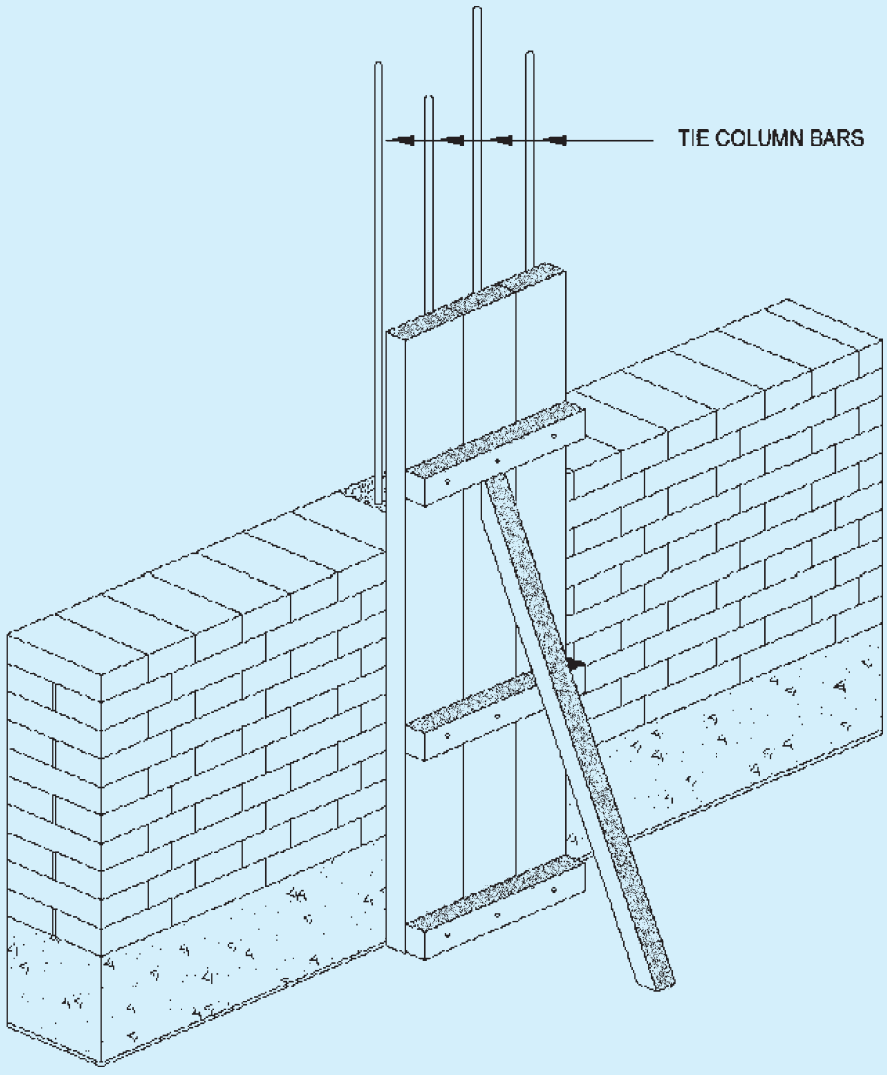
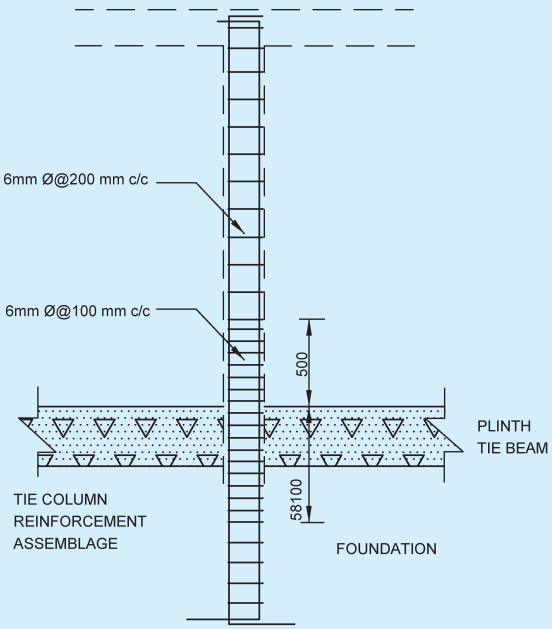
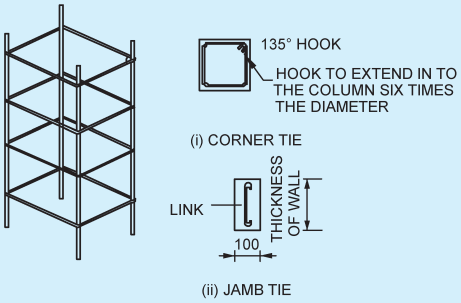


FIG. 60 FORMWORK FOR TIE COLUMNS

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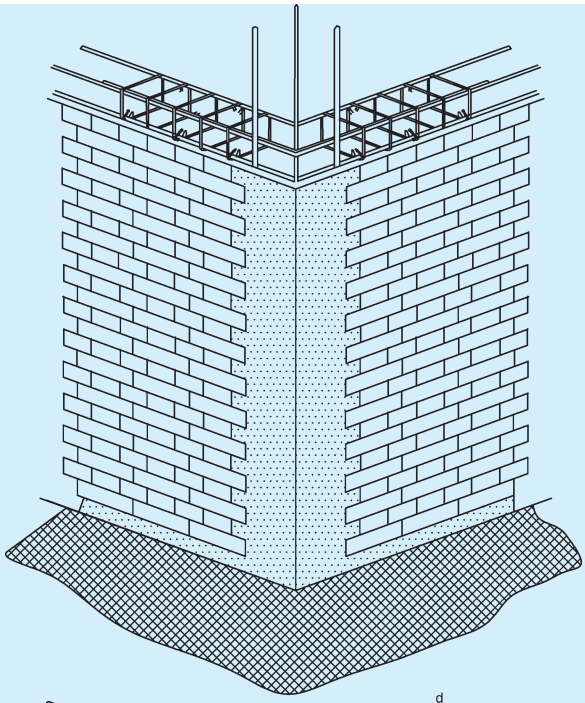


61A TIE COLUMN REINFORCEMENT SET IN POSITION PRIOR TO THE CONSTRUCTION OF FOUNDATION AND WALLS



61B TIE REINFORCEMENT DETAILS OF TIE COLUMN

FIG. 61 TIE COLUMN REINFORCEMENT



62A Sectional Elevation

62B Reinforcement Details

FIG. 62 TIE BEAM AND COLUMN

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ANNEX F

(*Clause* 10.6.1.2)

TYPICAL ITERATIVE METHOD FOR WALLS SUBJECTED TO FLEXURE AND AXIAL LOAD

F-1 There is no closed form solution available for the computation of stress in walls due to combined action of bending and axial compression. Engineers normally prefer to use design charts for computation of stresses in such conditions, but design charts for most masonry systems are not readily available. Therefore, iterative methods are used as most common tools for masonry structures. Two types of iterative procedures are given below, which can be used to analyse the adequacy of the section under specified load and determine the amount of reinforcement required, wherever necessary.

F-2 ITERATIVE PROCEDURE 1

Figure 63 shows a diagram of a wall subjected to an axial load and bending moment. The same diagram is applicable to both in-plane and out-of-plane bending of walls. There are three possible conditions for the wall:

a) Wall is uncracked,
b) Wall is cracked with the steel in compression (the extent of the crack has not reached the steel), or
c) Wall is cracked with the steel in tension.

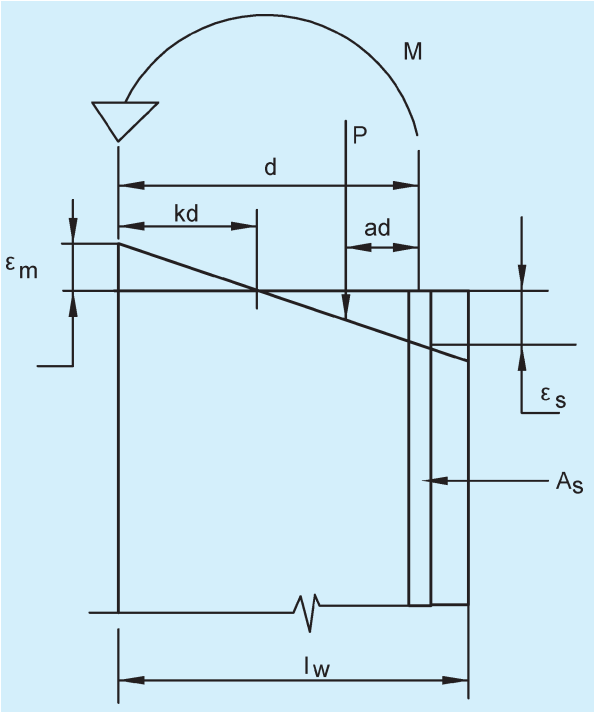


FIG. 63 FLEXURE AND AXIAL WALL LOADING

Figure 63 shows the interaction between bending moment and axial load. Loading conditions beyond the limits of the diagram are beyond the allowable stresses. The condition of the wall can be quickly diagnosed by using the non-dimensional parameter *M/Pd*. This parameter represents a straight line radiating from the diagram's origin as shown in Fig. 64. By summing moments, it can be shown that certain values of *M/Pd* divide the diagram into three regions. These values are given in Table 34. The allowable moments for Regions 1 and 2 can be obtained in closed form with simple equations. But in Region 3, it is a bit complicated. The process consists of initial assumption of thickness, length and other necessary parameters and determination of the amount of steel required.

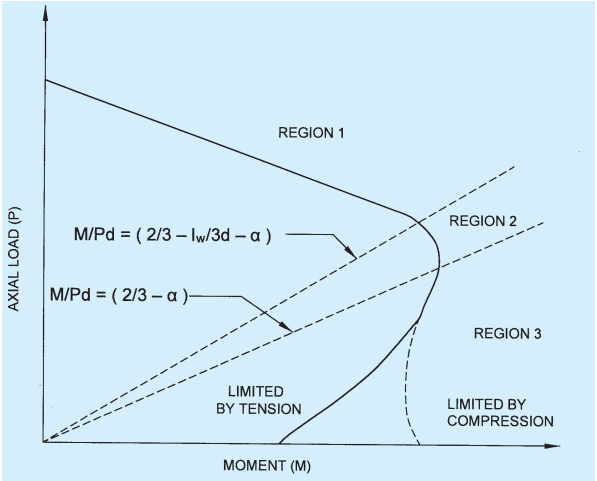


FIG. 64 INTERACTION DIAGRAM

For Region 3, the process starts with another assumption that the tension in steel controls. By making an initial guess about the location of the neutral axis, the expressions for M_p and a_2 provide an iterative process that quickly converges. The equations are derived from the summation of forces and moments and by using linear stress-strain relationships. The equations should always converge for all values of *P*, l_w, *M*, and *n*. If convergence is not obtained, it is likely that the assumed initial value of *a* has exceeded *d*. The initial value of *a* is to be reduced and same procedure is to be repeated. The iteration will often result in a negative steel area. This signifies that the element does not need reinforcement to resist the loads within the allowable stresses, even though the section is cracked (Region 3).

Following convergence, a check is made of the initial assumption that tension in steel controls. If not valid, then the compression controls and a new set of equations that do not require iteration are used.

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F-3 The following is a detailed step-by-step procedure of the analysis methodology described above:

a) Step 1:

Determine the wall condition:

1) Calculate a as the distance from the axial load to the centroid of the tension steel divided by *d*.
2) Calculate the quantity *M/Pd*.
3) Use Table 34 to determine the region for analysis (*see* Fig. 63).

Table 34 Flexure and Axial Loading - Wall Analysis

(*Clause* F-3)

Sl No. (1)	Region (2)	Condition of Wall (3)	Test (4)
i)	1	Wall is in compression and not cracked	$\frac{M}{Pd} \le \left[1 - \frac{l_w}{3d} - \alpha\right]$
ii)	2	Wall is cracked but steel is in compression	$\frac{M}{Pd} \le \left[\frac{2}{3} - \alpha\right]$
iii)	3	Wall is cracked and steel is in tension	$\frac{M}{Pd} > \left[\frac{2}{3} - \alpha\right]$

b) Step 2:

Calculate the allowable moment.

1) Region 1:

   The moment is limited by flexural compression in the masonry.

$$M_m = \frac{bl_w^2}{6} F_b - P\frac{l_w}{6}$$

   If M_m is greater than M applied, the section is satisfactory.

2) Region 2:

   The moment is also limited by flexural compression in the masonry.

$$M_m = P(1-\alpha)d - \frac{2}{3}\left[\frac{P^2}{F_b b}\right]$$

   If M_m is greater than M applied, the section is satisfactory.

3) Region 3:

   The moment may be limited by either the compression in the masonry or tension in the steel. An iterative approach as below shall be adopted.

   i) Assume a compression centroid location, *a*.

   ii) Perform the following iteration that assumes the tension in the steel controls (remember that A_s may be negative):

$$M_p = P\left(\frac{l_w}{2} - \alpha\right)$$

$$A_s = \frac{M - M_p}{F_s(d-a)}$$

$$\zeta = \frac{(P + A_s F_s)n}{F_s b}$$

$$a_2 = \frac{\sqrt{\zeta^2 + 2\zeta d} - \zeta}{3}$$

where

a = estimate of internal compression load centroid distance from the extreme compression fibre.

P = applied axial load at the centre of the wall.

M = applied moment.

A_s = area of trim or edge steel.

M_p = moment of applied axial load with respect to the centroid of internal compression force.

l_w = width of the wall for in-plane bending (thickness of wall for out of plane bending).

d = distance from the extreme compression fibre to the steel centroid.

F_s = allowable steel tension stress.

b = width of the wall for out-of-plane bending (thickness of wall for in-plane bending).

Use a_2 for a, and repeat until the value of a converges.

c) Step 3:

If the iteration converges and the resulting a is less than the following value, the wall is limited by the tension reinforcement and the analysis is complete. Otherwise continue to step 4.

$$a = \frac{d}{3\left(1 + \frac{F_s / F_b}{n}\right)}$$

d) Step 4:

If the value of a is larger than the above value, determine the required steel area using the following:

$$a = \frac{d}{2} - \sqrt{\left(\frac{d^2}{4} - \frac{2(P\alpha d + M)}{3F_b b}\right)}$$

If $\sqrt{\left(\frac{d^2}{4} - \frac{2(P\alpha d + M)}{3F_b b}\right)}$ is negative, there is inadequate compression capacity.

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Increase b or F_b or both. The steel area is:

$$A_s = \frac{\left(\frac{3F_b ab}{2} - P\right)}{\left[nF_b\left(\frac{d}{3a} - 1\right)\right]}$$

In all cases the wall trim steel should not be less than minimum values.

F-4 ITERATIVE PROCEDURE 2

The following is another procedure to determine the state of stress in wall elements subjected to combined action of bending and axial compression. Free body diagram of a wall with axial load, bending moment, and tensile and compressive forces is given in Fig. 65. The location of C is based on the neutral axis location kd. The location of T is at the centroid of the reinforcement.

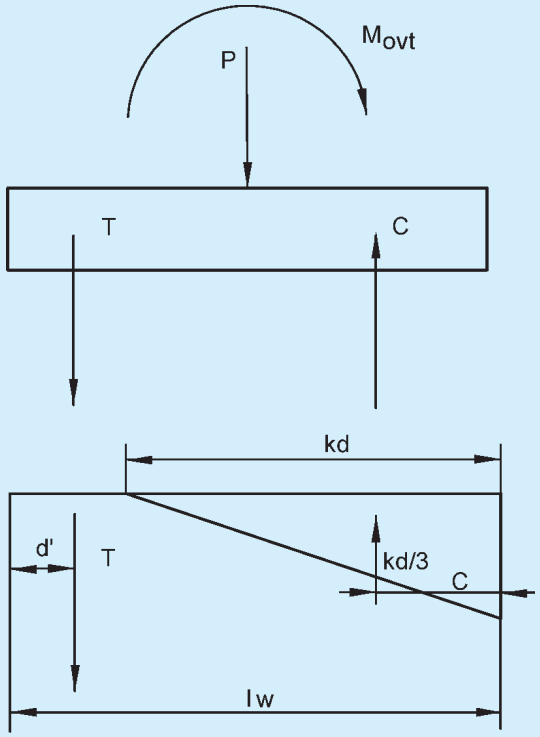


FIG. 65 FLEXURE BODY DIAGRAM OF A WALL

The problem can be solved by taking moments about the centerline of the wall, the tensile reinforcement (assuming that masonry compressive stresses control), or the compressive force (assuming that the stresses in the reinforcement control). By inserting the allowable value of stresses, which is assumed to control, a quadratic equation in terms of kd may be developed and solved.

For example, if P is at the centerline of the wall, taking moments about the centroid of the tensile reinforcement results in the equation:

$$C\left[(l_w - d') - \left(\frac{kd}{3}\right)\right] = P\left(\frac{l_w}{2} - d'\right) + M$$

but $C = ½\, F_m bkd$ and $l_w - d' = d$. Then

$$½\, F_m bkd\left(d - \frac{kd}{3}\right) = P\left(\frac{l_w}{2} - d'\right) + M$$

Dividing both side by $½\, F_m b$

$$kd^2 - \frac{(kd)^2}{3} = \frac{P\left(\frac{l_w}{2} - d'\right) + M}{½F_m b}$$

Multiplying by –3 and rearranging terms :

$$(kd)^2 - 3d(kd) + \frac{3\left[P\left(\frac{l_w}{2} - d'\right) + M\right]}{½F_m b} = 0$$

$$kd = \frac{3d - \sqrt{(-3d)^2 - 4\left(\frac{3\left[P\left(\frac{l_w}{2} - d'\right) + M\right]}{½F_m b}\right)}}{2}$$

Inserting the values for P, M, l_w, b, d and F_m yields kd. Note that this method is iterative since a location of d' shall be assumed.

Having solved for kd one can calculate C.

By $\Sigma F_v = 0$, $T = C - P$

From strain compatibility,

$f_s = \left(\frac{1-k}{k}\right) nF_m$, Thus f_s can be calculated.

If $f_s < F_s$, the masonry compressive stress controls and the solution is finished by calculating $A_s = T/f_s$. If however, $f_s > F_s$ the assumption that masonry stresses control is incorrect, and the neutral axis location is wrong.

A good starting assumption to calculate f_m is to take T assuming that masonry compressive stresses control, and to divide by F_s to get a trial A_s. This allows the designer to choose a bar layout and verify the initial assumption of d', the distance to the centroid of reinforcement.

$$A_s = T/F_s$$

Since $C = T + P$ the effects of the axial load can be included by using an effective amount of reinforcement.

$$(A_s)_{eff} = A_s + \frac{P}{F_s} \quad \left(or\ \frac{T+P}{F_s}\right)$$

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$$\rho_{eff} = \frac{(A_s)_{eff}}{bd}$$

$$k = \left[(n\rho)^2 + 2n\rho\right]^{\frac{1}{2}} - n\rho$$

$$j = 1 - \frac{k}{3}$$

The steel stress may be checked using

$$f_s = \frac{M'}{(A_s)_{eff}\, jd}$$

where

$$M' = P\left(\frac{l_w}{2} - d'\right) + M$$

$$T_{eff} = (A_s)_{eff} \times f_s$$

$$T = T_{eff} - P$$

The masonry stress may be checked by using:

$$f_m = \frac{2M'}{bjkd^2}$$

If $f_s > F_s$, a second iteration may be required may be required with a larger bar size or an extra bar. In a shear wall if an extra bar is added, the value of d', and the moments calculated using,

$$P\left(\frac{l_w}{2} - d'\right) + M$$

will need to be re-evaluated. Then one can reiterate from,

$$(A_s)_{eff} = A_s + \frac{P}{F_s}$$

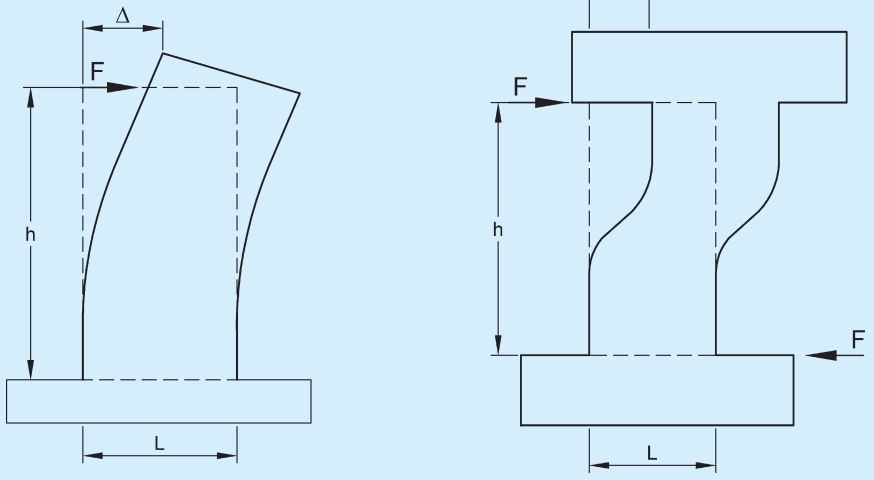
to reduce f_s so that it is less than F_s.

ANNEX G

(*Clause* 10.7.1)

DISTRIBUTION OF LATERAL FORCES IN THE PIERS OF A MASONRY WALL

G-1 Masonry walls are often seen to be perforated to make arrangement for windows and doors. The distribution of lateral force in a masonry wall is dependent on the position of the openings and the relative rigidity of the masonry piers created due to the presence of the openings in the masonry wall. The relative rigidity is dependent on the height by length ratio (h/L) of the piers and the end conditions of those masonry piers as the deflection of the masonry piers due to horizontal loading changes due to the end condition of the piers (*see* Fig. 66). Here is a simple process is described which can be used to distribute



66A CANTILEVERED WALL OR PIER (TOP FREE TO ROTATE)

66B PIER BETWEEN OPENINGS (TOP RESTRAINED FROM ROTATION)

FIG. 66 DEFLECTION DUE TO END CONDITIONS OF PIERS

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the lateral force in a wall which can be considered to be consist of some piers with some specific arrangements.

G-2 In any kind of placing of opening, the wall can be represented as a horizontal and vertical combination of piers with their respective end condition which will be used to find out their rigidities. Where large openings occur, it is difficult to obtain effective coupling of the wall segments or piers. If the wall is analysed as a horizontal combination of piers as shown in Fig. 67A and the combined rigidity

$$R = R_{c1} + R_{c2} + R_{c3}$$

where R_{c1} , R_{c2} , R_{c3} are the rigidities of the piers 1, 2, 3, respectively.

If the segments are combined vertically, as shown in Fig. 67B, the combined rigidity can be calculated as:

$$R = \frac{1}{\Delta C_1 + \Delta C_2 + \Delta C_3} = \frac{1}{\frac{1}{R_{c1}} + \frac{1}{R_{c2}} + \frac{1}{R_{c3}}}$$

Where R_{c1} , R_{c2} , R_{c3} are the rigidities of the piers 1, 2 and 3, respectively. Combination of these two types can be used to find the effective relative stiffness of a masonry wall.

The expression ignores the rotations that occur at the tops of segment 2 and 3 and therefore overestimates the rigidity of the wall. Along with this, it is valid only for the application of loads at the top level of the building.

As already said the rigidity R of the pier is dependent on its dimensions, modulus of elasticity E, modulus of rigidity G, and the support conditions. For a cantilever pier the displacement due to combined action of bending and shear is:

$$\Delta_c = \frac{Fh^3}{3EI} + \frac{1.2Fh}{GA}$$

where

F = horizontal force applied to the pier,
h = height of the pier,
I = moment of inertia of pier = $tL^3/12$,
G = modulus of rigidity = $0.4E_m$,
A = area of the pier = Lt,
L = length of the pier, and
t = thickness of pier.

So displacement of the cantilever pier is:

$$\Delta C = \frac{1}{Et}\left[4\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)\right]$$

The rigidity of a wall is proportional to the inverse of the deflection. For cantilever walls the rigidity will be:

$$R_c = \frac{1}{\Delta C} = \frac{Et}{\left[4\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)\right]}$$

$$\Rightarrow \frac{R_c}{Et} = \frac{1}{\left[4\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)\right]}$$

For a pier with both ends fixed against rotation the deflection due to combined action of bending and shear will be:

$$\Delta_f = \frac{Fh^3}{12EI} + \frac{1.2Fh}{GA} = \frac{F}{Et}\left[\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)\right]$$

$$\Rightarrow \frac{R_f}{Et} = \frac{1}{\left[\left(\frac{h}{L}\right)^3 + 3\left(\frac{h}{L}\right)\right]}$$

Values of R/Et for different h/L ratio can be taken from the chart in the Fig. 68.

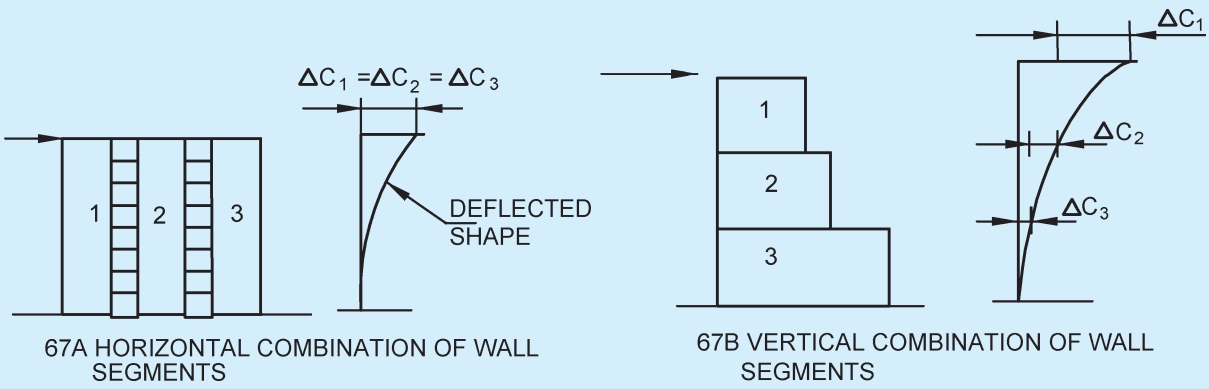


FIG. 67 WALL COMBINBATIONS FOR CALCULATING RIGIDITIES OF WALLS WITH OPENINGS

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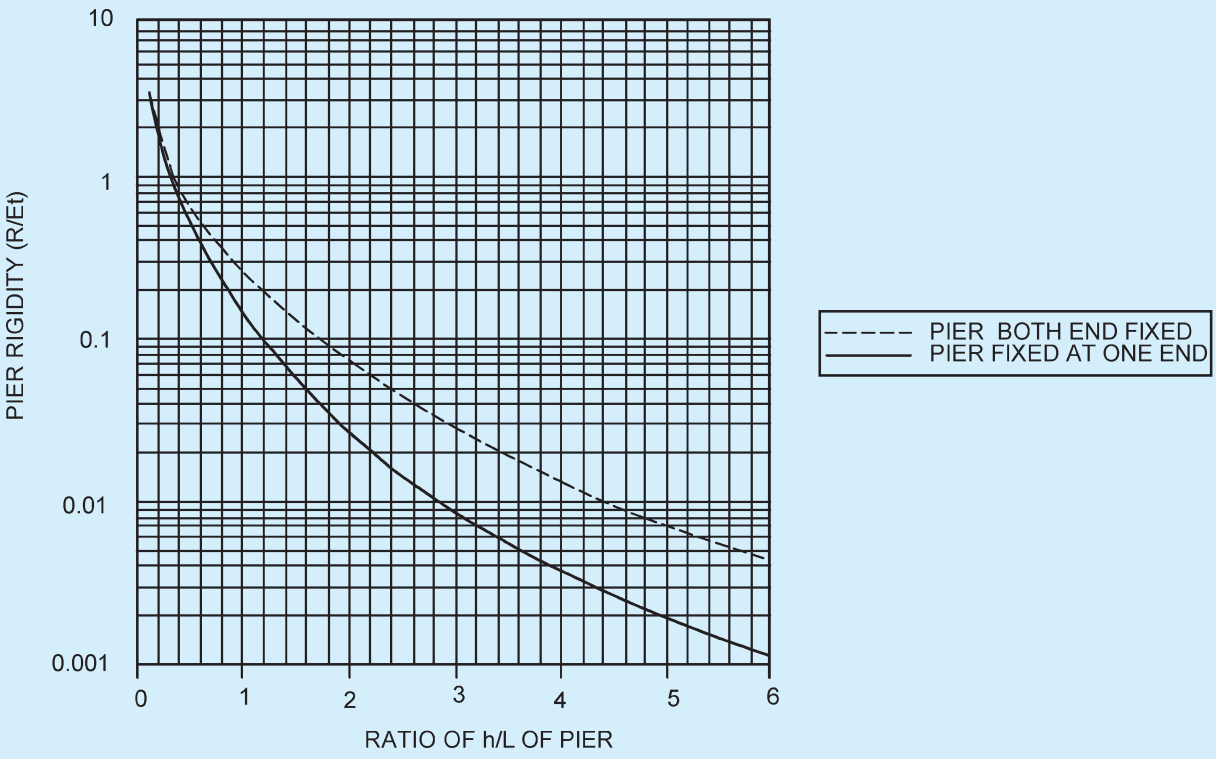


FIG. 68 CHARTS FOR CALCULATING WALL RIGIDITIES

From the relations given in equations above it is found that the relative contributions of the bending and shear deformation depend on the wall aspect ratio (*h*/*L*) and therefore, the rigidity varies over the height of the building. For high *h*/*L* ratios, the effect of shear deformation is very small and calculation of pier rigidities based on flexural stiffness is relatively accurate. For very squat walls (with *h*/*L*< 0.25), rigidities based on shear deformation are reasonably accurate, but for intermediate walls with *h*/*L* from 0.25 to 4, both components of relative rigidity should be considered.

G-3 The method is explained further explained by one illustration. For the wall as shown in Fig. 69,

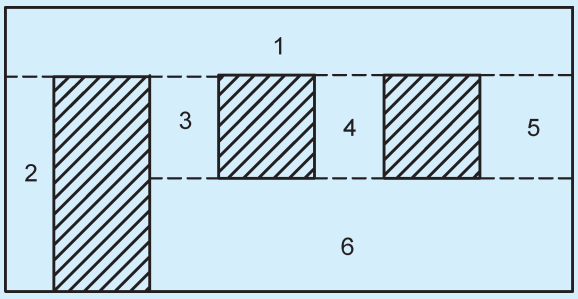


FIG. 69 WALL WITH OPENINGS (CALCULATION OF RIGIDITY AND LOAD DISTRIBUTION)

$$R_{\text{wall}} = \frac{1}{\Delta_{1c} + \Delta_{2,3,4,5,6(\text{f})}} = \frac{1}{\frac{1}{R_{1c}} + \frac{1}{R_{2,3,4,5,6(\text{f})}}}$$

(Vertical combination)

where

$R_{2,3,4,5,6(\text{f})} = R_{2(\text{f})} + R_{3,4,5,6(\text{f})}$ (Horizontal combination)

and $R_{3,4,5,6(f)} = \frac{1}{\Delta_{3,4,5(\text{f})} + \Delta_{6(\text{f})}} = \frac{1}{\frac{1}{R_{3,4,5(\text{f})}} + \frac{1}{R_{6(\text{f})}}}$

(Vertical combination)

$R_{3,4,5(\text{f})} = R_{3(\text{f})} + R_{4(\text{f})} + R_{5(\text{f})}$ (Horizontal combination)

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ANNEX H

(*Clause* 11)

MASONRY WALLS USING RAT-TRAP BOND

H-1 GENERAL

The following covers the construction of masonry walls using rat-trap bond. Only masonry with bricks (burnt clay bricks, fly ash clay bricks, fly ash lime bricks and stabilized soil blocks) is dealt herein. Use of other types of bricks/blocks and mud mortar are not specifically covered hereunder.

H-2 NECESSARY INFORMATION

H-2.1 For efficient planning, design and execution of the work, detailed information with regard to the following shall be furnished to those responsible for the work:

a) Layout plans showing the orientation of the structure;

b) Dimensioned details of the structure with details of sections (to a suitably large scale that is 1 : 20), levels of foundation, finished ground level, clear floor to floor heights of rooms, sizes of openings, etc.

c) Type and class of brickwork, types of bond and final finish for the brickwork; the mixes of mortar to be used, etc; full size details of architectural features, mouldings and other special work. Also course plans at different levels of sill and lintel to be made available for proper understanding and execution, if required.

d) Location and other details of openings, chases, embedments of service lines, such as for water supply, drainage, electrical installations, etc; and location and details of hearths, flues and chimneys in the brickwork.

H-2.2 All information as in **H-2.1** shall be made available to those who are responsible for the masonry work. Necessary drawings and instructions for planning the work shall be furnished. Arrangements shall also be made for the proper exchange of information between those engaged in masonry work and all those whose work will affect or will be affected.

NOTE — If necessary a brief training of the masons may be carried out orienting them with the technology know-how.

H-3 MATERIALS

H-3.1 Bricks

Burnt clay bricks, heavy duty bricks and bricks made out of other suitable materials like fly ash, stabilized soil block, etc, conforming to accepted standards [6-4(21)] with compressive strength greater than 6.0 MPa shall be used.

H-3.2 Mortars

Shall conform to grade H2 mortar for good practice [6-4(3)].

H-3.3 Storage of Materials

Storage of materials shall be in accordance with good practice [6-4(1)].

H-3.4 Materials for Damp-Proof Courses

Materials for damp proof courses shall be as specified in good practice [6-4(5)].

H-3.5 Materials for Flashing and Weathering

Lead flashing with sheet thickness between 1.6 and 2 mm or bitumen felts shall be in accordance with the accepted standards [6-4(22)].

H-3.6 Metal Reinforcement

Metal reinforcement for use in brick masonry shall be as per accepted standards [6-4(23].

H-4 DESIGN CONSIDERATIONS

H-4.1 Selection of Bricks

The brick shall be selected in accordance with Table 1 of good practice [6-4(4)].

When the requirements for strength of masonry predominate in the particular situation of use, the bricks shall be of such class to give the required strength for masonry and shall be selected in accordance with **4**.

H-4.2 Rat-Trap Bond Details

H-4.2.1 The rat-trap bond is laid by placing the bricks on edge forming a cavity of 80 mm (for a traditional brick size) with alternate courses of stretchers and headers (*see* Fig. 70). The headers and stretchers are

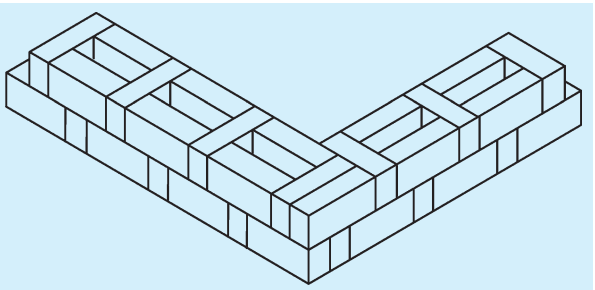


FIG. 70 ARRANGEMENT IN RAT-TRAP BOND

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staggered in subsequent layers to impart strength and stability to the walls.

The primary object of bond is to give strength to masonry, but when exposed, it also creates aesthetically pleasing view. This masonry technology is modular in nature, so the dimensions of the wall to be based on the module dimensions in multiples.

H-4.2.2 A typical module detail is shown in Fig. 71 with conventional bricks of size 230 mm × 110 mm × 75 mm. The brick adjacent to the openings has to be solid as per Fig. 72. So the opening dimensions also to be in multiple of the rat-trap bond module. This will be important as opening dimensions are predefined depending on the module dimension. In brickwork the cross joints in any course shall not be nearer than a quarter of brick length from those in the course below or above it.

H-4.3 Precautions

This type of masonry construction shall have to be carried out by trained masons to avoid wastage of mortar falling into the gap. Rat-trap bond shall never be carried out with brick which are below their minimum strength requirements.

H-4.4 Strength of Rat-Trap Bond

Because of cavities the load carrying capacity of rat-trap bond wall is expected to be less than its counterpart solid wall. Normally a load bearing rat-trap bond wall of 230 mm thick can be constructed for a ground plus one storey building. If first class bricks are used, then it can be used for two storeyed building provided cross walls are included at intervals of 3.5 m or less.

The suggested testing methodology is given at **H-7** for ensuring conformity to the observed load capacity. Typical laying of rat-trap bond is shown in Fig. 73. The bricks used are conventional bricks 230 mm × 110 mm × 75 mm. The height of each course is 110 mm

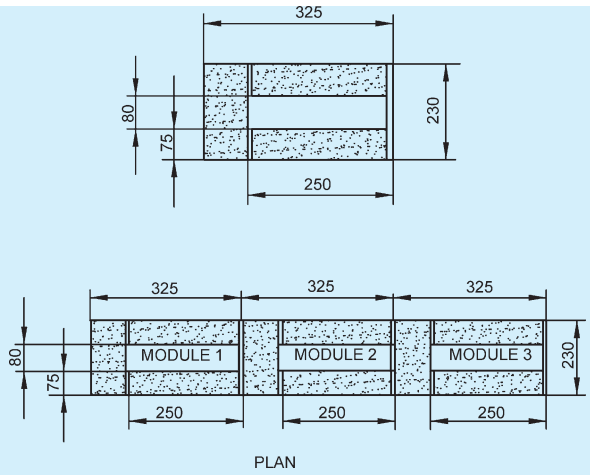


FIG. 71 TYPICAL MODULE DETAILS OF RAT-TRAP BOND

and the frog of the stretchers is kept facing each other in the cavity formed. This arrangement of bricks forms an internal air cavity of 80 mm (width) × 250 mm (length) × 110 mm (height).

H-4.5 Thickness of Joint

No bed joint shall be thicker than 12 mm. Further the thickness of the bed joints shall be such that four courses and three joints taken consecutively shall measure as follows:

a) *In the case of traditional bricks* — Four times the actual thickness of the brick plus 30 mm.

b) *In the case of modular bricks* — 390 mm conforming to the relevant accepted standards. The vertical mortar joints to be of the thickness of 10 mm and be applied directly to the brick before placing it. This requires some special skill, but defines the strength as well as the stability of the rat-trap bond wall. Besides, applying the mortar joint directly to the brick is a basic skill requirement of a mason and

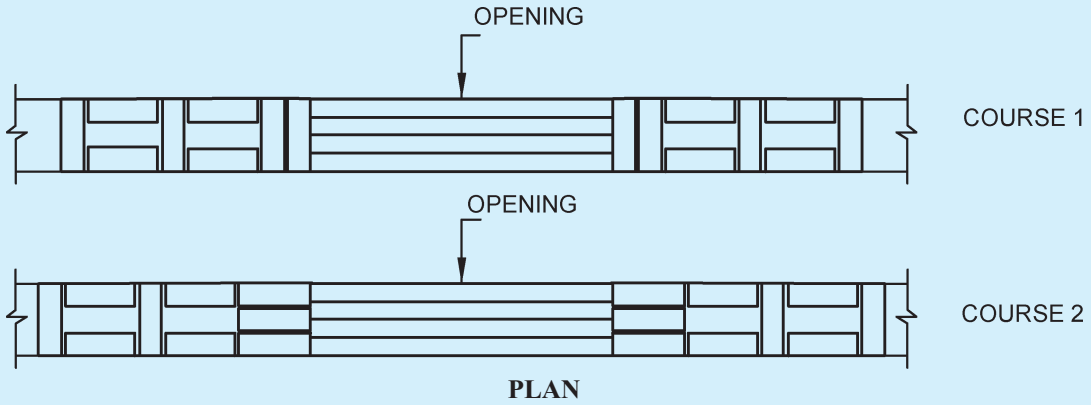


FIG. 72 OPENING IN RAT-TRAP BOND MASONRY

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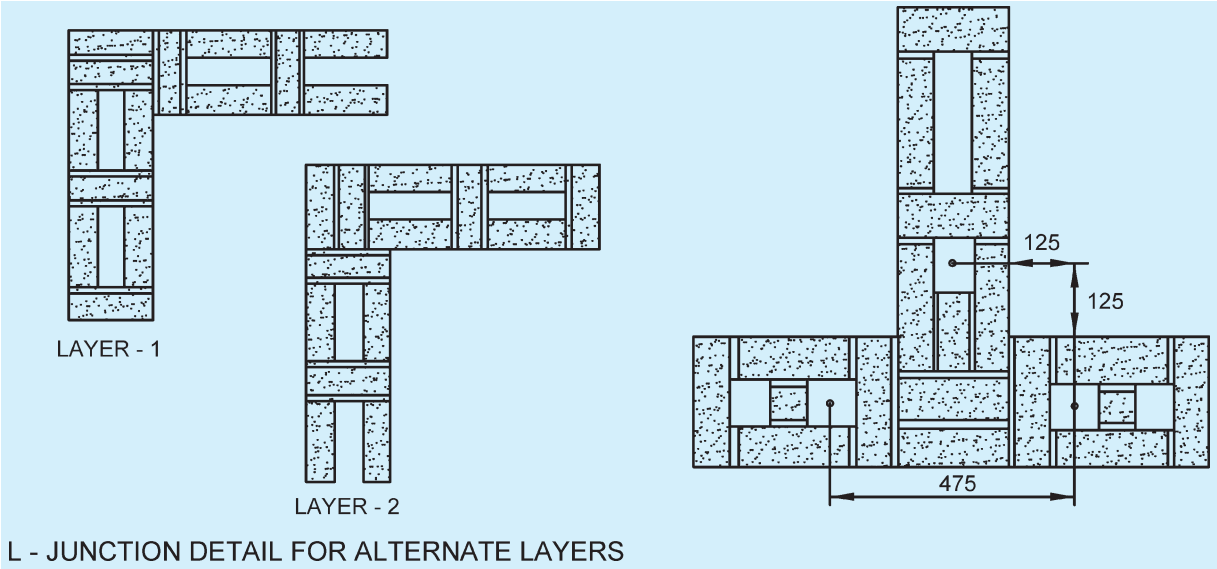


FIG. 73 TYPICAL LAYING OF RAT-TRAP BOND

determines the speed of work and finally the cost of the Rat-trap bond wall.

c) The face jolts of brickwork may be finished by 'jointing' or by 'pointing'. In case where brick size is less, the elevation of the header bricks to be made even in line with the stretcher brick by cement mortar same grade as bedding mortar. The main reasons for pointing the surface of block or brickwork joints are to increase its weather resistance and to give a neat finish to the work. Pointing can be carried out as construction of the brickwork proceeds, using ordinary mortar in which the bricks are bedded.

H-4.6 Structural and Functional Characteristics of Brickwork

H-4.6.1 *Structural Stability and Strength*

Reference may be made to Part 6 'Structural Design, Section 2 Soils and Foundation' of the Code, and **4** of this Section.

H-4.6.2 *Resistance to Moisture Penetration*

The suitability of various walls under different conditions of exposure is indicated in Table 3 of good practice [6-4(4)].

H-4.6.3 *Thermal Stresses*

The coefficient linear expansions of brick vary from 5×10^{-6}/°C to 11×10^{-6}/°C. Variations of temperature tend to produce linear changes in walls which, when restrained, may lead to internal stress resulting in cracks especially when the walls exceed 30 m. The effects of these stresses shall be taken into consideration for a proper design.

H-4.7 Control of Shrinkage Cracking

H-4.7.1 To confine cracks to the joints and to dissipate these into a large number of fine joints, it is desirable that the mortar used shall be weaker than the bricks.

H-4.7.2 Cracking due to shrinkage normally will occur at openings or other points where the vertical or horizontal section of a wall changes. A long wall with a few openings will tend to show wider cracks above and below the openings than a similar wall with many openings. Metal reinforcement may be embedded in brickwork at points where cracking is likely to occur.

H-4.8 Thermal Insulation

For requirements of thermal insulation in walls, the provisions of good practice [6-4(24)] shall apply.

H-4.9 Fire Resistance

For requirements regarding resistance to fire, the provisions of good practice [6-4(25)] shall apply.

H-4.10 Sound Insulation

Requirements for insulation against airborne sound are laid down in good practice [6-4(26)] shall apply.

H-5 LAYING OF BRICKWORK

H-5.1 Brick shall be laid on a full bed of mortar. When laying the bricks, it shall be slightly pressed so that the mortar gets into all the pores of the brick surface to ensure proper adhesion. Cross joints and wall joints shall be properly flushed and packed with mortar so that no hollow spaces are left. Properly filled joints ensure maximum strength and resistance to penetration of moisture which takes place mainly through joints.

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H-5.2 The following specific guidelines shall be followed:

a) In areas with a very high ground water table, it is advisable to build the first 4 to 5 courses of the wall, with either English or a Flemish bond. This is to avoid ground and spill water related dampness problems.

b) Always clean the surface where the first layer of bricks is to be laid, which is usually above the plinth level.

c) Arrange the joints between the bricks in such a way that only full bricks (shiners) fit. Ensure that the bonding is correct.

d) To properly maintain the brick cross, lay the first two masonry courses by marking mark each of the shiner and the header bricks at the centre.

e) Place the shiner/stretcher and header brick now in such a way that the marks are exactly matching. The remaining courses may then be laid to match with the first two courses.

f) Spread a full bed of mortar, and furrow it with a trowel. This will ensure that plenty of mortar is on the bottom of the bricks for the first course.

g) Lay the corner bricks first. Carefully position the corner bricks first. Be sure to lay all bricks with the frog inside the cavity of the wall in order to create an aesthetically pleasing outer wall surface.

h) The vertical mortar joints shall be applied directly to the brick before placing it. This requires some special skill, but defines the strength as well as the stability of the rat-trap bond wall.

j) The maximum rat-trap bond brick wall height per day should not exceed more than 9 layers.

k) Cavities of rat-trap bond shall be closed for the first course after damp proof course, below sill level, below and above lintel and at the top most course; this can be made by a layer of headers or headers.

H-5.3 Protection Against Damage

Care shall be taken during construction that edges of jambs, sills, heads, etc are not damaged. In inclement weather, newly built work shall be covered with gunny bags or tarpaulin so as to prevent the mortar from being washed away.

H-6 INSPECTION

H-6.1 General

The object of inspection of brick masonry work is to ensure its satisfactory performance and also to ascertain whether all the recommended practice of workmanship is adopted at every stage. As the correct strength of masonry cannot be ascertained without destruction, a close supervision during the course of construction is necessary to ensure satisfactory performance. The strength of brickwork depends on the strength of individual brick, strength of mortar, bond and workmanship.

H-6.2 Inspection of Materials

In case of large works, samples of bricks, sands, *Surkhi*, lime, cement, etc, which goes to form the brickwork, shall be periodically tested in a laboratory to make sure that they conform to the requirements stated in **H-3**. Simple field tests may suffice in the case of small works.

H-6.3 Inspection of Workmanship

A close supervision while the work is in progress will ensure a better quality work with the materials available for use. The following shall be observed at the time of inspection:

a) All loose materials, dirt and set lumps of mortar which may be lying over the surface over which brickwork is to be freshly started, shall be removed with a wire brush.

b) All the bricks shall be thoroughly soaked in potable water before use.

c) The surface over which the brickwork is to be started shall be made moist.

d) Plastic mortar results in thorough bedding of the brick and more complete filling of the joints which ensure greater strength. Care shall be taken to see that the required quantity of water is added to the mortar at the mixing platform itself and not over the courses.

e) All the joints shall, as far as possible, be thin and the specifications mentioned in **H-4.5** in this regard shall be strictly adhered to.

f) Care shall be taken to see that there is no through joints and the lap is not less than half the width of the brick, and that all the vertical joints are properly filled with mortar.

g) The verticality of the walls and horizontality of the courses shall be checked very often with plumb bob and spirit level respectively.

h) No portion of the work shall be left more than 1 m lower than the other. Where the masonry of one part has to be delayed the work shall be 'raked back' suitably at an angle not exceeding 45° according to bond and not toothed.

j) Where plastering is required to be done all the vertical as well as horizontal joints shall

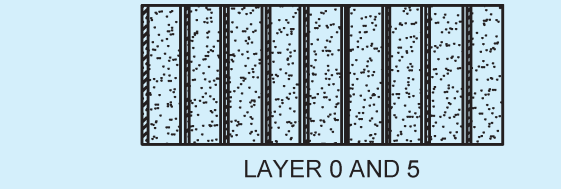
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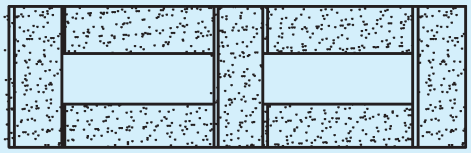
be raked to a depth of about 10 mm while the mortar is wet, and this will ensure satisfactory adhesion between the plaster and brickwork, and

k) Care shall be taken to ensure that the brick work is kept wet for first seven days using appropriate curing methods.

H-7 TESTING METHOD FOR RAT-TRAP BOND WALL SAMPLES

H-7.1 A test specimen of two modules along the length should be taken (*see* Fig. 74). The specimen should be made with the same mortar as that to be used in structure. The specimen should be loaded in a compression testing machine and failure load to be observed. The height of the specimen should be four brick height. The header layer at top and bottom are intended to distribute the load. A similar test as above should be done in an English bond per coupon (*see* Fig. 75).





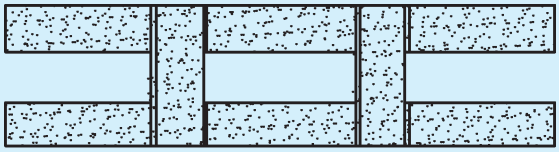
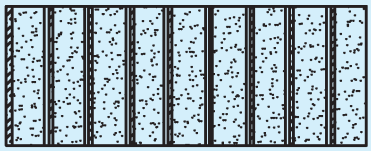
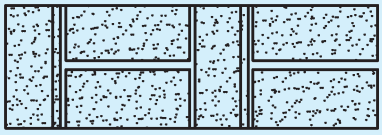


FIG. 74 RAT-TRAP BOND TEST SPECIMEN





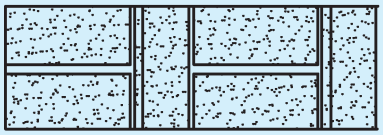


FIG. 75 ENGLISH BOND TEST SPECIMEN

H-7.2 The load on rat-trap bond specimen should be not less than 85 percent of the load capacity of English bond wall compressive strength.

H-7.3 While designing the compressive stress on rat-trap bond wall, it should be ensured that the stress is not more than 0.85 of that of solid wall as per **4** of this Section.

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ANNEX J

(*Clause* 12)

NOTATIONS, SYMBOLS AND ABBREVIATIONS

J-1 The following notations, letter symbols and abbreviations shall have the meaning indicated against each, unless otherwise specified in the text of this Section of the Code:

A = Area of a section
b = Width of bearing
DPC = Damp proof course
e = Resultant eccentricity
f_b = Basic compressive stress
f_c = Permissible compressive stress
f_d = Compressive stress due to dead loads
f_s = Permissible shear stress
f_m = Compressive strength of masonry (in prism test)
GL = Ground level
H = Actual height between lateral supports
H' = Height of opening
$H1$, $H2$ = High strength mortars
h = Effective height between lateral supports
k_a = Area factor
k_p = Shape modification factor
k_s = Stress reduction factor
L = Actual length of wall
$L1$, $L2$ = Lower strength mortars
$M1$, $M2$ = Medium strength mortars
P = Total horizontal load
PL = Plinth level
RCC = Reinforced cement concrete
RS = Rolled steel
S_p = Spacing of piers/buttresses/cross walls
SR = Slenderness ratio
t = Actual thickness
t_p = Thickness of pier
t_w = Thickness of wall
W = Resultant load
W_1 = Axial load
W_2 = Eccentric load
w_p = Width of piers/buttresses/cross walls
μ = Ratio of flexural strength of wall in the vertical direction to that in the horizontal direction

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part/Section.

	IS No.	*Title*
(1)	1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
	1725 : 2013	Stabilized soil blocks used in general building construction — Specification (*second revision*)
	2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
	2185	Specification for concrete masonry units
	(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
	(Part 2) : 1983	Hollow and solid light weight concrete blocks (*first revision*)
	(Part 3) : 1984	Autoclaved cellular aerated concrete blocks (*first revision*)
	(Part 4) : 2008	Preformed foam cellular concrete blocks
	2222 : 1991	Specification for burnt clay perforated building bricks (*third revision*)
	2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types) (*first revision*)
	3115 : 1992	Specification for lime based blocks (*second revision*)
	3316 : 1974	Specification for structural granite (*first revision*)

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	IS No.	*Title*
	3620 : 1979	Specification for laterite stone block for masonry (*first revision*)
	3952 : 2013	Burnt clay hollow bricks and blocks for walls and partitions — Specification (*third revision*)
	4139 : 1989	Specification for calcium silicate bricks (*second revision*)
	12440 : 1988	Specification for precast concrete stone masonry blocks
	12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)
	13757 : 1993	Specification for burnt clay fly ash building bricks
(2)	4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
(3)	2250 : 1981	Code of practice for preparation and use of masonry mortars (*first revision*)
(4)	2110 : 1980	Code of practice for *in-situ* construction of walls, in building with soil-cement (*first revision*)
	2212 : 1991	Code of practice for brickwork (*first revision*)
	1597	Code of practice for construction of stone masonry
	(Part 1) : 1992	Rubble stone masonry (*first revision*)
	(Part 2) : 1992	Ashlar masonry (*first revision*)
	2572 : 2005	Code of practice for construction of hollow and solid concrete block masonry (*first revision*)
	2849 : 1983	Specification for non-load bearing gypsum partition blocks (solid and hollow types) (*first revision*)
	3630 : 1992	Code of practice for construction of non-load bearing gypsum block partitions (*first revision*)
	6041 : 1985	Code of practice for construction of autoclaved cellular concrete block masonry (*first revision*)
	6042 : 1969	Code of practice for construction of lightweight concrete block masonry
(5)	2212 : 1991	Code of practice for brickwork (*first revision*)
(6)	3414 : 1968	Code of practice for design and installation of joints in buildings
(7)	10440 : 1983	Code of practice for construction of RB and RBC floors and roofs
(8)	1893 : 1984	Criteria for earthquake resistant design of structures (*fourth revision*)
(9)	1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)
(10)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
(11)	13920 : 2016	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces (*first revision*)
(12)	1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
(13)	2185 (Part 1) : 2005	Concrete masonry units — Specification: Part 1 Hollow and solid concrete blocks (*third revision*)
(14)	1597 (Part 2) : 1992	Code of practice for construction of stone masonry: Part 2 Ashlar masonry (*first revision*)
(15)	2751 : 1979	Code of practice for welding of mild steel plain and deformed bars for reinforced concrete construction (*first revision*)
(16)	9417 : 1989	Welding — Cold-worked steel bars for reinforced concrete construction — Recommendations for welding (*first revision*)
(17)	883 : 2016	Code of practice for design of structural timber in building (*fifth revision*)
(18)	432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars *(third revision)*
(19)	1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
(20)	2502 : 1963	Code of practice for bending and fixing of bars for concrete reinforcement
(21)	1077 : 1992	Specification for common burnt clay building bricks (*fifth revision*)
	2180 : 1988	Specification for heavy duty burnt clay building bricks (*third revision*)
	1725 : 2013	Stabilized soil blocks used in general buildingconstruction — Specification (*second revision*)

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IS No.	*Title*
(22) 405	Lead Sheets and Strips : Part 2
(Part 2) : 1992	For other than chemical purposes
1322 : 1993	Specification for bitumen felts for water proofing and damp-proofing (*fourth revision*)
(23) 432	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement.
(Part 1) : 1982	Mild steel and medium tensile steel bars (*third revision*)
(Part 2) : 1982	Hard-drawn steel wire (*third revision*)
1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)
412 : 1975	Expanded metal steel sheets for general purposes (*second revision*)
2062 : 2011	Hot rolled medium and high tensile structural steel (*seventh revision*)
(24) 3792 :1978	Guide for heat insulation of non-industrial buildings (*first revision*)
(25) 1642 : 2013	Code of practice for fire safety of buildings (general): Details of construction (*second revision*)
(26) 1950 : 1962	Code of practice for sound insulation of non-industrial buildings

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5A Plain and Reinforced Concrete

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Subsection 5A) covers the structural design aspects of plain and reinforced concrete.

The Section 5 of Part 6 of the Code covers plain and reinforced concrete and also the prestressed concrete. The Section has been subdivided into the following subsections:

5A Plain and Reinforced Concrete

5B Prestressed Concrete

This Subsection 5A was first published in 1970 as Subsection 5A of SP 7 (Part 6) and was subsequently revised in 1983 and 2005, to bring it in line with revised version of IS 456 : 1978 and IS 456 : 2000, respectively on which this chapter was based.

The second revision (NBC 2005) incorporated a number of important changes. The major thrust being:

a) In recent years, durability of concrete structures have become the cause of concern to all concrete technologists. This has led to codify the durability requirements world over. In this revision of the Code, in order to introduce in-built protection from factors affecting a structure, earlier clause on durability has been elaborated and a detailed clause covering different aspects of design of durable structure has been incorporated.

b) Sampling and acceptance criteria for concrete have been revised. With this revision acceptance criteria has been simplified in line with the provisions given in BS 5328 (Part 4) : 1990 ‘Concrete: Part 4 Specification for the procedures to be used in sampling, testing and assessing compliance of concrete’.

Some of the significant changes incorporated in the 2005 version were: inclusion of all the three grades of ordinary Portland cement, namely 33 Grade, 43 Grade and 53 Grade and sulphate resisting Portland cement in the list of types of cement used (in addition to other types of cement); modification of the permissible limits for solids in water keeping in view the durability requirements; modification of the clause on admixtures in view of the availability of new types of admixtures including superplasticizers; inclusion of grades higher than M 40 in Table 2 ‘Grades of Concrete’; recommendations regarding minimum grade of concrete to be not less than M 20 in reinforced concrete work (*see also* **5.1.3**); revision of the formula for estimation of modulus of elasticity of concrete; specification of workability only in terms of slump, in the absence of proper correlation between compacting factor, vee-bee time and slump, modification of the clause on ‘Durability’ to include detailed guidance concerning the factors affecting durability; modification of the table on ‘Environmental Exposure Conditions’ to include ‘very severe’ and ‘extreme’ exposure conditions, also covering requirements for shape and size of member, depth of concrete cover, concrete quality, requirement against exposure to aggressive chemical and sulphate attack, minimum cement requirement and maximum water cement ratio, limits of chloride content, alkali silica reaction, and importance of compaction, finishing and curing; incorporation of a clause on ‘Quality Assurance Measures’ to give due emphasis to good practices of concreting; introduction of proper limits on the accuracy of measuring equipments to ensure accurate batching of concrete; modification of the clause on ‘Construction Joints’; and modification of the clause on ‘Inspection’ to give more emphasis on quality assurance.

The significant changes incorporated in Section 5A (C) of the 2005 version were: detailing of requirements for ‘Fire Resistance’; modification of the figure for estimation of modification factor for tension reinforcement used in calculation of basic values of span to effective depth to control the deflection of flexural member; addition of recommendations regarding effective length of cantilever; addition of recommendations regarding deflection due to lateral loads; inclusion of recommendations for adjustments of support moments in restrained slabs; introduction of stability index in the determination of effective length of compression members, to determine sway or no sway conditions; inclusion of recommendations for lap length of hooks for bars in direct tension and flexural tension; modification of recommendations regarding strength of welds; modification in recommendations regarding cover to reinforcement; prescription of cover based on durability requirements for different exposure conditions; introduction of the term ‘nominal cover’; and prescription of the cover based on durability requirement as well as for fire requirements.

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The significant change incorporated in Section 5A (D) of the 2005 version included modification of the clause on walls. The modified clause includes design of walls against horizontal shear.

In Section 5 of the 2005 version on limit state method, a new clause was added for calculation of enhanced shear strength of sections close to supports. Some modifications were also made in the clause on Torsion. Formula for calculation of crack width were added (separately in Annex F).

Working stress method was added in Annex A so as to give greater emphasis to limit state design. In this annex, modifications regarding torsion and enhanced shear strength on the same lines as in Section 5 have been made.

Whilst the common methods of design and construction have been covered in this code, special systems of design and construction of any plain or reinforced concrete structure not covered by this code may be permitted on production of satisfactory evidence regarding their adequacy and safety by analysis or test or both (*see* **18**).

In this Code it has been assumed that the design of plain and reinforced cement concrete work is entrusted to a qualified engineer and that the execution of cement concrete work is carried out under the direction of a qualified and experience supervisor.

In this third revision of this Subsection, the following major modifications have been incorporated:

a) All the 4 amendments so far issued to IS 456 : 2000 'Code of practice for plain and reinforced concrete (*fourth revision*)' have been incorporated.
b) Provisions relating to use of mineral admixtures, their effects on properties of fresh and hardened concrete have been elaborated, including precautions associated therewith.
c) Aggregates from other than natural sources, including iron slag aggregate, steel slag aggregate, copper slag aggregate, bottom ash from thermal power plant, and aggregate derived from construction and demolition waste, have been included through cross reference to the revised IS 383, namely IS 383 : 2016 'Specification for coarse and fine aggregate for concrete (*third revision*)'.
d) Provisions relating to stripping time of forms for beams and slabs have been modified, also emphasizing the need for immediate replacement of props have been included.
e) The stripping time in case of the concrete made using cement other than OPC or using cementitious materials like fly ash and slag, has been specified, also giving guidance on minimum cube strength requirements of concrete before removal of formwork in case provision of stripping time applicable for concrete made using OPC, is to be used.
f) Provisions related to self compacting concrete (SCC) and high performance concrete (HPC) have been included as part of special concretes.
g) Design provisions related to steel fibre reinforced concrete have been included as part of special concretes.
h) Provisions related to shear stress for coupled shear walls have been included.
j) Comprehensive provisions on ductile detailing have been included from IS 13920 : 2016 'Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces (*first revision*)' to help extensive implementation of ductile detailing provisions in all relevant structures.
k) List of Indian Standards referred as good practice has been updated, especially in view of formulation of a number of new/revision of Indian Standards relating to concrete.

This Subsection is largely based on the following Indian Standards:

IS 456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
IS 13920 : 2016	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic forces (*first revision*)

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5A Plain and Reinforced Concrete

SECTION 5A (A) GENERAL

1 SCOPE

1.1 This Code (Part 6/Subsection 5A) deals with the general structural use of plain and reinforced concrete.

1.1.1 For the purpose of this Subsection, plain concrete structures are those where reinforcement, if provided is ignored for determination of strength of the structure.

1.2 Special requirements of structures, such as shells, folded plates, arches, chimneys, blast resistant structures, hydraulic structures, liquid retaining structures and earthquake resistant structures, covered in respective Indian Standards, have not been covered in this Subsection; these Indian Standards shall be used in conjunction with this Subsection. *See* good practices [6-5A(1)].

2 TERMINOLOGY

For the purpose of this Subsection, the definitions given in accepted standards [6-5A(2)] shall apply.

3 SYMBOLS

For the purpose of this Subsection, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place:

A — Area

b — Breadth of beam, or shorter dimension of a rectangular column

b_{ef} — Effective width of slab

b_f — Effective width of flange

b_w — Breadth of web or rib

D — Overall depth of beam or slab or diameter of column; dimension of a rectangular column in the direction under consideration

D_f — Thickness of flange

DL — Dead load

d — Effective depth of beam or slab

d' — Depth of compression reinforcement from the highly compressed face

E_c — Modulus of elasticity of concrete

EL — Earthquake load

E_s — Modulus of elasticity of steel

e — Eccentricity

f_{ck} — Characteristic cube compressive strength of concrete

f_{cr} — Modulus of rupture of concrete (flexural tensile strength)

f_{ct} — Splitting tensile strength of concrete

f_d — Design strength

f_y — Characteristic strength of steel

H_w — Unsupported height of wall

H_{we} — Effective height of wall

I_{ef} — Effective moment of inertia

I_{gr} — Moment of inertia of the gross section excluding reinforcement

I_r — Moment of inertia of cracked section

K — Stiffness of member

k — Constant or coefficient or factor

L_d — Development length

LL/IL — Live load or imposed load

l — Length of a column or beam between adequate lateral restraints or the unsupported length of a column

l_{ef} — Effective span of beam or slab or effective length of column

l_{ex} — Effective length about x-x axis

l_{ey} — Effective length about y-y axis

l_n — Clear span, face-to-face of supports

l_n' — l_n for shorter of the two spans at right angles

l_x — Length of shorter side of slab

l_y — Length of longer side of slab

l_0 — Distance between points of zero moments in a beam

l_1 — Span in the direction in which moments are determined, centre-to-centre of supports

l_2 — Span transverse to l_1, centre-to-centre of supports

l_2' — l_2 for the shorter of the continuous spans

M — Bending moment

m — Modular ratio

n — Number of samples

P — Axial load on a compression member

q_o — Calculated maximum bearing pressure of soil

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R — Radius
s — Spacing of stirrups or standard deviation
T — Torsional moment
t — Wall thickness
V — Shear force
W — Total load
WL — Wind Load
w — Distributed load per unit area
w_d — Distributed dead load per unit area
w_l — Distributed imposed load per unit area
x — Depth of neutral axis
Z — Modulus of section
z — Lever arm
α, β — Angle or ratio
γ_f — Partial safety factor for load
γ_m — Partial safety factor for material
δ_m — Percentage reduction in moment
ε_{cc} — Creep strain of concrete
σ_{cbc} — Permissible stress in concrete in bending compression
σ_{cc} — Permissible stress in concrete in direct compression
σ_{mc} — Permissible stress in metal in direct compression
σ_{sc} — Permissible stress in steel in compression
σ_{st} — Permissible stress in steel in tension
σ_{sv} — Permissible stress in shear reinforcement
τ_{bd} — Design bond stress
τ_c — Shear stress in concrete
$\tau_{c,max}$ — Maximum shear stress in concrete with shear reinforcement
τ_v — Nominal shear stress
Φ — Diameter of bar

SECTION 5A (B1) MATERIALS, WORKMANSHIP, INSPECTION AND TESTING

4 MATERIALS

4.1 Cement

The cement used shall be any of the following conforming to accepted standards [6-5A(3)] and the type selected should be appropriate for the intended use:

a) Ordinary Portland cement,
b) Rapid-hardening Portland cement,
c) Portland slag cement,
d) Portland pozzolana cement (fly ash based),
e) Portland pozzolana cement (calcined clay based),
f) Hydrophobic cement,
g) Low heat Portland cement, and
h) Sulphate resisting Portland cement.

Other combinations of Portland cement with mineral admixture (*see* **4.2**) of quality conforming with relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them.

4.1.1 Low heat Portland cement conforming to accepted standards [6-5A(4)] shall be used with adequate precautions with regard to removal of formwork, etc.

4.1.2 High alumina cement conforming to accepted standard [6-5A(5)] or supersulphated cement conforming to accepted standard [6-5A(6)] may be used only under special circumstances with the prior approval of the Engineer-in-Charge. Specialist literature may be consulted for guidance regarding the use of these types of cements.

4.1.3 The attention of the Engineer-in-Charge and users of cement is drawn to the fact that quality of various cements mentioned in **4.1** is to be determined on the basis of its conformity to the performance characteristics given in the respective Indian Standard specification for that cement. Any trade-mark or any trade name indicating any special features not covered in the standard or any qualification or other special performance characteristics sometimes claimed/ indicated on the bags or containers or in advertisements alongside the 'Statutory Quality Marking' or otherwise have no relation whatsoever with the characteristics guaranteed by the Quality Marking as relevant to that cement. Consumers are, therefore, advised to go by the characteristics as given in the corresponding Indian Standard Specification or seek specialist advice to avoid any problem in concrete making and construction.

4.2 Mineral Admixtures

Mineral admixtures listed below may be used along with ordinary Portland cement. Uniform blending of the additions with the cement should be ensured. For this purpose, specific facility is required to be available at the construction site or RMC plant.

NOTE — In case more than one type of mineral admixture is to be used in the same concrete or mineral admixture is used along with blended cement, the necessary trials for suitability of concrete so made shall be done and duly approved by the Engineer-in-Charge.

4.2.1 *Pozzolanas*

Pozzolanic materials as given below may be used.

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4.2.1.1 *Fly ash (pulverized fuel ash)*

Fly ash conforming to accepted standard [6-5A(7)] may be used as part replacement of ordinary Portland cement.

4.2.1.2 *Silica fume*

Silica fume conforming to accepted standard [6-5A(8)] may be used as part replacement of ordinary Portland cement. Silica fume is usually used in proportion of 5 to 10 percent of the cement.

4.2.1.3 *Rice husk ash*

Rice husk ash giving required performance and uniformity characteristics may be used with the approval of the Engineer-in-Charge.

NOTE — Rice husk ash is produced by burning rice husk and contains large proportion of silica. To achieve amorphous state, rice husk may be burnt at controlled temperature. It is necessary to evaluate the product from a particular source for performance and uniformity since it can be as deleterious as silt when incorporated in concrete. Water demand and drying shrinkage should be studied before using rice husk.

4.2.1.4 *Metakaolin*

Metakaolin conforming to accepted standard [6-5A(9)] may be used as part replacement of ordinary Portland cement.

4.2.2 *Ground Granulated Blast Furnace Slag*

Ground granulated blast furnace slag obtained by grinding granulated blast furnace slag conforming to accepted standards [6-5A(10)] may be used as part replacement of ordinary Portland cement.

4.2.3 *Precautions*

4.2.3.1 For concrete made with mineral admixtures, the setting time and rate of gain of strength may be different from those of concrete made with ordinary Portland cement alone. Cognizance of such modified properties shall be taken into account in deciding de-shuttering time, rate of movement of formwork in slipform construction, initial time of prestressing, longer curing period and for early age loading. The compatibility of chemical admixtures and cementitious materials should be ensured by trials.

Concrete containing mineral admixtures generally have equal or improved finishability compared to similar concrete mixes without them. Mixes that contain high dosages of mineral admixtures, specially silica fume, can be sticky and difficult to finish.

Concrete containing mineral admixtures may exhibit an increase in plastic shrinkage cracking because of its low bleeding characteristics. The problem may be avoided by ensuring that such concrete is protected against drying, both during and after finishing.

4.2.3.2 Compatibility of chemical admixtures and superplasticizers conforming to accepted standards [6-5A(11)] with the binder system shall be ensured by trials.

4.2.3.3 Some other properties of concrete such as modulus of elasticity, tensile strength, creep and shrinkage are not likely to be significantly different. For design purposes, it will be sufficiently accurate to adopt the same values as those used for concrete made with ordinary Portland cement alone.

4.3 *Aggregates*

Aggregates, derived from natural sources and from other than natural sources, shall comply with the requirements of accepted standards [6-5A(12)].

4.3.1 Other types of aggregates such as crushed overburnt brick or tile, which may be found suitable with regard to strength, durability of concrete and freedom from harmful effects may be used for plain concrete members, but such aggregates should not contain more than 0.5 percent of sulphates as SO_3 and should not absorb more than 10 percent of their own mass of water.

4.3.2 Heavy weight aggregates or light weight aggregates such as bloated clay aggregates and sintered fly ash aggregates may also be used provided the Engineer-in-Charge is satisfied with the data on the properties of concrete made with them.

NOTE — Some of the provisions of the code would require modification when these aggregates are used; specialist literature may be consulted for guidance.

4.3.3 *Size of Aggregate*

The nominal maximum size of coarse aggregate should be as large as possible within the limits specified but in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all reinforcement thoroughly and fill the corners of the form. For most work, 20 mm aggregate is suitable. Where there is no restriction to the flow of concrete into sections, 40 mm or larger size may be permitted. In concrete elements with thin sections, closely spaced reinforcement or small cover, consideration should be given to the use of 10 mm nominal maximum size.

Plums above 160 mm and up to any reasonable size may be used in plain concrete work up to a maximum limit of 20 percent by volume of concrete when specifically permitted by the Engineer-in-Charge. The plums shall be distributed evenly and shall be not closer than 150 mm from the surface.

4.3.3.1 For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum

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size of the aggregate should usually be restricted to 5 mm less than the minimum clear distance between the main bars or 5 mm less than the minimum cover to the reinforcement whichever is smaller.

4.3.4 Coarse and fine aggregate shall be batched separately.

4.4 Water

Water, natural or treated, used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

Potable water is generally considered satisfactory for mixing concrete. As a guide the following concentrations represent the maximum permissible values:

a) To neutralize 100 ml sample of water, using phenolphthalein as an indicator, it should not require more than 5 ml of 0.02 normal NaOH. The details of test are given in **7.1** of good practice [6-5A(13)].

b) To neutralize 100 ml sample of water, using mixed indicator, it should not require more than 25 ml of 0.02 normal H_2SO_4. The details of test shall be as given in **7** of good practice [6-5A(13)].

c) Permissible limits for solids shall be as given in Table 1.

Table 1 Permissible Limit for Solids

(*Clause* 4.4)

Sl No.	Parameter	Tested as Per	Permissible Limit *Max*
(1)	(2)	(3)	(4)
i)	Organic	Good practice [6-5A(13)]	200 mg/l
ii)	Inorganic	Good practice [6-5A(13)]	3 000 mg/l
iii)	Sulphates (as SO_3)	Good practice [6-5A(13)]	400 mg/l
iv)	Chlorides (as Cl)	Good practice [6-5A(13)]	2 000 mg/l for concrete not containing embedded steel and 500 mg/l for reinforced concrete work
v)	Suspended matter	Good practice [6-5A(13)]	2 000 mg/l

4.4.1 In case of doubt regarding development of strength, the suitability of water for making concrete shall be ascertained by the compressive strength and initial setting time tests specified in **4.4.1.2** and **4.4.1.3**.

4.4.1.1 The sample of water taken for testing shall represent the water proposed to be used for concreting, due account being paid to seasonal variation. The sample shall not receive any treatment before testing other than that envisaged in the regular supply of water proposed for use in concrete. The sample shall be stored in a clean container previously rinsed out with similar water.

4.4.1.2 Average 28 days compressive strength of at least three 150 mm concrete cubes prepared with water proposed to be used shall not be less than 90 percent of the average of strength of three similar concrete cubes prepared with distilled water. The cubes shall be prepared, cured and tested in accordance with good practice [6-5A(14)].

4.4.1.3 The initial setting time of test block made with the appropriate cement and the water proposed to be used shall not be less than 30 min and shall not differ by ± 30 min from the initial setting time of control test block prepared with the same cement and distilled water. The test blocks shall be prepared and tested in accordance with the good practice [6-5A(15)].

4.4.2 The *p*H value of water shall be not less than 6.

4.4.3 *Sea Water*

Sea water shall not be used for mixing or curing of concrete because of presence of harmful salts. Under unavoidable circumstances sea water may be used for mixing or curing in plain concrete with no embedded steel after having given due consideration to possible disadvantages and precautions including use of appropriate cement system.

4.4.4 Water found satisfactory for mixing is also suitable for curing concrete. However, water used for curing should not produce any objectionable stain or unsightly deposit on the concrete surface.

4.5 Chemical Admixtures

4.5.1 Admixture, if used shall comply with accepted standards [6-5A(15)]. Previous experience with and data on such materials should be considered in relation to the likely standards of supervision and workmanship to the work being specified.

4.5.2 Admixtures should not impair durability of concrete nor combine with the constituent to form harmful compounds nor increase the risk of corrosion of reinforcement.

4.5.3 The workability, compressive strength and the slump loss of concrete with and without the use of admixtures shall be established during the trial mixes before use of admixtures.

4.5.4 The relative density of liquid admixtures shall be checked for each drum containing admixtures and compared with the specified value before acceptance.

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4.5.5 The chloride content of admixtures shall be independently tested for each batch before acceptance.

4.5.6 If two or more admixtures are used simultaneously in the same concrete mix, data should be obtained to assess their interaction and to ensure their compatibility.

4.5.7 The amount of admixture added to a mix shall be recorded in the production record. Redosing of admixtures is not normally permitted. In special circumstances, if necessary, additional dose of admixture may be added at project site and mixed adequately in mixer itself to regain the workability of concrete with the mutual agreement between the producer/supplier and the purchaser/user of concrete. However, the producer/supplier shall assure the ultimate quality of concrete supplied by him and maintain record of quantity and time of addition.

4.6 Reinforcement

The reinforcement shall be any of the following conforming to the accepted standards [6-5A(16)]:

a) Mild steel and medium tensile steel bars.
b) High strength deformed steel bars.
c) Hard-drawn steel wire fabric.
d) Structural steel of Grade A.

4.6.1 All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil, mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement.

4.6.2 Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures. Specialist literature may be referred to in such cases. Reduction in design bond strength of coated bars shall be looked into.

4.6.3 The modulus of elasticity of steel shall be taken as 200 kN/mm^2. The characteristic yield strength of different steel shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard.

4.7 Fibres

Fibres may be added to concrete for special applications to enhance properties, for which specialist literature may be referred to. *See also* **16B**.

4.8 Storage of Materials

Storage of materials shall be as described in good practice [6-5A(17)].

5 CONCRETE

5.1 Grades

The concrete shall be in grades designated as per Table 2.

Table 2 Grades of Concrete

(*Clauses* 5.1, 8.2.2, 14.1.1 *and* 35.1)

Sl No.	Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days N/mm^2
(1)	(2)	(3)	(4)
i)	Ordinary concrete	M 10	10
		M 15	15
		M 20	20
ii)	Standard concrete	M 25	25
		M 30	30
		M 35	35
		M 40	40
		M 45	45
		M 50	50
		M 55	55
		M 60	60
iii)	High strength concrete	M 65	65
		M 70	70
		M 75	75
		M 80	80
		M 90	90
		M 95	95
		M 100	100

NOTES

1 In the designation of concrete mix, M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2.

2 For concrete of grades above M 60, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

5.1.1 The characteristic strength is defined as the strength of material below which not more than 5 percent of the test results are expected to fall.

5.1.2 The minimum grade of concrete for plain and reinforced concrete shall be as per Table 5.

5.1.3 Concrete of grades lower than those given in Table 5 may be used for lean concrete, foundation for masonry walls or temporary reinforced concrete construction.

5.2 Properties of Concrete

5.2.1 *Increase of Strength with Age*

There is normally a gain of strength beyond 28 days.

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The quantum of increase depends upon the grade and type of cement, curing and environmental conditions, etc. The design should be based on 28 days characteristic strength of concrete unless there is an evidence to justify a higher strength for a particular structure due to age.

5.2.1.1 For concrete of grade M 30 and above, the rate of increase of compressive strength with age shall be based on actual investigations.

5.2.1.2 Where members are subjected to lower direct load during construction, they should be checked for stresses resulting from combination of direct load and bending during construction.

5.2.2 *Tensile Strength of Concrete*

The flexural and splitting tensile strengths shall be obtained in accordance with good practice [6-5A(18)]. When the designer wishes to use an estimate of the tensile strength from the compressive strength, the following formula may be used:

Flexural strength, $f_{cr} = 0.7\sqrt{f_{ck}}$ N/mm^2

where

f_{ck} = characteristic cube compressive strength of concrete, in N/mm^2.

5.2.3 *Elastic Deformation*

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete.

5.2.3.1 The modulus of elasticity of concrete can be assumed as follows:

$$E_c = 5\ 000\sqrt{f_{ck}}$$

where

E_c = short term static modulus of elasticity, in N/mm^2.

Actual measured values may differ by ±20 percent from the values obtained from the above expression.

5.2.4 *Shrinkage*

The total shrinkage of concrete depends upon the constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and, to a lesser extent, by the cement content.

5.2.4.1 In the absence of test data, the approximate value of the total shrinkage strain for design may be taken as 0.000 3 {for more information, *see* accepted standard [6-5A(19)]}.

5.2.5 *Creep of Concrete*

Creep of concrete depends, in addition to the factors listed in **5.2.4**, on the stress in the concrete, age at loading and the duration of loading. As long as the stress in concrete does not exceed one-third of its characteristic compressive strength, creep may be assumed to be proportional to the stress.

5.2.5.1 In the absence of experimental data and detailed information on the effect of the variables, the ultimate creep strain may be estimated from the following values of creep coefficient (that is, ultimate creep strain/elastic strain at the age of loading); for long span structure, it is advisable to determine actual creep strain, likely to take place:

Age at Loading	*Creep Coefficient*
7 days	2.2
28 days	1.6
1 year	1.1

NOTE — The ultimate creep strain, estimated as described above does not include the elastic strain.

5.2.6 *Thermal Expansion*

The coefficient of thermal expansion depends on nature of cement, the aggregate, the cement content, the relative humidity and the size of sections.

The value of coefficient of thermal expansion for concrete with different aggregates may be taken as given below:

Type of Aggregate	*Coefficient of Thermal Expansion for Concrete/°C*
Quartzite	1.2 to 1.3 × 10^{-5}
Sandstone	0.9 to 1.2 × 10^{-5}
Granite	0.7 to 0.95 × 10^{-5}
Basalt	0.8 to 0.95 × 10^{-5}
Limestone	0.6 to 0.9 × 10^{-5}

6 WORKABILITY OF CONCRETE

6.1 The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of workability of concrete measured in accordance with good practice [6-5A(20)] are given below:

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Sl No.	*Placing Conditions*	*Degree of Workability*	*Slump* mm
(1)	(2)	(3)	(4)
i)	Blinding concrete; Shallow sections; Pavements using pavers	Very low	*See* **6.1.1**
ii)	Mass concrete; Lightly reinforced sections in slabs, beams, walls, columns; Floors; Hand placed pavements; Canal lining; Strip footings	Low	25-75
iii)	Heavily reinforced sections in slabs, beams, walls, columns	Medium	50-100
iv)	Slipform work	Medium	75-100
v)	Pumpable concrete	High	100-125
vi)	Trench fill	High	100-150
vii)	Tremie concrete	Very high	*See* **6.1.2**

NOTE — For most of the placing conditions, internal vibrators (needle vibrators) are suitable. The diameter of the needle shall be determined based on the density and spacing of reinforcement bars and thickness of sections. For tremie concrete, vibrators are not required to be used (*see also* **12.3**).

6.1.1 In the 'very low' category of workability where strict control is necessary, for example pavement quality concrete, measurement of workability by determination of compacting factor will be more appropriate than slump (*see* accepted standard [6-5A(20)]) and a value of compacting factor of 0.75 to 0.80 is suggested.

6.1.2 In the 'very high' category of workability, measurement of workability by determination of flow will be appropriate {*see* accepted standard [6-5A(11)]}.

7 DURABILITY OF CONCRETE

7.1 General

A durable concrete is one that performs satisfactorily in the working environment during its anticipated exposure conditions during service life. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

7.1.1 One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. With normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, and by adequate curing.

The factors influencing durability include,

a) the environment;
b) the cover to embedded steel;
c) the type and quality of constituent materials;
d) the cement content and water/cement ratio of the concrete;
e) workmanship, to obtain full compaction and efficient curing; and
f) the shape and size of the member.

The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition, workmanship, design and detailing should be considered. Maintenance plays an important role in sustained durability of concrete (*see also* **9.1**). The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of current testing regimes for control and compliance as described in this Section.

7.2 Requirements for Durability

7.2.1 *Shape and Size of Member*

The shape or design details of exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care should also be taken to minimise any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture (*see* **12.5**). Member profiles and their intersections with other members shall be designed and detailed in a way to ensure easy flow of concrete and proper compaction during concreting.

Concrete is more vulnerable to deterioration due to chemical or climatic attack when it is in thin sections, in sections under hydrostatic pressure from one side only, in partially immersed sections and at corners and edges of elements. The life of the structure can be lengthened by providing extra cover to steel, by chamfering the corners or by using circular cross-sections or by using surface coatings which prevent or reduce the ingress of water, carbon dioxide or aggressive chemicals.

7.2.2 *Exposure Conditions*

7.2.2.1 *General environment*

The general environment to which the concrete will be exposed during its working life is classified into five levels of severity, that is, mild, moderate, severe, very severe and extreme as described in Table 3.

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Table 3 Environmental Exposure Conditions

(*Clauses* 7.2.2.1 *and* 34.3.2)

Sl No.	Environment	Exposure Conditions
(1)	(2)	(3)
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal area
ii)	Moderate	a) Concrete surfaces sheltered from severe rain or freezing whilst wet b) Concrete exposed to condensation and rain c) Concrete continuously under water d) Concrete in contact or buried under non-aggressive soil/ground water e) Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	a) Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation b) Concrete completely immersed in sea water c) Concrete exposed to coastal environment
iv)	Very severe	a) Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet b) Concrete in contact with or buried under aggressive sub-soil/ground water
v)	Extreme	a) Surface of members in tidal zone b) Members in direct contact with liquid/solid aggressive chemicals

7.2.2.2 *Abrasion*

Abrasion of concrete surfaces results from friction, which may cause a grinding action; or by repetitive impact and overloading, which causes local crushing.

Abrasion resistant surfaces primarily involve consideration of surface finishing technique curing regime, aggregate characteristics and cement content. Compressive strength of concrete may also provide a relative indication of resistance.

Specialist literatures may be referred to for durability requirements of concrete surfaces exposed to abrasive action, for example, in case of machinery and metal tyres.

7.2.2.3 *Freezing and thawing*

Where freezing and thawing actions under wet conditions exist, enhanced durability can be obtained by the use of suitable air entraining admixtures. When concrete lower than grade M 50 is used under these conditions, the mean total air content by volume of the fresh concrete at the time of delivery into the construction should be:

Nominal Maximum Size Aggregate mm	*Entrained Air Percentage*
10	7 ± 1
20	5 ± 1
40	4 ± 1

Since air entrainment reduces the strength, suitable adjustments may be made in the mix design for achieving required strength.

7.2.2.4 *Exposure to sulphate attack*

Table 4 gives recommendations for the type of cement, maximum free water/cement ratio and minimum cement content, which are required at different sulphate concentrations in near-neutral ground water having *p*H of 6 to 9.

For the very high sulphate concentrations in Class 5 conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy; or polyurethane materials should also be used to prevent access by the sulphate solution.

7.2.3 *Requirement of Concrete Cover*

7.2.3.1 The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete.

7.2.3.2 The nominal cover to the reinforcement shall be provided as per **25.4**.

7.2.4 *Concrete Mix Proportions*

7.2.4.1 *General*

The free water-cement ratio is an important factor in governing the durability of concrete and should always be the lowest value. Appropriate values for minimum cement content and the maximum free water-cement ratio are given in Table 5 for different exposure conditions. The minimum cement content and maximum water-cement ratio apply to 20 mm nominal maximum size aggregate. For other sizes of aggregate they should be changed as given in Table 6.

7.2.4.2 *Maximum cement content*

Cement content not including fly ash and ground granulated blast furnace slag in excess of 450 kg/m^3 should not be used unless special consideration has been given in design to the increased risk of cracking due to drying shrinkage in thin sections, or to early thermal cracking and to the increased risk of damage due to alkali silica reactions.

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Table 4 Requirements for Concrete Exposed to Sulphate Attack

(*Clauses* 7.2.2.4 *and* 8.1.2)

Sl No.	Class	Concentration of Sulphates, Expressed as SO_3			Type of Cement	Dense, Fully Compacted Concrete. Made with 20 mm Nominal Maximum Size Aggregates in Accordance with Accepted Standard [6-5A(12)]	
		In Soil		In Ground Water			
		Total SO_3	SO_3 in 2:1 Water: Soil Extract			Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio
		Percent	g/l	g/l			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1	Traces (<0.2)	Less than 1.0	Less than 0.3	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	280	0.55
ii)	2	0.2 to 0.5	1.0 to 1.9	0.3 to 1.2	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	330	0.50
					Supersulphated cement or sulphate resisting Portland cement	310	0.50
iii)	3	0.5 to 1.0	1.9 to 3.1	1.2 to 2.5	Supersulphated cement or sulphate resisting Portland cement	330	0.50
					Portland pozzolana cement or Portland slag cement	350	0.45
iv)	4	1.0 to 2.0	3.1 to 5.0	2.5 to 5.0	Supersulphated or sulphate resisting Portland cement	370	0.45
v)	5	More than 2.0	More than 5.0	More than 5.0	Sulphate resisting Portland cement or supersulphated cement with protective coatings	400	0.40

NOTES

1 Cement content given in this table is irrespective of grades of cement.

2 Use of supersulphated cement is generally restricted where the prevailing temperature is above 40°C.

3 Supersulphated cement gives an acceptable life provided that the concrete is dense and prepared with a water-cement ratio of 0.4 or less, in mineral acids, down to *p*H 3.5.

4 The cement contents given in col 7 of this table are the minimum recommended. For SO_3 contents near the upper limit of any class, cement contents above these minimum are advised. For the purpose of calculation of SO_3 content (if the test results are in the form of SO_4), the following relation shall be used: $SO_3 = 0.833\ SO_4$.

5 For severe conditions, such as thin sections under hydrostatic pressure on one side only and sections partly immersed, considerations should be given to a further reduction of water-cement ratio.

6 Portland slag cement conforming to accepted standard [6-5A(21)] with slag content more than 50 percent exhibits better sulphate resisting properties.

7 Where chloride is encountered along with sulphates in soil or ground water, ordinary Portland cement with C_3A content from 5 to 8 percent shall be desirable to be used in concrete, instead of sulphate resisting cement. Alternatively, Portland slag cement conforming to accepted standard [6-5A(21)] having more than 50 percent slag or a blend of ordinary Portland cement and slag may be used.

7.2.5 *Mix Constituents*

7.2.5.1 *General*

For concrete to be durable, careful selection of the mix and materials is necessary, so that deleterious constituents do not exceed the limits.

7.2.5.2 *Chlorides in concrete*

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded metal. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimise the chances of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete coming from concrete materials, that is, cement, aggregates, water and admixtures, as well as by diffusion from the environment should be limited. The total amount of chloride content (as Cl) in the concrete at the time of placing shall be as given in Table 7.

The total acid soluble chloride content should be calculated from the mix proportions and the measured chloride contents of each of the constituents. Wherever possible, the total chloride content of the concrete should be determined.

7.2.5.3 *Sulphates in concrete*

Sulphates are present in most cements and in some

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Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 5.1.2, 5.1.3, 7.2.4.1 *and* 8.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	?	300	0.55	M 20
ii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of grades and types of cement and is inclusive of mineral admixtures mentioned in **4.2**. The mineral admixtures such as fly ash or ground granulated blast furnace slag shall be taken into account in the concrete composition with respect to the minimum cement content and maximum water-cement ratio not exceeding the limit of fly ash and slag specified in accordance with accepted standards [6-5A(22)] and [6-5A(21)], beyond which these additions, though permitted, shall not be considered for these purposes.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

3 The minimum cement content, maximum free water-cement ratio and minimum grade of concrete are individually related to exposure.

Table 6 Adjustments to Minimum Cement Contents for Aggregates Other than 20 mm Nominal Maximum Size

(*Clause* 7.2.4.1)

Sl No.	Nominal Maximum Aggregate Size	Adjustments to Minimum Cement Contents in Table 5
	mm	kg/m^3
(1)	(2)	(3)
i)	10	+40
ii)	20	0
iii)	40	–30

Table 7 Limits of Chloride Content of Concrete

(*Clause* 7.2.5.2)

Sl No.	Type or Use of Concrete	Maximum Total Acid Soluble Chloride Content Expressed as kg/m^3 of Concrete
(1)	(2)	(3)
i)	Concrete containing metal and steam cured at elevated temperature and prestressed concrete	0.4
ii)	Reinforced concrete or plain concrete containing embedded metal	0.6
iii)	Concrete not containing embedded metal or any material requiring protection from chloride	3.0

aggregates; excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO_3 (where $SO_3 = 0.833\ SO_4$), should not exceed 4 percent by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix.

The 4 percent limit does not apply to concrete made with supersulphated cement complying with accepted standard [6-5A(6)].

7.2.5.4 *Alkali-aggregate reaction*

Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis (Na_2O and K_2O) originating from cement or other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occur when all the following are present together:

a) A high moisture level, within the concrete;
b) A cement with high alkali content, or another source of alkali; and
c) Aggregate containing an alkali reactive constituent.

Where the service records of particular cement/aggregate combination are well established, and do not include any instances of cracking due to alkali-aggregate reaction, no further precautions should be necessary. When the materials are unfamiliar, precautions should take one or more of the following forms:

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a) Use of non-reactive aggregate from alternate sources.

b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent (as Na_2O equivalent).

   Further advantage can be obtained by use of fly ash conforming to accepted standard [6-5A(7)] or granulated blast furnace slag conforming to accepted standard [6-5A(10)] as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 25 percent or slag content is at least 50 percent.

c) Measures to reduce the degree of saturation of the concrete during service such as use of impermeable membranes.

d) Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix. For more guidance, specialist literatures may be referred.

7.2.6 *Concrete in Aggressive Soils and Water*

7.2.6.1 *General*

The destructive action of aggressive waters on concrete is progressive. The rate of deterioration decreases as the concrete is made stronger and more impermeable, and increases as the salt content of the water increases. Where structures are only partially immersed or are in contact with aggressive soils or waters on one side only, evaporation may cause serious concentrations of salts with subsequent deterioration, even where the original salt content of the soil or water is not high.

NOTE — Guidance regarding requirements for concrete exposed to sulphate attack is given in **7.2.2.4**.

7.2.6.2 *Drainage*

At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete.

Additional protection may be obtained by the use of suitable impermeable barriers.

7.2.7 *Compaction, Finishing and Curing*

Adequate compaction without segregation should be ensured by providing suitable workability and by employing appropriate placing and compacting equipment and procedures. Full compaction is particularly important in the vicinity of construction and movement joints and of embedded water bars and reinforcement.

Good finishing practices are essential for durable concrete.

Overworking the surface and the addition of water/cement to aid in finishing should be avoided; the resulting laitance will have impaired strength and durability and will be particularly vulnerable to freezing and thawing under wet conditions.

It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone (*see* **12.5**).

7.2.8 *Concrete in Sea-Water*

Concrete in sea-water or exposed directly along the sea-coast shall be at least M 20 Grade in the case of plain concrete and M 30 in case of reinforced concrete. The use of slag or pozzolana cement is advantageous under such conditions.

7.2.8.1 Special attention shall be given to the design of the mix to obtain the densest possible concrete; slag, broken brick, soft limestone, soft sandstone, or other porous or weak aggregates shall not be used.

7.2.8.2 As far as possible, preference shall be given to precast members unreinforced, well-cured and hardened, without sharp corners, and having trowel-smooth finished surfaces free from crazing, cracks or other defects; plastering should be avoided.

7.2.8.3 No construction joints shall be allowed within 600 mm below low water-level or within 600 mm of the upper and lower planes of wave action. Where unusually severe conditions or abrasion are anticipated, such parts of the work shall be protected by bituminous or silico-fluoride coatings or stone facing bedded with bitumen.

7.2.8.4 In reinforced concrete structures, care shall be taken to protect the reinforcement from exposure to saline atmosphere during storage, fabrication and use. It may be achieved by treating the surface of reinforcement with cement wash or by suitable methods.

8 CONCRETE MIX PROPORTIONING

8.1 Mix Proportion

The mix proportion shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

8.1.1 The determination of the proportions of cement, aggregates and water to attain the required strengths shall be made as follows:

a) By designing the concrete mix; such concrete shall be called 'Design mix concrete', or

b) By adopting nominal concrete mix; such concrete shall be called 'Nominal mix concrete'.

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Design mix concrete is preferred to nominal mix. If design mix concrete cannot be used for any reason on the work for grades of M 20 or lower, nominal mixes may be used with the permission of Engineer-in-Charge, which, however, is likely to involve a higher cement content.

8.1.2 *Information Required*

In specifying a particular grade of concrete, the following information shall be included:

a) Type of mix, that is, design mix concrete or nominal mix concrete;
b) Grade designation;
c) Type of cement;
d) Maximum nominal size of aggregate;
e) Minimum cement content (for design mix concrete);
f) Maximum water-cement ratio;
g) Workability;
h) Mix proportion (for nominal mix concrete);
j) Exposure conditions as per Tables 4 and 5;
k) Maximum temperature of concrete at the time of placing;
m) Method of placing; and
n) Degree of supervision.

8.1.2.1 In appropriate circumstances, the following additional information may be specified:

a) Type of aggregate,
b) Maximum cement content, and
c) Whether an admixture shall or shall not be used and the type of admixture and the condition of use.

8.2 Design Mix Concrete

8.2.1 As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this standard. If so desired, the employer shall be provided with supporting data including graphs showing strength versus water-cement ratio for range of proportions, complete trial mix proportioning details to substantiate the choice of cement content, fine and coarse aggregate content, water, mineral admixtures, chemical admixtures, etc.

8.2.2 The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than appropriate values given in Table 2. Proportion/grading of aggregates shall be made by trial in such a way as to make densest possible concrete. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

8.2.3 Mix design done earlier not prior to one year may be considered adequate for later work provided there is no change in source and the quality of the materials.

8.2.4 *Standard Deviation*

The standard deviation for each grade of concrete shall be calculated, separately.

8.2.4.1 *Standard deviation based on test strength of sample*

a) *Number of test results of samples* — The total number of test strength of samples required to constitute an acceptable record for calculation of standard deviation shall be not less than 30. Attempts should be made to obtain the 30 samples, as early as possible, when a mix is used for the first time.
b) *In case of significant changes in concrete* — When significant changes are made in the production of concrete batches (for example changes in the materials used, mix design, equipment or technical control), the standard deviation value shall be separately calculated for such batches of concrete.
c) *Standard deviation to be brought up to date* — The calculation of the standard deviation shall be brought up to date after every change of mix design.

8.2.4.2 *Assumed standard deviation*

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation given in Table 8 may be assumed for design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly. However, when adequate past records for a similar grade exist and justify to the designer a value of standard deviation different from that shown in Table 8, it shall be permissible to use that value.

8.3 Nominal Mix Concrete

Nominal mix concrete may be used for concrete of M 20 or lower. The proportions of materials for nominal mix concrete shall be in accordance with Table 9.

8.3.1 The cement content of the mix specified in Table 9 for any nominal mix shall be proportionately increased if the quantity of water in a mix has to be increased to overcome the difficulties of placement and compaction, so that the water-cement ratio as specified is not exceeded.

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Table 8 Assumed Standard Deviation

(*Clause* 8.2.4.2 *and* Table 11)

Sl No.	Grade of Concrete	Assumed Standard Deviation N/mm^2
(1)	(2)	(3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
	M 25	
iv)	M 30	5.0
v)	M 35	
vi)	M 40	
vii)	M 45	
viii)	M 50	
ix)	M 55	
x)	M 60	

NOTES

1 The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate grading and moisture content; and periodical checking of workability and strength. Where there is deviation from the above, the values given in the above table shall be increased by 1 N/mm^2.

2 For grades above M 60, the standard deviation shall be established by actual trials based on assumed proportions, before finalizing the mix.

Table 9 Proportions for Nominal Mix Concrete

(*Clauses* 8.3 *and* 8.3.1)

Sl No.	Grade of Concrete	Total Quantity of Dry Aggregates by Mass per 50 kg of Cement, to be Taken as the Sum of the Individual Masses of Fine and Coarse Aggregates kg *Max*	Proportion of Fine Aggregate to Coarse Aggregate (by Mass)	Quantity of Water per 50 kg of Cement l *Max*
(1)	(2)	(3)	(4)	(5)
i)	M 5	800	Generally 1:2 but subject to an upper limit of 1 : 1½ and a lower limit of 1 : 2½	60
ii)	M 7.5	625		45
iii)	M 10	480		34
iv)	M 15	330		32
v)	M 20	250		30

NOTES

1 The proportion of the fine to coarse aggregates should be adjusted from upper limit to lower limit progressively as the grading of fine aggregates becomes finer and the maximum size of coarse aggregate becomes larger. Graded coarse aggregate shall be used.

Example

For an average grading of fine aggregate {that is, Zone II of Table 4 of the accepted standard [6-5A(12)]}, the proportions shall be 1:1½, 1:2 and 1:2½ for maximum size of aggregates 10 mm, 20 mm and 40 mm, respectively.

2 Quantity of water required from durability point of view may be less than the value given above.

9 PRODUCTION OF CONCRETE

9.1 Quality Assurance Measures

9.1.1 In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care during the use of structure including timely maintenance and repair by the owner. The maintenance plays an important role in sustained durability of concrete.

9.1.2 Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipment; resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step in concreting which will be covered by the next step is inspected as the work proceeds (*see also* **16**).

9.1.3 Each party involved in the realization of a project should establish and implement a Quality Assurance Plan, for its participation in the project. Supplier's and subcontractor's activities shall be covered in the plan. The individual Quality Assurance Plans shall fit into the general Quality Assurance Plan. A Quality Assurance Plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures, and the organization and maintaining adequate documentation of the building process and its results. Such documentation should generally include,

a) test reports and manufacturer's certificate for materials, concrete mix design details;
b) pour cards for site organization and clearance for concrete placement;
c) record of site inspection of workmanship, field tests;
d) non-conformance reports, change orders;
e) quality control charts; and
f) statistical analysis.

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NOTE — Quality control charts are recommended, wherever the concrete is in continuous production over considerable period.

9.2 Batching

To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank {*see also* accepted standard [6-5A(23)] }.

For large and medium project sites, the concrete shall be sourced from ready-mixed concrete plants or from captive on-site or off-site automatic batching and mixing plants. The concrete produced and supplied by ready-mixed concrete plants shall be in accordance with good practices [6-5A(24)]. In case of concrete from captive on-site or off-site automatic batching and mixing plants, similar quality control shall be followed.

9.2.1 The grading of aggregate shall be controlled by obtaining the coarse aggregate in different sizes and blending them in right proportions, the different sizes being stocked in separate stock-piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as frequently as possible, the frequency for a given job being determined by the Engineer-in-Charge to ensure that the specified grading is maintained.

9.2.2 The accuracy of the measuring equipment shall be within ± 2 percent of the quantity of cement and mineral admixtures being measured and within ± 3 percent of the quantity of aggregate, chemical admixtures and water being measured. In a batching plant, the concrete production equipment shall be calibrated initially at the time of installation or reconditioning of the equipment and subsequently at the following intervals:

a) Mechanical/knife edge systems : At least once every two months

b) Electrical/load cell systems : At least once every three months

9.2.3 All ingredients of concrete shall be used by mass only except water and chemical admixtures, which may be by volume.

9.2.4 Volume batching may be allowed only where weigh-batching is not practical and provided accurate bulk densities of materials to be actually used in concrete have earlier been established. Allowance for bulking shall be made in accordance with accepted standard [6-5A(25)]. The mass volume relationship should be checked as frequently as necessary, the frequency for the given job being determined by Engineer-in-Charge to ensure that the specified grading is maintained.

9.2.5 It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture contents in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the Engineer-in-Charge according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, accepted standard [6-5A(25)] may be referred to. Where batching plants are used, it is recommended to determine moisture content by moisture probes fitted to the batching plants. To allow for the variation in mass of aggregate due to variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made. In the absence of exact data, only in the case of nominal mixes, the amount of surface water may be estimated from the values given in Table 10.

Table 10 Surface Water Carried by Aggregate

(*Clause* 9.2.5)

Sl No.	Aggregate	Approximate Quantity of Surface Water	
		Percent by Mass	litre/m^3
(1)	(2)	(3)	(4)
i)	Very wet sand	7.5	120
ii)	Moderately wet sand	5.0	80
iii)	Moist sand	2.5	40
iv)	Moist gravel or crushed rock[1)]	1.25-2.5	20-40

[1)] Coarser the aggregate, less the water it will carry.

9.2.6 No substitutions in materials used on the work or alterations in the established proportions, except as permitted in **9.2.4** and **9.2.5** shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

9.3 Mixing

Concrete shall be mixed in a mechanical mixer {(see also the accepted standard [6-5A(26)]}. It shall be ensured that stationary or central mixers and truck mixers shall comply with the performance criteria of mixing efficiency as per the accepted standard [6-5A(27)]. Mixing efficiency test shall be performed at least once in a year. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be remixed.

9.3.1 As a guidance, the mixing time shall be at least 2 min for conventional free fall (drum) batch type concrete mixers. For other types of more efficient mixers, manufacturer's recommendations shall be followed.

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9.3.2 Workability should be checked at frequent intervals {*see* accepted standard [6-5A(20)] }.

9.3.3 Dosages of retarders, plasticizers and superplasticizers shall be restricted to 0.5, 1.0 and 2.0 percent, respectively by mass of cementitious materials; however, the dosages of polycarboxylate based admixtures shall not exceed 1.0 percent. A higher value of above admixtures may be used, if agreed upon between the manufacturer and the constructor based on performance tests relating to workability, setting time and early age strength.

10 FORMWORK

10.1 General

The formwork shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete and shall be such as to prevent loss of slurry from the concrete. For further details regarding design, detailing, etc, reference may be made to good practice [6-5A(28)]. The tolerances on the shapes, lines and dimensions shown in the drawing shall be within the limits given below:

a)	Deviation from specified dimensions of cross-section of columns and beams	: $^{+10}_{-5}$ mm
b)	Deviation from dimensions of footings:	
	1) Dimensions in plan	: $^{+50}_{-10}$ mm
	2) Eccentricity	: 0.02 times the width of the footing in the direction of deviation but not more than 50 mm
	3) Thickness	: $^{+50}_{-10}$ mm or ± 0.05 times the specified thickness, whichever is less

These tolerances apply to concrete dimensions only, and not to positioning of vertical reinforcing steel or dowels.

10.2 Cleaning and Treatment of Formwork

All rubbish, particularly, chippings, shavings and sawdust shall be removed from the interior of the forms before the concrete is placed. The face of formwork in contact with the concrete shall be cleaned and treated with form release agent. Release agents should be applied so as to provide a thin uniform coating to the forms without coating the reinforcement.

10.3 Stripping Time

10.3.1 Forms shall not be released until the concrete has achieved a strength of at least twice the stress to which the concrete may be subjected at the time of removal of formwork. The strength referred to shall be that of concrete using the same cement and aggregates and admixture, if any, with the same proportions and cured under conditions of temperature and moisture similar to those existing on the work.

10.3.2 While the above criteria of strength shall be the guiding factor for removal of formwork in normal circumstances where ambient temperature does not fall below 15°C, the following striking period may deem to satisfy the guideline given in **10.3.1**:

Type of Formwork	*Minimum Period Before Striking Formwork*	
	For Concrete Made Using OPC	For Concrete Made Using Cement Other than OPC or Using Cementitious Materials Like Fly Ash and Slag
(1)	(2)	(3)
a) Vertical formwork to columns, walls, beams	16-24 h	16-24 h
b) Soffit formwork to slabs (Props to be refixed immediately after removal of formwork)	3 days	7 days
c) Soffit formwork to beams (Props to be refixed immediately after removal of formwork)	7 days	10 days
d) Props to slabs:		
1) Spanning up to 4.5m	7 days	10 days
2) Spanning over 4.5 m	14 days	14 days
e) Props to beams and arches:		
1) Spanning up to 6 m	14 days	14 days
2) Spanning over 6 m	21 days	21 days

NOTE — Utmost care shall be taken to provide props. The props shall be provided immediately after stripping each shuttering panel and not after stripping all the panels of the entire slab.

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For lower temperature, the stripping time recommended above may be suitably modified.

10.3.2.1 In case of use of cements other than OPC or in case of use of cementitious materials, *in-lieu* of the minimum period specified in **10.3.2** col 3, the stripping of formwork may be done in accordance with the provisions of **10.3.2** col 2, provided concrete cube testing is done to ensure that the following minimum strength is achieved:

3 days	:	45 percent of specified strength
7 days	:	60 percent of specified strength
14 days	:	85 percent of specified strength

10.3.3 The number of props left under, their sizes and disposition shall be such as to be able to safely carry the full dead load of the slab, beam or arch as the case may be together with any live load likely to occur during curing or further construction.

10.3.4 Where the shape of the element is such that the formwork has re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

11 ASSEMBLY OF REINFORCEMENT

11.1 Reinforcement shall be bent and fixed in accordance with procedure specified in good practice [6-5A(29)]. The high strength deformed steel bars should not be re-bent or straightened without the approval of Engineer-in-Charge.

Bar bending schedules shall be prepared for all reinforcement work.

11.2 All reinforcement shall be placed and maintained in the position shown in the drawings by providing proper cover blocks, spacers, supporting bars, etc.

11.2.1 Crossing bars should not be tack-welded for assembly of reinforcement unless permitted by Engineer-in-Charge.

11.3 Placing of Reinforcement

Rough handling, shock loading (prior to embedment) and the dropping of reinforcement from a height should be avoided. Reinforcement should be secured against displacement outside the specified limits.

11.3.1 *Tolerances on Placing of Reinforcement*

Unless otherwise specified by Engineer-in-Charge, the reinforcement shall be placed within the following tolerances:

a) For effective depth 200 mm or less : ± 10 mm

b) For effective depth more than 200 mm : ± 15 mm

11.3.2 *Tolerance for Cover*

Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by $^{+10}_{0}$ mm.

Nominal cover as given in **25.4.1** should be specified to all steel reinforcement including links. Spacers between the links (or the bars where no links exist) and the formwork should be of the same nominal size as the nominal cover.

Spacers, chairs and other supports detailed on drawings, together with such other supports as may be necessary, should be used to maintain the specified nominal cover to the steel reinforcement. Spacers or chairs should be placed at a maximum spacing of 1 m and closer spacing may sometimes be necessary.

Spacers, cover blocks should be of concrete of same strength or PVC.

11.4 Welded Joints or Mechanical Connections

Welded joints or mechanical connections in reinforcement may be used but in all cases of important connections, test shall be made to prove that the joints are of the full strength of bars connected. Welding of reinforcements shall be done in accordance with good practices [6-5A(30)].

11.5 Where reinforcement bars upto 12 mm for high strength deformed steel bars and up to 16 mm for mild steel bars are bent aside at construction joints and afterwards bent back into their original positions, care should be taken to ensure that at no time is the radius of the bend less than 4 bar diameters for plain mild steel or 6 bar diameters for deformed bars. Care shall also be taken when bending back bars, to ensure that the concrete around the bar is not damaged beyond the bend.

11.6 Reinforcement should be placed and tied in such a way that concrete placement be possible without segregation of the mix. Reinforcement placing should allow compaction by immersion vibrator. Within the concrete mass, different types of metal in contact should be avoided to ensure that bimetal corrosion does not take place.

12 TRANSPORTING, PLACING, COMPACTION AND CURING

12.1 Transporting and Handling

After mixing, concrete shall be transported to the formwork as rapidly as possible by methods which will prevent the segregation or loss of any of the ingredients

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or ingress of foreign matter or water and maintaining the required workability.

12.1.1 During hot or cold weather, concrete shall be transported in deep containers. Other suitable methods to reduce the loss of water by evaporation in hot weather and heat loss in cold weather may also be adopted.

12.2 Placing

The concrete shall be deposited as nearly as practicable in its final position to avoid rehandling. The concrete shall be placed and compacted before initial setting of concrete commences and should not be subsequently disturbed. Methods of placing should be such as to preclude segregation. Care should be taken to avoid displacement of reinforcement or movement of formwork. As a general guidance, the maximum permissible free fall of concrete may be taken as 1.5 m.

12.3 Compaction

Concrete should be thoroughly compacted and fully worked around the reinforcement, around embedded fixtures and into corners of the formwork.

12.3.1 Concrete shall be compacted using mechanical vibrators complying with accepted standard [6-5A(31)]. Over vibration and under vibration of concrete are harmful and should be avoided. Vibration of very wet mixes should also be avoided.

Whenever vibration has to be applied externally, the design of formwork and the disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

12.4 Construction Joints and Cold Joints

Joints are a common source of weakness and, therefore, it is desirable to avoid them. If this is not possible, their number shall be minimised. Concreting shall be carried out continuously up to construction joints, the position and arrangement of which shall be indicated by the designer.

Construction joints shall be placed at accessible locations to permit cleaning out of laitance, cement slurry and unsound concrete, in order to create rough/ uneven surface. It is recommended to clean out laitance and cement slurry by using wire brush on the surface of joint immediately after initial setting of concrete and to clean out the same immediately thereafter. The prepared surface should be in a clean saturated surface dry condition when fresh concrete is placed, against it.

In the case of construction joints at locations where the previous pour has been cast against shuttering the recommended method of obtaining a rough surface for the previously poured concrete is to expose the aggregate with a high pressure water jet or any other appropriate means.

Fresh concrete should be thoroughly vibrated near construction joints so that mortar from the new concrete flows between large aggregates and develop proper bond with old concrete.

Where high shear resistance is required at the construction joints, shear keys may be provided.

Sprayed curing membranes and release agents should be thoroughly removed from joint surfaces.

12.5 Curing

Curing is the process of preventing the loss of moisture from the concrete whilst maintaining a satisfactory temperature regime. The prevention of moisture loss from the concrete is particularly important if the water-cement ratio is low, if the cement has a high rate of strength development, if the concrete contains granulated blast furnace slag or pulverized fuel ash. The curing regime should also prevent the development of high temperature gradients within the concrete.

The rate of strength development at early ages of concrete made with supersulphated cement is significantly reduced at lower temperatures. Supersulphated cement concrete is seriously affected by inadequate curing and the surface has to be kept moist for at least seven days.

12.5.1 *Moist Curing*

Exposed surfaces of concrete shall be kept continuously in a damp or wet condition by ponding or by covering with a layer of sacking, canvas, hessian or similar materials and kept constantly wet for at least seven days from the date of placing concrete in case of ordinary Portland Cement and at least 10 days where mineral admixtures or blended cements are used. The period of curing shall not be less than 10 days for concrete exposed to dry and hot weather conditions. In the case of concrete where mineral admixtures or blended cements are used, it is recommended that above minimum periods may be extended to 14 days.

12.5.2 *Membrane Curing*

Approved curing compounds may be used *in-lieu* of moist curing with the permission of the Engineer-in-Charge. Such compounds shall be applied to all exposed surfaces of the concrete as soon as possible after the concrete has set. Impermeable membranes such as polyethylene sheeting covering closely the concrete surface may also be used to provide effective barrier against evaporation.

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12.6 Supervision

It is exceedingly difficult and costly to alter concrete once placed. Hence, constant and strict supervision of all the items of the construction is necessary during the progress of the work, including the proportioning and mixing of the concrete. Supervision is also of extreme importance to check the reinforcement and its placing before being covered.

12.6.1 Before any important operation, such as concreting or stripping of the formwork is started, adequate notice shall be given to the construction supervisor.

13 CONCRETING UNDER SPECIAL CONDITIONS

13.1 Work in Extreme Weather Conditions

During hot or cold weather, the concreting should be done as per good practice [6-5A(32)].

13.2 Under-Water Concreting

13.2.1 When it is necessary to deposit concrete under water, the methods, equipment, materials and proportions of the mix to be used shall be submitted to and approved by the Engineer-in-Charge before the work is started.

13.2.2 Under-water concrete should have a slump recommended in **6.1**. The water-cement ratio shall not exceed 0.6 and may need to be smaller, depending on the grade of concrete or the type of chemical attack. For aggregates of 40 mm maximum particle size, the cement content shall be at least 350 kg/m^3 of concrete.

13.2.3 Coffer-dams or forms shall be sufficiently tight to ensure still water if practicable, and in any case to reduce the flow of water to less than 3 m/min through the space into which concrete is to be deposited. Coffer-dams or forms in still water shall be sufficiently tight to prevent loss of mortar through the walls. De-watering by pumping shall not be done while concrete is being placed or until 24 h thereafter.

13.2.4 Concrete cast under water should not fall freely through the water. Otherwise it may be leached and become segregated. Concrete shall be deposited continuously until it is brought to the required height. While depositing, the top surface shall be kept as nearly level as possible and the formation of seams avoided. The methods to be used for depositing concrete under water shall be one of the following:

a) *Tremie* — The concrete is placed through vertical pipes the lower end of which is always inserted sufficiently deep into the concrete which has been placed previously but has not set. The concrete emerging from the pipe pushes the material that has already been placed to the side and upwards and thus does not come into direct contact with water.

   When concrete is to be deposited under water by means of tremie, the top section of the tremie shall be a hopper large enough to hold one entire batch of the mix or the entire contents the transporting bucket, if any. The tremie pipe shall not be less than 200 mm in diameter and shall be large enough to allow a free flow of concrete and strong enough to withstand the external pressure of the water in which it is suspended, even if a partial vacuum develops inside the pipe. Preferably, flanged steel pipe of adequate strength for the job should be used. A separate lifting device shall be provided for each tremie pipe with its hopper at the upper end. Unless the lower end of the pipe is equipped with an approved automatic check valve, the upper end of the pipe shall be plugged with a wadding of the gunny sacking or other approved material before delivering the concrete to the tremie pipe through the hopper, so that when the concrete is forced down from the hopper to the pipe, it will force the plug (and along with it any water in the pipe) down the pipe and out of the bottom end, thus establishing a continuous stream of concrete. It will be necessary to raise slowly the tremie in order to cause a uniform flow of the concrete, but the tremie shall not be emptied so that water enters the pipe. At all times after the placing of concrete is started and until all the concrete is placed, the lower end of the tremie pipe shall be below the top surface of the plastic concrete. This will cause the concrete to build up from below instead of flowing out over the surface, and thus avoid formation of laitance layers. If the charge in the tremie is lost while depositing, the tremie shall be raised above the concrete surface, and unless sealed by a check valve, it shall be re-plugged at the top end, as at the beginning, before refilling for depositing concrete.

b) *Direct placement with pumps* — As in the case of the tremie method, the vertical end piece of the pipe line is always inserted sufficiently deep into the previously cast concrete and should not move to the side during pumping.

c) *Drop bottom bucket* — The top of the bucket shall be covered with a canvas flap. The bottom doors shall open freely downward and outward when tripped. The bucket shall be filled completely and lowered slowly to avoid

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backwash. The bottom doors shall not be opened until the bucket rests on the surface upon which the concrete is to be deposited and when discharged, shall be withdrawn slowly until well above the concrete.

d) *Bags* — Bags of at least 0.028 m^3 capacity of jute or other coarse cloth shall be filled about two-thirds full of concrete, the spare end turned under so that bag is square ended and securely tied. They shall be placed carefully in header and stretcher courses so that the whole mass is interlocked. Bags used for this purpose shall be free from deleterious materials.

e) *Grouting* — A series of round cages made from 50 mm mesh of 6 mm steel and extending over the full height to be concreted shall be prepared and laid vertically over the area to be concreted so that the distance between centres of the cages and also to the faces of the concrete shall not exceed 1 m. Stone aggregate of not less than 50 mm nor more than 200 mm size shall be deposited outside the steel cages over the full area and height to be concreted with due care to prevent displacement of the cages.

A stable 1:2 cement-sand grout with a water-cement ratio of not less than 0.6 and not more than 0.8 shall be prepared in a mechanical mixer and sent down under pressure (about 0.2 N/mm^2) through 38 to 50 mm diameter pipes terminating into steel cages, about 50 mm above the bottom of the concrete. As the grouting proceeds, the pipe shall be raised gradually up to a height of not more than 600 mm above its starting level after which it may be withdrawn and placed into the next cage for further grouting by the same procedure.

After grouting the whole area for a height of about 600 mm, the same operation shall be repeated, if necessary, for the next layer of 600 mm and so on.

The amount of grout to be sent down shall be sufficient to fill all the voids which may be either ascertained or assumed as 55 percent of the volume to be concreted.

13.2.5 To minimise the formulation of laitance, great care shall be exercised not to disturb the concrete as far as possible while it is being deposited.

14 SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX

14.1 General

Samples from fresh concrete shall be taken as per accepted standard [6-5A(20)] and cubes shall be made, cured and tested at 28 days in accordance with accepted standard [6-5A(14)].

14.1.1 In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 ± 2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test. For this purpose the values should be arrived at based on actual testing. In all cases, the 28 days compressive strength specified in Table 2 shall alone be the criterion for acceptance or rejection of the concrete in accordance with **15**.

14.2 Frequency of Sampling

14.2.1 *Sampling Procedure*

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested that is, the sampling should be spread over the entire period of concreting and cover all mixing units.

14.2.2 *Frequency*

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of Concrete in the Work m^3	*Number of Samples*
1-5	1
6-15	2
16-30	3
31-50	4
51 and above	4 plus one additional sample for each additional 50 m^3 or part thereof

NOTE — At least one sample shall be taken from each shift. Where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by the suppliers and the purchasers.

14.3 Test Specimen

Three test specimens shall be made for each sample for testing at 28 days. Additional specimens may be required for various purposes such as to determine the strength of concrete at 7 days or at the time of striking the formwork, or to determine the duration of curing, or to check the testing error. Additional specimens may also be required for testing specimens cured by accelerated methods as described in accepted standard [6-5A(33)]. The specimens shall be tested as described in accepted standard [6-5A(14)].

14.4 Test Results of Sample

The test results of the sample shall be the average of the strength of three specimens. The individual variation

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should not be more than ±15 percent of the average. If more, the test results of the sample are invalid.

15 ACCEPTANCE CRITERIA

15.1 Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following conditions are met:

a) The mean strength determined from any group of four non-overlapping consecutive test results complies with the appropriate limits in col 2 of Table 11.

b) Any individual test result complies with the appropriate limits in col 3 of Table 11.

15.2 Flexural Strength

When both the following conditions are met, the concrete complies with the specified flexural strength:

a) The mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2.

b) The strength determined from any test result is not less than the specified characteristic strength less by 0.3 N/mm^2.

15.3 Quantity of Concrete Represented by Strength Test Results

The quantity of concrete represented by a group of four consecutive test results shall include the batches from which the first and last samples were taken together with all intervening batches.

For the individual test result requirements given in col 3 of Table 11 or in **15.2**(b), only the particular batch from which the sample was taken shall be at risk.

Where the mean rate of sampling is not specified the maximum quantity of concrete that four consecutive test results represent shall be limited to 60 m^3.

15.4 If the concrete is deemed not to comply pursuant to **15.1** or **15.2** as the case may be, the structural adequacy of the parts affected shall be investigated (*see* **16**) and any consequential action as needed shall be taken.

15.5 Concrete of each grade shall be assessed separately.

15.6 Concrete is liable to be rejected if it is porous or honey-combed, its placing has been interrupted without providing a proper construction joint, the reinforcement has been displaced beyond the tolerances specified, or construction tolerances have not been met. However, the hardened concrete may be accepted after carrying out suitable remedial measures to the satisfaction of the Engineer-in-Charge.

Table 11 Characteristic Compressive Strength Compliance Requirement

(*Clauses* 15.1 *and* 15.3)

Specified Grade	Mean of the Group of 4 Non-Overlapping Consecutive Test Results	Individual Test Results
	N/mm^2 *Min*	N/mm^2 *Min*
(1)	(2)	(3)
M 15 and above	≥ f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm^2) or f_{ck} + 3, whichever is greater	≥ f_{ck} − 3

NOTES

1 In the absence of established value of standard deviation, the values given in Table 8 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.

2 For concrete of quantity up to 30 m^3 (where the number of samples to be taken is less than four as per the frequency of sampling given in **14.2.2**), the mean of test results of all such samples shall be f_{ck} + 4 N/mm^2, minimum and the requirement of minimum individual test results shall be f_{ck} − 2 N/mm^2, minimum. However, when the number of sample is only one as per **14.2.2**, the requirement shall be f_{ck} + 4 N/mm^2, minimum.

16 INSPECTION AND TESTING OF STRUCTURES

16.1 Inspection

To ensure that the construction complies with the design an inspection procedure should be set up covering materials, records, workmanship and construction.

16.1.1 Tests should be made on reinforcement and the constituent materials of concrete in accordance with the relevant standards. Where applicable, use should be made of suitable quality assurance schemes.

16.1.2 Care should be taken to see that,

a) design and detail are capable of being executed to a suitable standard, with due allowance for dimensional tolerances;

b) there are clear instructions on inspection standards;

c) there are clear instructions on permissible deviations;

d) elements critical to workmanship, structural performance, durability and appearance are identified; and

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e) there is a system to verify that the quality is satisfactory in individual parts of the structure, especially the critical ones.

16.2 Immediately after stripping the formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good before concrete has thoroughly hardened.

16.3 Testing

In case of doubt regarding the grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of **16.4** and/or load test (*see* **16.6**) may be carried out.

16.4 Core Test

16.4.1 The points from which cores are to be taken and the number of cores required shall be at the discretion of the Engineer-in-Charge and shall be representative of the whole of concrete concerned. In no case, however, shall fewer than three cores be tested.

16.4.2 Cores shall be prepared and tested as described in accepted standard [6-5A(14)].

16.4.3 Concrete in the member represented by a core test shall be considered acceptable if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of the grade of concrete specified for the corresponding age and no individual core has a strength less than 75 percent.

16.5 In case the core test results do not satisfy the requirements of **16.4.3** or where such tests have not been done, load test (*see* **16.6**) may be restored to.

16.6 Load Tests for Flexural Member

16.6.1 Load tests should be carried out as soon as possible after expiry of 28 days from the time of placing of concrete.

16.6.2 The structure should be subjected to a load equal to full dead load of the structure plus 1.25 times the imposed load for a period of 24 h and then the imposed load shall be removed.

NOTE — Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

16.6.3 The deflection due to imposed load only shall be recorded. If within 24 h of removal of the imposed load, the structure does not recover at least 75 percent of the deflection under superimposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80 percent, the structure shall be deemed to be unacceptable.

16.6.3.1 If the maximum deflection in mm, shown during 24 h under load is less than $40\left(\frac{l^2}{D}\right)$, where l is the effective span in m; and D, the overall depth of the section, in mm, it is not necessary for the recovery to be measured and the recovery provisions of **16.6.3** shall not apply.

16.7 Members Other Than Flexural Members

Members other than flexural members should be preferably investigated by analysis.

16.8 Non-Destructive Tests

Non-destructive tests are used to obtain estimation of the properties of concrete in the structure. The methods adopted include ultrasonic pulse velocity and rebound hammer {*see* accepted standards [6-5A(34)]}, probe penetration, pullout and maturity. Non-destructive tests provide alternatives to core tests for estimating the strength of concrete in a structure, or can supplement the data obtained from a limited number of cores. These methods are based on measuring a concrete property that bears some relationship to strength. The accuracy of these methods, in part, is determined by the degree of correlation between strength and the physical quality measured by the non-destructive tests.

Any of these methods may be adopted, in which case the acceptance criteria shall be agreed upon prior to testing.

SECTION 5A (B2) SPECIAL CONCRETE

16A SELF COMPACTING CONCRETE

16A.1 General

The Self Compacting Concrete (SCC) is highly flowable, non-segregating concrete that fills uniformly and completely every corner of formwork by its own weight without the need for any compaction and encapsulates reinforcement or any other embedment. The provisions relating to its application areas, features, mix proportioning principles, and production and engineering properties are given hereunder. The provisions for concrete making materials and concrete as given in Section 5A (B1) 'Materials, Workmanship, Inspection and Testing' shall apply to SCC except where different provisions or departures have been indicated hereunder.

16A.2 Application Areas

SCC may be used in *in-situ* concrete or for precast concrete applications. It is particularly appropriate for sections with highly congested reinforcement such as, nuclear power plant structures, machine foundations, piers and abutments; and areas having restricted access

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to concrete placement and compaction like shafts in hydropower structures. SCC is also suitable for the construction of tunnel lining sections and casting of concrete-filled steel tubular columns. SCC may also be used for columns and beams in normal construction with appropriate formwork design.

SCC may be produced in a batching plant on site or in ready-mixed concrete plant and transported to site by transit mixers. It may be placed either by pumping or other placement methods into horizontal or vertical forms.

16A.3 Features of Fresh Self Compacting Concrete

The features of fresh SCC are:

a) Filling ability (Flowability),
b) Passing ability,
c) Segregation resistance, and
d) Viscosity.

16A.3.1 *Filling Ability (Flowability)*

Filling ability of SCC determines its ability to flow into and fill all spaces within the formwork, under its own weight. The filling ability is tested using slump-flow test.

16A.3.1.1 *Procedure*

Slump flow test shall be carried out in accordance with accepted standard [6-5A(20)].

16A.3.1.2 *Classes of slump-flow and their application*

There are three classes of slump-flow, as follows:

a) *SF1 (slump flow 550 mm - 650 mm)* — This class of SCC is appropriate for,
   1) unreinforced or slightly reinforced concrete structures that are cast from the top with free displacement from the delivery point (such as slabs),
   2) casting by a pump injection system (such as tunnel linings), and
   3) sections those are small enough to prevent long horizontal flow (for example, piles and some deep foundations).
b) *SF2 (slump flow 650 mm - 750 mm)* is suitable for many normal applications (for example, walls, columns)
c) *SF3 (slump flow 750 mm - 850 mm)* is typically produced with a small maximum size of aggregates (less than 20 mm) and is used for vertical applications in structures having congested reinforcement, structures with complex shapes, etc. *SF*3 will often give better surface finish than *SF*2 for normal vertical applications but segregation resistance is more difficult to control.

16A.3.2 *Passing Ability (Free from Blocking at Reinforcement)*

Passing ability describes the capacity of the fresh mix to flow through confined spaces and narrow openings such as areas of congested reinforcement without segregation. If there is little or no reinforcement, there may be no need to specify passing ability as a requirement. L-box test is generally carried out to check the passing ability and the procedure shall be in accordance with accepted standard [6-5A(20)]. In this test, the height of the concrete left in the vertical section (h_1) and at the end of the horizontal section (h_2) is measured. The ratio of h_2/h_1 is calculated as the blocking ratio; which shall be between 0.8 and 1.0.

16A.3.3 *Segregation Resistance (Stability)*

Segregation resistance is the ability of fresh concrete to remain homogeneous in composition while in its fresh state. Segregation resistance is generally carried out using sieve test to check this property of fresh concrete.

16A.3.3.1 *Procedure*

Segregation resistance (sieve) test shall be carried out in accordance with accepted standard [6-5A(20)].

16A.3.3.2 *Test results*

There are two classes of segregation resistance, namely *SR*1 and *SR*2. For *SR*1 class, segregation resistance should be above 15 percent and ≤ 20 percent, and for *SR*2 it should be ≤15 percent.

*SR*1 is generally applicable for thin slabs and for vertical applications with a flow distance of less than 5 m and a confinement gap greater than 80 mm. *SR*2 is preferred in vertical applications if the flow distance is more than 5 m with a confinement gap greater than 80 mm in order to take care of segregation during flow. Segregation resistance becomes an important parameter with higher slump-flow classes and/or the lower viscosity class, or if placing conditions promote segregation. If none of these apply, it is usually not necessary to specify a segregation resistance class.

16A.3.4 *Viscosity*

Viscosity can be assessed by the V-funnel flow time. Concrete with a low viscosity will have a very quick initial flow and then stop. Concrete with a high viscosity may continue to creep forward over an extended time.

16A.3.4.1 *Procedure*

Viscosity by V-funnel test is carried out in accordance with accepted standard [6-5A(20)]. A V-shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time.

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16A.3.4.2 *Test results*

The viscosity is divided into two classes, namely *V*1 and *V*2. For *V*1 class, the time taken to pass the concrete from V-funnel shall be ≤ 8 s and for *V*2 class, it shall be above 8 s and ≤ 25 s.

*V*1 has good filling ability even with congested reinforcement. It is capable of self-levelling and generally has excellent surface finish. *V*2 class viscosity is more likely to exhibit thixotropic effects, which may be helpful in limiting the formwork pressure or improving segregation resistance. But it may cause negative effects on surface finish and sensitivity to stoppages or delays between successive lifts.

16A.4 Mix Proportioning

16A.4.1 *Mix Proportion Principles*

The principles listed below shall be followed:

a) Lower coarse aggregate content;
b) Increased paste content;
c) Low water/powder ratio (*see* Note);
d) High range superplasticizer; and
e) Viscosity modifying admixture, if required.

NOTE — Powder is the material of particle size smaller than 0.125 mm. It includes this size fraction in the cement, mineral admixtures and aggregate.

16A.4.2 *Mix Design Procedure*

For mix design procedure, reference may be made to good practice [6-5A(35)].

16A.5 Production of Self Compacting Concrete

16A.5.1 *General*

SCC is less tolerant to changes in constituent characteristics and batching variances as compared to conventional concrete. Accordingly, it is important that all aspects of the production and placing processes are carefully supervised.

The production of SCC should be carried out in plants where the equipment, operation and materials are suitably controlled under a Quality Assurance Scheme. It is important that all personnel who will be involved in the production and delivery of SCC are adequately trained including practical demonstrations.

16A.5.2 *Constituents*

SCC is more sensitive than conventional concrete to variation in the physical properties of its constituents and especially to changes in aggregate moisture content, grading and shape. So, more frequent production checks are necessary. The moisture content of aggregates should be continuously monitored and the mix adjusted to account for any variation.

Storage of constituent materials for SCC shall be same as that for materials for conventional concrete. However, as the SCC mix is more sensitive to variations, special precautions shall be taken for storage of aggregates, which should be properly stored to avoid cross-contamination between different types and sizes and protected from weather to minimise the fluctuation of surface moisture content and movement of fines. Ground stock should be stored in purpose-built partitioned bays, which should allow free drainage of excess moisture in the aggregates and rainwater.

16A.5.3 *Mixing Equipment and Trial Mixes*

SCC shall be produced with efficient forced action concrete mixers. The time necessary to achieve complete mixing of SCC may be longer than for conventional concrete due to reduced frictional forces and to fully activate the superplasticizer.

16A.5.4 *Formwork*

Formwork should be watertight and grout tight when placing SCC. The need to design the formwork for water tightness is greater than conventional formwork so as to avoid honeycombs and surface defects. The high fluid nature of SCC may lead to higher formwork pressure than conventional concrete, especially when the casting rate is high. As a result of the highly fluid nature of SCC, a high placement rate is likely and should be anticipated. Formwork designs, that accommodate the expected liquid head formwork pressure, can allow unrestricted placement rates and permit fast casting rate of the SCC. It is recommended to design the formwork for full liquid head.

16A.5.5 *Curing*

Curing is essential for all concrete, and early protection of exposed surfaces is essential to preventing rapid moisture loss that could lead to plastic shrinkage cracking. The top-surface of elements made with SCC can dry quickly because of the increased quantity of paste, the low water/fines ratio and the lack of bleed water at the surface. Initial curing should therefore commence as soon as practicable after placing and finishing in order to minimise the risk of surface crusting and shrinkage cracks caused by early age moisture evaporation.

16A.6 Engineering Properties

16A.6.1 *General*

SCC and conventional concrete of similar compressive strength have comparable properties.

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16A.6.2 *Compressive Strength*

SCC with a similar water-cement ratio usually have a slightly higher strength compared to conventional concrete due to the lack of vibration giving an improved interface between the aggregate and hardened paste.

16A.6.3 *Tensile Strength*

SCC may be supplied with any specified concrete grade. For a given concrete grade, the tensile strength may be safely assumed to be the same as the one for a conventional concrete as the volume of paste (cement + fines + water) has no significant effect on tensile strength.

16A.6.4 *Static Modulus of Elasticity*

Increasing the paste volume may decrease the modulus of elasticity, E_c. As SCC has higher paste content than conventional concrete, some difference can be expected and the E_c may be somewhat lower and should be adequately covered by the safe assumptions in design.

If SCC does have a slightly lower E_c than conventional concrete, in prestressing work, this will affect the relationship between the compressive strength and the camber due to pre-tensioning or post-tensioning. For this reason, careful control should be exercised over the strength at the time when the pre-tensioning and post-tensioning strands or wires are released.

16A.6.5 *Creep*

Due to the higher volume of cement paste, the creep coefficient for SCC may be expected to be higher than for conventional concrete of equal strength, but such differences are small and shall be covered by the safe assumptions in design.

16A.6.6 *Shrinkage*

As concrete compressive strength is related to the water-cement ratio, in SCC with a low water-cement ratio drying shrinkage reduces, but with increased cementitious content and increased water content the drying shrinkage and autogenous shrinkage can increase.

16A.6.7 *Durability*

SCC is free from shortcomings due to improper compaction and result in consistently low and uniform permeability, offering less weak points for deleterious actions of the environment.

16B HIGH PERFORMANCE CONCRETE

16B.1 General

High performance concrete is a concrete whose ingredients, proportions and production methods are specifically chosen to meet special performance and uniformity requirements. The higher performance requirements may be as follows:

Sl No.	*Higher Performance Requirements*	*Remarks/Applications*
(1)	(2)	(3)
i)	High resistance to deterioration of reinforced concrete due to carbonation	This is to help achieve longer service life. This is particularly applicable in semi-arid regions
ii)	High resistance to chloride attack/ingress	This is for longer service life of reinforced concrete exposed to severe chloride environment/coastal environment
iii)	High resistance to abrasion	This may be required in concrete structures, like parts of hydraulic structures exposed to continuous abrasive action due to silt, such as spillways/glacis; and concrete pavements exposed to heavy traffic
iv)	High resistance to impact	This may be required in structures like blast resistant structures and spillways
v)	Improvement in flexure and shear performance	This is required in bridge girders, joints of RCC framed structure, shear walls, etc
vi)	High resistance to cracking due to shrinkage (plastic and drying shrinkage)	This may be required in concrete/mortar used for repair of distressed concrete structures, etc

High strength concrete generally improves performance of all above parameters. The concrete mix proportioning for high strength concrete may be carried out in accordance with the good practice [6-5A(35)]. However, special measures are needed to further improve the specific performance requirements. As a guide, the measures given in **16B.2** may be adopted. For further details, expert literature may be referred.

16B.2 Measures for Improving Specific Performance Requirements

16B.2.1 *Resistance to Carbonation*

Resistance to carbonation of concrete is dependent mainly upon the following:

a) Type of binder, content of binder and *p*H value of concrete; and

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b) Permeability of concrete.

Addition of silica fume, GGBS and fly ash improve denseness and reduce permeability, thus increasing resistance to ingress of carbon dioxide and moisture (needed for carbonation). The addition of fly ash above 35 percent tends to lower the alkalinity, and thus the resistance to carbonation. Lower water-cement ratios and higher grades of concrete can be adopted to improve performance in this case. Minimum OPC content is essential for adequate carbonation resistance for different exposure conditions.

Carbonation resistance can be checked by using accelerated carbonation tests (using 3 to 4 percent CO_2 concentrations for minimum 70 days exposure) at mix proportioning stage. For quality assurance purpose, rapid tests like rapid chloride ion penetration test (RCPT), air permeability test or electrical resistivity test may be used. Their values may be established by correlation with accelerated carbonation test values at mix proportioning stage.

16B.2.2 *Resistance to Chloride Ingress*

To improve performance of concrete exposed to chloride environment, the following two aspects need to be considered:

a) Total initial chloride content in concrete should be minimised; and
b) Permeability of concrete should be low.

Whereas chloride content of concrete can be controlled by checking chloride content of mix ingredients, the permeability of concrete can be reduced by careful selection of mix proportions and by use of supplementary cementing materials, either through use of blended cements like PPC and PSC or by direct addition of mineral admixtures, like fly ash, GGBS and silica fume. To control permeability, durability test of resistance to chloride ions shall be carried out by using chloride diffusion test by immersion or ponding method (using 3 percent NaCl exposure for 90 days) at mix proportioning stage. For quality assurance purpose rapid tests corresponding values like rapid chloride ion penetration test (RCPT) or electrical resistivity test shall be carried out. Corresponding values for these tests shall be established by developing a correlation with chloride diffusion test (by immersion/ponding) at mix proportioning stage.

16B.2.3 *Resistance to Abrasion*

To ensure good performance against abrasion, following points should be considered:

a) Use of higher grades of concrete;
b) Use of good quality strong aggregate;
c) Use of silica fume; and
d) Use of steel fibres (suited for increasing abrasion resistance in spillways/glacis, etc).

Test methods for measuring abrasion resistance are:

1) Revolving disc type test.
2) Under water abrasion resistance test using steel balls.

For further details regarding test methods and criteria, specialist literature may be referred.

16B.2.4 *Improving Performance in Flexure, Shear, Impact, Ductility and Energy Absorption*

Resistance to impact is generally increased when the strength of concrete is high and energy absorption is high. Energy absorption and toughness can be increased by use of steel fibres in concrete. Whereas addition of steel fibres, glass or carbon fibres improves flexural and shear strength also, the use of synthetic fibres like polypropylene fibres do not significantly improve the above properties. Polypropylene fibres do however reduce shrinkage cracking and are suitable for concrete/ mortar used for concrete repairs.

For checking impact resistance, falling weight impact test can be used, wherein number of blows for crack initiation in small concrete slab panel are counted.

For further details regarding test methods and criteria, specialist literature may be referred. The use of steel fibre reinforced concrete shall be further governed by **16B.2.4.1.**

16B.2.4.1 *Use of steel fibre reinforced concrete (SFRC)*

Following properties of concrete can be improved by using SFRC:

a) Ductility,
b) Toughness and energy absorption,
c) Abrasion, and
d) Flexural strength and shear strength.

Compressive and direct tensile strength gain in flexural and direct tensile strength is very significant when higher percentage of steel fibres are used which give the concrete a strain hardening effect (increase in ultimate load after initial crack). However significant improvements are achieved in strain softening zone also.

Steel fibres having aspect ratio 60 to 80 may be incorporated in concrete of different grades to improve the ductility of concrete. Fibre content varying from 0.5 to 2.5 percent volume may be incorporated in to the concrete to improve different mechanical and durability characteristics. However higher addition can cause problems in uniform mixing and placing of concrete which need to be checked at mix proportioning stage before using the mix. Corrosion of steel fibres

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can also occur particularly in lower grades, so use of coated fibres and higher grades of concrete are recommended. Alternatively, a plain concrete cover of few mm can also be provided.

Design of steel fibre reinforced concrete (SFRC) for structural performance shall be in accordance with Annex A.

SECTION 5A (C) GENERAL DESIGN CONSIDERATION

17 BASES FOR DESIGN

17.1 Aim of Design

The aim of design is the achievement of an acceptable probability that structures being designed will perform satisfactorily during their intended life. With an appropriate degree of safety, they should sustain all the loads and deformations of normal construction and use and have adequate durability and adequate resistance to the effects of misuse and fire.

17.2 Methods of Design

17.2.1 Structure and structural elements shall normally be designed by Limit State Method. Account should be taken of accepted theories, experiment and experience and the need to design for durability. Calculations alone do not produce safe, serviceable and durable structures. Suitable materials, quality control, adequate detailing and good supervision are equally important.

17.2.2 Where the Limit State Method cannot be conveniently adopted, Working Stress Method (*see* Annex B) may be used.

17.2.3 *Design Based on Experimental Basis*

Designs based on experimental investigations on models or full size structure or element may be accepted if they satisfy the primary requirements of **17.1** and subject to experimental details and the analysis connected therewith being approved by the Engineer-in-Charge.

17.2.3.1 Where the design is based on experimental investigation on full size structure or element, load tests shall be carried out to ensure the following:

a) The structure shall satisfy the requirements for deflection (*see* **22.2**) and cracking (*see* **34.3.2**) when subjected to a load for 24 h equal to the characteristic load multiplied by 1.33 γ_f where γ_f shall be taken from Table 18, for the limit state of serviceability. If within 24 h of the removal of the load, the structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under the load, the test loading should be repeated after a lapse of 72 h. The recovery after the second test should be at least 75 percent of the maximum deflection shown during the second test.

   NOTE — If the maximum deflection in mm, shown during 24 h under load is less than $40\left(\frac{\ell^2}{D}\right)$ where ℓ is the effective span in m; and D is the overall depth of the section, in mm, it is not necessary for the recovery to be measured.

b) The structure shall have adequate strength to sustain for 24 h, a total load equal to the characteristic load multiplied by 1.33 γ_f where γ_f shall be taken from Table 18 for the limit state of collapse.

17.3 Durability, Workmanship and Materials

It is assumed that the quality of concrete, steel and other materials and of the workmanship, as verified by inspections, is adequate for safety, serviceability and durability.

17.4 Design Process

Design, including design for durability, construction and use in service should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, production, workmanship and also maintenance and use of structure in service.

18 LOADS AND FORCES

18.1 General

In structural design, account shall be taken of the dead, imposed and wind loads and forces such as those caused by earthquake, and effects due to shrinkage, creep, temperature, etc, where applicable.

18.2 Dead Loads

Dead loads shall be calculated on the basis of unit weights which shall be established taking into consideration the materials specified for construction.

18.2.1 Alternatively, the dead loads may be calculated on the basis of unit weights of materials given in **2** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. Unless more accurate calculations are warranted, the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^3 and 25 kN/m^3, respectively.

18.3 Imposed Loads, Wind Loads and Snow Loads

Imposed loads, wind loads and snow loads shall be assumed in accordance with **3**, **4** and **6** of Part 6

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'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

18.4 Earthquake Forces

The earthquake forces shall be calculated in accordance with **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

18.5 Shrinkage, Creep and Temperature Effects

If the effects of shrinkage, creep and temperature are liable to affect materially the safety and serviceability of the structure, these shall be taken into account in the calculations (*see* **5.2.4**, **5.2.5** and **5.2.6** of this Subsection and **7** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

18.5.1 In ordinary buildings, such as low rise dwellings whose lateral dimension do not exceed 45 m, the effects due to temperature fluctuations and shrinkage and creep can be ignored in design calculations.

18.6 Other Forces and Effects

In addition, account shall be taken of the following forces and effects if they are liable to affect materially the safety and serviceability of the structure:

a) Foundation movement (*see* Part 6 'Structural Design, Section 4 Masonry' of the Code),
b) Elastic axial shortening,
c) Soil and fluid pressures (*see* **7** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code),
d) Vibration,
e) Fatigue,
f) Impact (*see* **7** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code),
g) Erection loads (*see* **3** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code), and
h) Stress concentration effect due to point load and the like.

18.7 Combination of Loads

The combination of loads shall be as given in **8** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

18.8 Dead Load Counteracting Other Loads and Forces

When dead load counteracts the effects due to other loads and forces in structural member or joint, special care shall be exercised by the designer to ensure adequate safety for possible stress reversal.

18.9 Design Load

Design load is the load to be taken for use in the appropriate method of design; it is the characteristic load in case of working stress method and characteristic load with appropriate partial safety factors for limit state design.

19 STABILITY OF THE STRUCTURE

19.1 Overturning

The stability of a structure as a whole against overturning shall be ensured so that the restoring moment shall be not less than the sum of 1.2 times the maximum overturning moment due to the characteristic dead load and 1.4 times the maximum overturning moment due to the characteristic imposed loads. In cases where dead load provides the restoring moment, only 0.9 times the characteristic dead load shall be considered. Restoring moment due to imposed loads shall be ignored.

19.1.1 The anchorages or counterweights provided for overhanging members (during construction and service) should be such that static equilibrium should remain, even when overturning moment is doubled.

19.2 Sliding

The structure shall have a factor against sliding of not less than 1.4 under the most adverse combination of the applied characteristic forces. In this case only 0.9 times the characteristic dead load shall be taken into account.

19.3 Probable Variation in Dead Load

To ensure stability at all times, account shall be taken of probable variations in dead load during construction, repair or other temporary measures. Wind and seismic loading shall be treated as imposed loading.

19.4 Moment Connection

In designing the framework of a building, provisions shall be made by adequate moment connections or by a system of bracings to effectively transmit all the horizontal forces to the foundations.

19.5 Lateral Sway

Under transient wind load the lateral sway at the top should not exceed $H/500$, where H is the total height of the building. For seismic loading, reference should be made to **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

20 FIRE RESISTANCE

20.1 A structure or structural element required to have fire resistance should be designed to possess an appropriate degree of resistance to flame penetration;

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heat transmission and failure. The fire resistance of a structural element is expressed in terms of time in hours in accordance with **3** of Part 4 'Fire and Life Safety' of the Code. Fire resistance of concrete elements depends upon details of member size, cover to steel reinforcement detailing and type of aggregate (normal weight or light weight) used in concrete. Essential requirements of fire safety of buildings with respect to details of construction are also given in **3** of Part 4 'Fire and Life Safety' of the Code.

20.2 Minimum requirements of concrete cover and member dimensions for normal-weight aggregate concrete members so as to have the required fire resistance shall be in accordance with **25.4.3** and Fig. 1, respectively.

20.3 The reinforcement detailing should reflect the changing pattern of the structural action and ensure that both individual elements and the structure as a whole contain adequate support, ties, bonds and anchorages for the required fire resistance.

20.3.1 Additional measures such as application of fire resistant finishes, provision of fire resistant false ceilings and sacrificial steel in tensile zone, should be adopted in case the nominal cover required exceeds 40 mm for beams and 35 mm for slabs, to give protection against spalling.

20.4 Specialist literature may be referred to for determining fire resistance of the structures which have not been covered in Fig. 1 or Table 16A.

21 ANALYSIS

21.1 General

All structures may be analysed by the linear elastic theory to calculate internal actions produced by design loads. *In-lieu* of rigorous elastic analysis, a simplified analysis as given in **21.4** for frames and as given in **21.5** for continuous beams may be adopted.

21.2 Effective Span

Unless otherwise specified, the effective span of a member shall be as follows:

a) *Simply supported beam or slab* — The effective span of a member that is not built integrally with its supports shall be taken as clear span plus the effective depth of slab or beam or centre-to-centre of supports, whichever is less.

b) *Continuous beam or slab* — In the case of continuous beam or slab, if the width of the support is less than 1/12 of the clear span, the effective span shall be as given in **21.2** (a). If the supports are wider than 1/12 of the clear span or 600 mm, whichever is less, the effective span shall be taken as under :

1) For end span with one end fixed and the other continuous or for intermediate spans, the effective span shall be the clear span between supports;
2) For end span with one end free and the other continuous, the effective span shall be equal to the clear span plus half the effective depth of the beam or slab or the clear span plus half the width of the discontinuous support, whichever is less;
3) In the case of spans with roller or rocker bearings, the effective span shall always be the distance between the centres of bearings.

c) *Cantilever* — The effective length of a cantilever shall be taken as its length to the face of the support plus half the effective depth except where it forms the end of a continuous beam where the length to the centre of support shall be taken.

d) *Frames* — In the analysis of a continuous frame, centre-to-centre distance shall be used.

21.3 Stiffness

21.3.1 *Relative Stiffness*

The relative stiffness of the members may be based on the moment of inertia of the section determined on the basis of any one of the following definitions:

a) *Gross section* — The cross-section of the member ignoring reinforcement;

b) *Transformed section* — The concrete cross-section plus the area of reinforcement transformed on the basis of modular ratio (*see* **B-1.3**); or

c) *Cracked section* — The area of concrete in compression plus the area of reinforcement transformed on the basis of modular ratio.

The assumptions made shall be consistent for all the members of the structure throughout any analysis.

21.3.2 For deflection calculations, appropriate values of moment of inertia as specified in Annex C should be used.

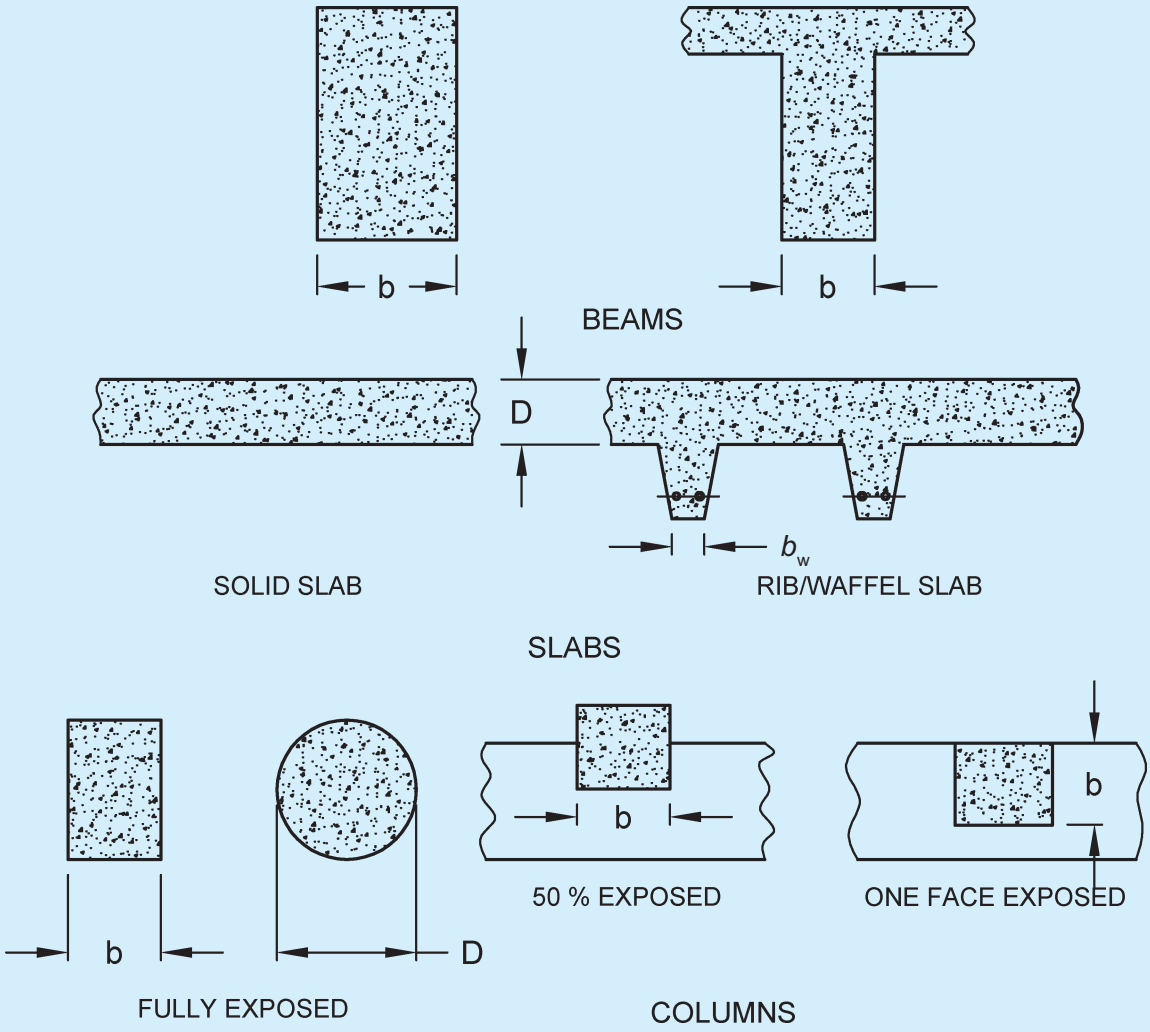
21.4 Structural Frames

The simplifying assumptions as given in **21.4.1** to **21.4.3** may be used in the analysis of frames.

21.4.1 *Arrangement of Imposed Load*

a) Consideration may be limited to combinations of,

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Fire Resistance	*Minimum Beam Width*	*Rib Width of Slabs*	*Minimum Thickness of Floors*	*Minimum Column Dimension (b or D)*			*Minimum Wall Thickness*		
				Fully Exposed	50% Exposed	One Face Exposed	$p < 0.4\%$	$0.4\% \leq p \leq 1\%$	$p > 1\%$
	b	b_w	*D*						
h	mm	mm	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
0.5	200	125	75	150	125	100	150	100	100
1	200	125	95	200	160	120	150	120	100
1.5	200	125	110	250	200	140	175	140	100
2	200	125	125	300	200	160	—	160	100
3	240	150	150	400	300	200	—	200	150
4	280	175	170	450	350	240	—	240	180

NOTES

1 These minimum dimensions relate specifically to the covers given in Table 16A.

2 *p* is the percentage of steel reinforcement.

FIG. 1 MINIMUM DIMENSIONS OF REINFORCED CONCRETE MEMBERS FOR FIRE RESISTANCE

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1) design dead load on all spans with full design imposed load on two adjacent spans; and
2) design dead load on all spans with full design imposed load on alternate spans.

b) When design imposed load does not exceed three-fourths of the design dead load, the load arrangement may be design dead load and design imposed load on all the spans.

NOTE — For beams and slabs continuous over support **21.4.1**(a) may be assumed.

21.4.2 *Substitute Frame*

For determining the moments and shears at any floor or roof level due to gravity loads, the beams at that level together with columns above and below with their far ends fixed may be considered to constitute the frame.

21.4.2.1 Where side sway consideration becomes critical due to unsymmetry in geometry or loading, rigorous analysis may be required.

21.4.3 For lateral loads, simplified methods may be used to obtain the moments and shears for structures that are symmetrical. For unsymmetrical or very tall structures, more rigorous methods should be used.

21.5 Moment and Shear Coefficients for Continuous Beams

21.5.1 Unless more exact estimates are made, for beams of uniform cross-section which support substantially uniformly distributed loads over three or more spans which do not differ by more than 15 percent of the longest, the bending moments and shear forces used in design may be obtained using the coefficients given in Table 12 and Table 13, respectively.

For moments at supports where two unequal spans meet or in case where the spans are not equally loaded, the average of the two values for the negative moment at the support may be taken for design.

Table 12 Bending Moment Coefficients

(*Clause* 21.5.1)

Sl No.	Type of Load	Span Moments		Support Moments	
		Near Middle of End Span	At Middle of Interior Span	At Support Next to the End Support	At Other Interior Supports
(1)	(2)	(3)	(4)	(5)	(6)
i)	Dead load and imposed load (fixed)	$+\frac{1}{12}$	$+\frac{1}{16}$	$-\frac{1}{10}$	$-\frac{1}{12}$
ii)	Imposed load (not fixed)	$+\frac{1}{10}$	$+\frac{1}{12}$	$-\frac{1}{9}$	$-\frac{1}{9}$

NOTE — For obtaining the bending moment, the coefficient shall be multiplied by the total design load and effective span.

Where coefficients given in Table 12 are used for calculation of bending moments, redistribution referred to in **21.7** shall not be permitted.

21.5.2 *Beams and Slabs Over Free End Supports*

Where a member is built into a masonry wall which develops only partial restraint, the member shall be designed to resist a negative moment at the face of the support of $Wl/24$ where W is the total design load and l is the effective span, or such other restraining moment as may be shown to be applicable. For such a condition shear coefficient given in Table 13 at the end support may be increased by 0.05.

Table 13 Shear Force Coefficients

(*Clauses* 21.5.1 *and* 21.5.2)

Sl No.	Type of Load	At End Support	At Support Next to the End Support		At All Other Interior Supports
			Outer Side	Inner Side	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Dead load and imposed load (fixed)	0.4	0.6	0.55	0.5
ii)	Imposed load (not fixed)	0.45	0.6	0.6	0.6

NOTE — For obtaining the shear force, the coefficient shall be multiplied by the total design load.

21.6 Critical Sections for Moment and Shear

21.6.1 For monolithic construction, the moments computed at the face of the supports shall be used in the design of the members at those section. For non-monolithic construction the design of the member shall be done keeping in view **21.2**.

21.6.2 *Critical Section for Shear*

The shears computed at the face of the support shall be used in the design of the member at that section except as in **21.6.2.1**.

21.6.2.1 When the reaction in the direction of the applied shear introduces compression into the end region of the member, sections located at a distance less than d from the face of the support may be designed for the same shear as that computed at distance d (*see* Fig. 2).

NOTE — The above clauses are applicable for beams generally carrying uniformly distributed load or where the principal load is located farther than $2d$ from the face of the support.

21.7 Redistribution of Moments

Redistribution of moments may be done in accordance with **36.1.1** for limit state method and in accordance with **B-1.2** for working stress method. However, where

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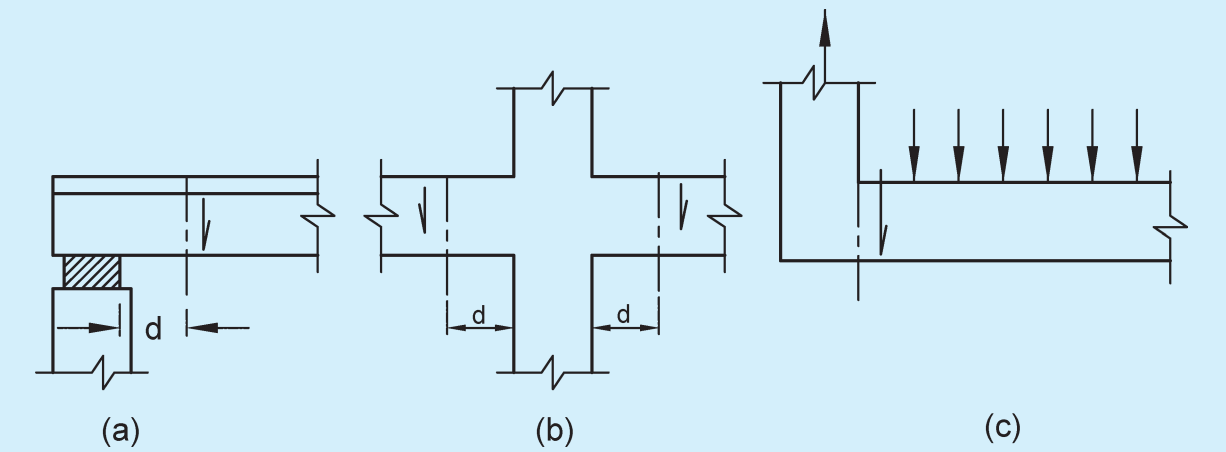


FIG. 2 TYPICAL SUPPORT CONDITIONS FOR LOCATING FACTORED SHEAR FORCE

simplified analysis using coefficients is adopted, redistribution of moments shall not be done.

22 BEAMS

22.0 Effective Depth

Effective depth of a beam is the distance between the centroid of the area of tension reinforcement and the maximum compression fibre, excluding the thickness of finishing material not placed monolithically with the member and the thickness of any concrete provided to allow for wear. This will not apply to deep beams.

22.1 T-Beams and L-Beams

22.1.1 *General*

A slab which is assumed to act as a compression flange of a T-beam or L-beam shall satisfy the following:

a) The slab shall be cast integrally with the web, or the web and the slab shall be effectively bonded together in any other manner; and

b) If the main reinforcement of the slab is parallel to the beam, transverse reinforcement shall be provided as in Fig. 3; such reinforcement shall not be less than 60 percent of the main reinforcement at mid span of the slab.

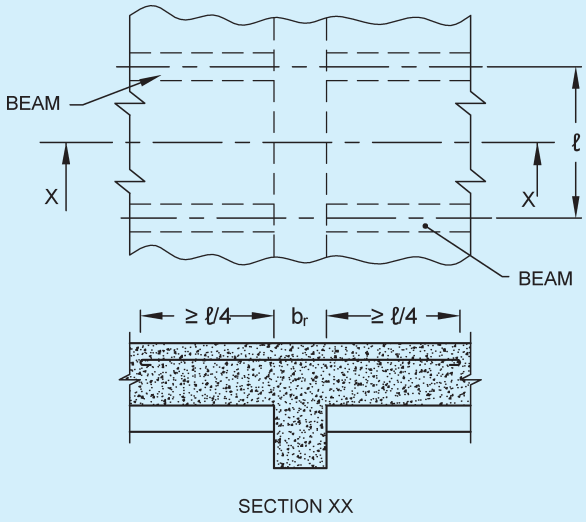


FIG. 3 TRANSVERSE REINFORCEMENT IN FLANGE OF T- BEAM WHEN MAIN REINFORCEMENT OF SLAB IS PARALLEL TO THE BEAM

22.1.2 *Effective Width of Flange*

In the absence of more accurate determination, the effective width of flange may be taken as the following but in no case greater than the breadth of the web plus half the sum of the clear distances to the adjacent beams on either side:

a) For T-beams, $b_f = \frac{l_0}{6} + b_w + 6D_f$

b) For L-beams, $b_f = \frac{l_0}{12} + b_w + 3D_f$

c) For isolated beams, the effective flange width shall be obtained as below but in no case greater than the actual width:

T-beams, $b_f = \frac{l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$

L-beams, $b_f = \frac{0.5l_0}{\left(\frac{l_0}{b}\right)+4} + b_w$

where

b_f = effective width of flange,

l_0 = distance between points of zero moments in the beam,

b_w = breadth of the web,

D_f = thickness of flange, and

b = actual width of the flange.

NOTE — For continuous beams and frames, 'l_0' may be assumed as 0.7 times the effective span.

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22.2 Control of Deflection

The deflection of a structure or part thereof shall not adversely affect the appearance or efficiency of the structure or finishes or partitions. The deflection shall generally be limited to the following:

a) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.

b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm, whichever is less.

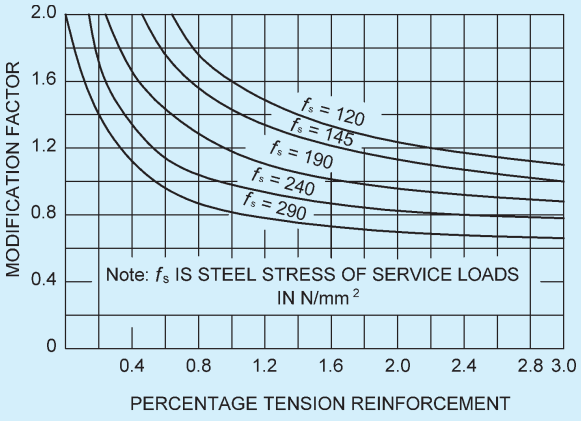
22.2.1 The vertical deflection limits may generally be assumed to be satisfied provided that the span to depth ratios are not greater than the values obtained as below:

a) Basic values of span to effective depth ratios for spans up to 10 m:

Cantilever	:	7
Simply supported	:	20
Continuous	:	26

b) For spans above 10 m, the values in (a) may be multiplied by 10/span in metres, except for cantilever in which case deflection calculations should be made.

c) Depending on the area and the stress of steel for tension reinforcement, the values in (a) or (b) shall be modified by multiplying with the modification factor obtained as per Fig. 4.



$$f_s = 0.58 f_y \frac{\text{Area of cross – section of steel required}}{\text{Area of cross – section of steel provided}}$$

FIG. 4 MODIFICATION FACTOR FOR TENSION REINFORCEMENT

d) Depending on the area of compression reinforcement, the value of span to depth ratio be further modified by multiplying with the modification factor obtained as per Fig. 5.

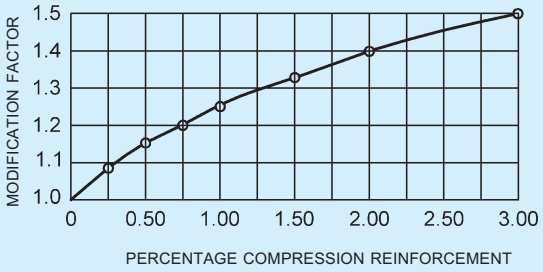


FIG. 5 MODIFICATION FACTOR FOR COMPRESSION REINFORCEMENT

e) For flanged beams, the values of (a) or (b) be modified as per Fig. 6 and the reinforcement percentage for use in Fig. 4 and Fig. 5 should be based on area of section equal to $b_f d$.

NOTE — When deflections are required to be calculated, the method given in Annex C may be used.

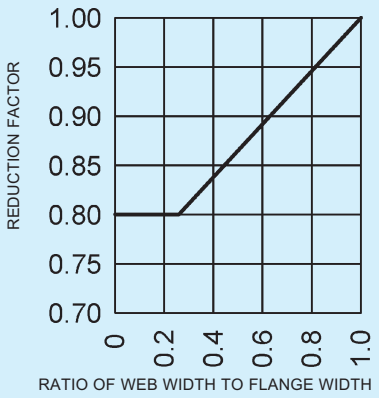


FIG. 6 REDUCTION FACTORS FOR RATIOS OF SPAN TO EFFECTIVE DEPTH FOR FLANGED BEAMS

22.3 Slenderness Limits for Beams to Ensure Lateral Stability

A simply supported or continuous beam shall be so proportioned that the clear distance between the lateral restraints does not exceed 60 b or 250 $\left(\frac{b^2}{d}\right)$, whichever is less, where d is the effective depth of the beam and b the breadth of the compression face midway between the lateral restraints.

For a cantilever, the clear distance from the free end of the cantilever to the lateral restraint shall not exceed 25 b or 100 $\left(\frac{b^2}{d}\right)$, whichever is less.

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23 SOLID SLABS

23.1 General

The provisions of **22.2** for beams apply to slabs also.

NOTES

1 For slabs spanning in two directions, the shorter of the two spans should be used for calculating the span to effective depth ratios.

2 For two-way slabs of shorter spans (up to 3.5 m) with mild steel reinforcement, the span to overall depth ratios given below may generally be assumed to satisfy vertical deflection limits for loading class up to 3 kN/m^2.

a) Simply supported slabs : 35

b) Continuous slabs : 40

For high strength deformed bars of Grade Fe 415, the values given above should be multiplied by 0.8.

23.2 Slabs Continuous Over Supports

Slabs spanning in one direction and continuous over supports shall be designed according to the provisions applicable to continuous beams.

23.3 Slabs Monolithic with Supports

Bending moments in slabs (except flat slabs) constructed monolithically with the supports shall be calculated by taking such slabs either as continuous over supports and capable of free rotation, or as members of a continuous framework with the supports, taking into account the stiffness of such supports. If such supports are formed due to beams which justify fixity at the support of slabs, then the effects on the supporting beam, such as, the bending of the web in the transverse direction of the beam and the torsion in the longitudinal direction of the beam, wherever applicable, shall also be considered in the design of the beam.

23.3.1 For the purpose of calculation of moments in slabs in a monolithic structure, it will generally be sufficiently accurate to assume that members connected to the ends of such slabs are fixed in position and direction at the ends remote from their connections with the slabs.

23.3.2 *Slabs Carrying Concentrated Load*

23.3.2.1 If a solid slab supported on two opposite edges, carries concentrated loads the maximum bending moment caused by the concentrated loads shall be assumed to be resisted by an effective width of slab (measured parallel to the supporting edges) as follows:

a) For a single concentrated load, the effective width shall be calculated in accordance with the following equation provided that it shall not exceed the actual width of the slab:

$$b_{ef} = kx\left(1-\frac{x}{l_{ef}}\right)+a$$

where

b_{ef} = effective width of slab,

k = constant having the values given in Table 14 depending upon the ratio of the width of the slab (l') to the effective span l_{ef},

x = distance of the centroid of the concentrated load from nearer support,

l_{ef} = effective span, and

a = width of the contact area of the concentrated load from nearer support measured parallel to the supported edge.

And provided further that in case of a load near the unsupported edge of a slab, the effective width shall not exceed the above value nor half the above value plus the distance of the load from the unsupported edge.

Table 14 Values of *k* for Simply Supported and Continuous Slabs

(*Clause* 23.3.2.1)

Sl No.	l'/l_{ef}	*k* for Simply Supported Slabs	*k* for Continuous Slabs
(1)	(2)	(3)	(4)
i)	0.1	0.4	0.4
ii)	0.2	0.8	0.8
iii)	0.3	1.16	1.16
iv)	0.4	1.48	1.44
v)	0.5	1.72	1.68
vi)	0.6	1.96	1.84
vii)	0.7	2.12	1.96
viii)	0.8	2.24	2.08
ix)	0.9	2.36	2.16
x)	1.0 and above	2.48	2.24

b) For two or more concentrated loads placed in a line in the direction of the span, the bending moment per metre width of slab shall be calculated separately for each load according to its appropriate effective width of slab calculated as in (a) and added together for design calculations.

c) For two or more loads not in a line in the direction of the span, if the effective width of slab for one load does not overlap the effective width of slab for another load, both calculated as in (a) above, then the slab for each load can be designed separately. If the effective width of slab for one load overlaps the effective width of slab for an adjacent load, the overlapping portion of the slab shall be designed for the combined effect of the two loads.

d) For cantilever solid slabs, the effective width shall be calculated in accordance with the

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following equation :

$$b_{ef} = 1.2a_1 + a$$

where

b_{ef} = effective width,

a_1 = distance of the concentrated load from the face of the cantilever support, and

a = width of contact area of the concentrated load measured parallel to the supporting edge.

Provided that the effective width of the cantilever slab shall not exceed one-third the length of the cantilever slab measured parallel to the fixed edge.

And provided further that when the concentrated load is placed near the extreme ends of the length of cantilever slab in the direction parallel to the fixed edge, the effective width shall not exceed the above value, nor shall it exceed half the above value plus the distance of the concentrated load from the extreme end measured in the direction parallel to the fixed edge.

23.3.2.2 For slabs other than solid slabs, the effective width shall depend on the ratio of the transverse and longitudinal flexural rigidities of the slab. Where this ratio is one, that is, where the transverse and longitudinal flexural rigidities are approximately equal, the value of effective width as found for solid slabs may be used. But as the ratio decreases, proportionately smaller value shall be taken.

23.3.2.3 Any other recognized method of analysis for cases of slabs covered by **23.3.2.1** and **23.3.2.2** and for all other cases of slabs may be used with the approval of the Engineer-in-Charge.

23.3.2.4 The critical section for checking shear shall be as given in **33.2.4.1**.

23.4 Slabs Spanning in Two Directions at Right Angles

The slabs spanning in two directions at right angles and carrying uniformly distributed load may be designed by any acceptable theory or by using coefficients given in Annex D. For determining bending moments in slabs spanning in two directions at right angles and carrying concentrated load, any accepted method approved by the Engineer-in-Charge may be adopted.

NOTE — The most commonly used elastic methods are based on Pigeaud's or Wester-guard's theory and the most commonly used limit state of collapse method is based on Johansen's yield-line theory.

23.4.1 *Restrained Slab with Unequal Conditions at Adjacent Panels*

In some cases the support moments calculated from Table 30 for adjacent panels may differ significantly. The following procedure may be adopted to adjust them:

a) Calculate the sum of the midspan moment and the average of the support moments (neglecting signs) for each panel.
b) Treat the values from Table 30 as fixed end moments.
c) According to the relative stiffness of adjacent spans, distribute the fixed end moments across the supports, giving new support moments.
d) Adjust midspan moment such that, when added to the support moments from (c) (neglecting signs), the total should be equal to that from (a).

   If the resulting support moments are significantly greater than the value from Table 30, the tension steel over the supports will need to be extended further. The procedure should be as follows:

   1) Take the span moment as parabolic between supports: its maximum value is as found from (d).
   2) Determine the points of contraflexure of the new support moments [from (c)] with the span moment [from (1)].
   3) Extend half the support tension steel at each end to at least an effective depth or 12 bar diameters beyond the nearest point of contraflexure.
   4) Extend the full area of the support tension steel at each end to half the distance from (3).

23.5 Loads on Supporting Beams

The loads on beams supporting solid slabs spanning in two directions at right angles and supporting uniformly

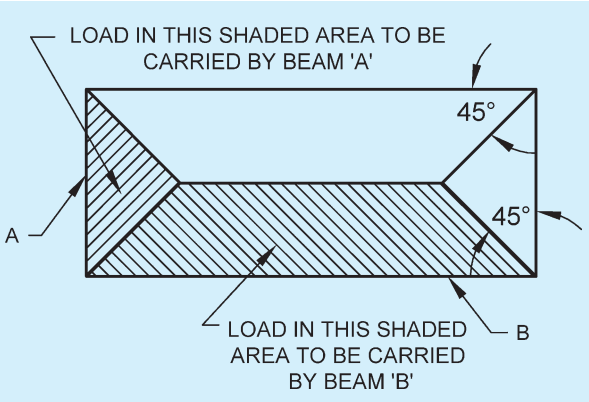


FIG. 7 LOAD CARRIED BY SUPPORTED BEAMS

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distributed loads, may be assumed to be in accordance with Fig. 7.

24 COMPRESSION MEMBERS

24.1 Definitions

24.1.1 Column or strut is a compression member, the effective length of which exceeds three times the least lateral dimension.

24.1.2 *Short and Slender Compression Members*

A compression member may be considered as short when both the slenderness $\frac{l_{ex}}{D}$ and $\frac{l_{ey}}{b}$ ratios are less than 12:

where

l_{ex} = effective length in respect of the major axis,
D = depth in respect of the major axis,
l_{ey} = effective length in respect of the minor axis, and
b = width of the member.

It shall otherwise be considered as a slender compression member.

24.1.3 *Unsupported Length*

The unsupported length, l, of a compression member shall be taken as the clear distance between end restraints except that,

a) in flat slab construction, it shall be clear distance between the floor and the lower extremity of the capital, the drop panel or slab, whichever is the least.
b) in beam and slab construction, it shall be the clear distance between the floor and the underside of the shallower beam framing into the columns in each direction at the next higher floor level.
c) in columns restrained laterally by struts, it shall be the clear distance between consecutive struts in each vertical plane, provided that to be an adequate support, two such struts shall meet the columns at approximately the same level and the angle between vertical planes through the struts shall not vary more than 30° from a right angle. Such struts shall be of adequate dimensions and shall have sufficient anchorage to restrain the member against lateral deflection.
d) in columns restrained laterally by struts or beams, with brackets used at the junction, it shall be the clear distance between the floor and the lower edge of the bracket, provided that the bracket width equals that of the beam strut and is at least half that of the column.

24.2 Effective Length of Compression Members

In the absence of more exact analysis, the effective length l_{ef} of columns may be obtained as described in Annex E.

24.3 Slenderness Limits for Columns

24.3.1 The unsupported length between end restraints shall not exceed 60 times the least lateral dimension of a column.

24.3.2 If, in any given plane, one end of a column is unrestrained, its unsupported length, l shall not exceed

$$100\left(\frac{b^2}{D}\right)$$

where

b = width of that cross-section, and
D = depth of the cross-section measured in the plane under consideration.

24.4 Minimum Eccentricity

All columns shall be designed for minimum eccentricity, equal to the unsupported length of column/500 plus lateral dimensions/30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

25 REQUIREMENTS GOVERNING REINFORCEMENT AND DETAILING

25.1 General

Reinforcing steel of same type and grade shall be used as main reinforcement in a structural member. However, simultaneous use of two different types or grades of steel for main and secondary reinforcement respectively is permissible.

25.1.1 Bars may be arranged singly, or in pairs in contact, or in groups of three or four bars bundled in contact. Bundled bars shall be enclosed within stirrups or ties. Bundled bars shall be tied together to ensure the bars remaining together. Bars larger than 32 mm diameter shall not be bundled, except in columns. Congestion of reinforcement should be avoided during detailing. Various methods such as choosing the diameter and grade of steel carefully and bundling of reinforcement, if required, are available.

25.1.2 The recommendations for detailing for earthquake-resistant construction given in Annex F should be taken into consideration, where applicable (*see also* **8** of Part 6 'Structural Design, Section 4 Masonry' of the Code).

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25.2 Development of Stress in Reinforcement

The calculated tension or compression in any bar at any section shall be developed on each side of the section by an appropriate development length or end anchorage or by a combination thereof.

25.2.1 *Development Length of Bars*

The development length L_d is given by:

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$$

where

ϕ = nominal diameter of the bar,

σ_s = stress in bar at the section considered at design load, and

τ_{bd} = design bond stress given in **25.2.1.1**.

NOTES

1 The development length includes anchorage values of hooks in tension reinforcement.

2 For bars of sections other than circular, the development length should be sufficient to develop the stress in the bar by bond.

3 For plain cement concrete of M 15 grade with nominal reinforcement, the design bond stress may be taken as 1.0 N/mm^2.

25.2.1.1 Design bond stress in limit state method for plain bars in tension shall be as below:

Grade of Concrete	M 20	M 25	M 30	M 35	M 40 and above
Design Bond Stress, τ_{bd}, N/mm^2	1.2	1.4	1.5	1.7	1.9

For deformed bars conforming to accepted standard [6-5A(36)] these values shall be increased by 60 percent.

For fusion bonded epoxy coated deformed bars conforming to accepted standard [6-5A(37)], design bond stress values shall be taken as 80 percent of the values given in the above table.

For bars in compression, the values of bond stress for bars in tension shall be increased by 25 percent.

The values of bond stress in working stress design, are given in **B-2.1**.

25.2.1.2 *Bars bundled in contact*

The development length of each bar of bundled bars shall be that for the individual bar, increased by 10 percent for two bars in contact, 20 percent for three bars in contact and 33 percent for four bars in contact.

25.2.2 *Anchoring Reinforcing Bars*

25.2.2.1 *Anchoring bars in tension*

a) Deformed bars may be used without end anchorages provided development length requirement is satisfied. Hooks should normally be provided for plain bars in tension.

b) *Bends and hooks* — Bends and hooks shall conform to good practice [6-5A(29)] :

   1) *Bends* — The anchorage value of bend shall be taken as 4 times the diameter of the bar for each 45° bend subject to a maximum of 16 times the diameter of the bar.

   2) *Hooks* — The anchorage value of a standard *U*-type hook shall be equal to 16 times the diameter of the bar.

25.2.2.2 *Anchoring bars in compression*

The anchorage length of straight bar in compression shall be equal to the development length of bars in compression as specified in **25.2.1**. The projected length of hooks, bends and straight lengths beyond bends, if provided for a bar in compression, shall only be considered for development length.

25.2.2.3 *Mechanical devices for anchorage*

Any mechanical or other device capable of developing the strength of the bar without damage to concrete may be used as anchorage with the approval of the Engineer-in-Charge.

25.2.2.4 *Anchoring shear reinforcement*

a) *Inclined bars* — The development length shall be as for bars in tension; this length shall be measured as under:

   1) In tension zone, from the end of the sloping or inclined portion of the bar, and

   2) In the compression zone, from the mid depth of the beam.

b) *Stirrups* — Notwithstanding any of the provisions of this standard, in case of secondary reinforcement, such as stirrups and transverse ties, complete development lengths and anchorage shall be deemed to have been provided when the bar is bent through an angle of at least 90° round a bar of at least its own diameter and is continued beyond the end of the curve for a length of at least eight diameters, or when the bar is bent through an angle of 135° and is continued beyond the end of the curve for a length of at least six bar diameters or when the bar is bent through an angle of 180° and is continued beyond the end of the curve for a length of at least four bar diameters.

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25.2.2.5 *Bearing stresses at bends*

The bearing stress in concrete for bends and hooks described in good practice [6-5A(29)] need not be checked. The bearing stress inside a bend in any other bend shall be calculated as given below:

$$\text{Bearing stress} = \frac{F_{bt}}{r\phi}$$

where

F_{bt} = tensile force due to design loads in a bar or group or bars,

r = internal radius of the bend, and

ϕ = size of the bar or, in bundle, the size of bar of equivalent area.

For limit state method of design, this stress shall not exceed $\frac{1.5 f_{ck}}{1+2\phi/a}$ where f_{ck} is the characteristic cube strength of concrete and a, for a particular bar or group of bars in contact shall be taken as the centre-to-centre distance between bars or groups of bars perpendicular to the plane of the bend; for a bar or group of bars adjacent to the face of the member a shall be taken as the cover plus size of bar (ϕ). For working stress method of design, the bearing stress shall not exceed $\frac{f_{ck}}{1+2\phi/a}$.

25.2.2.6 If a change in direction of tension or compression reinforcement induces a resultant force acting outward tending to split the concrete, such force should be taken up by additional links or stirrups. Bent tension bar at a re-entrant angle should be avoided.

25.2.3 *Curtailment of Tension Reinforcement in Flexural Members*

25.2.3.1 For curtailment, reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of the member or 12 times the bar diameter, whichever is greater except at simple support or end of cantilever. In addition **25.2.3.2** to **25.2.3.5** shall also be satisfied.

NOTE — A point at which reinforcement is no longer required to resist flexure is where the resistance moment of the section, considering only the continuing bars, is equal to the design moment.

25.2.3.2 Flexural reinforcement shall not be terminated in a tension zone unless any one of the following conditions is satisfied:

a) The shear at the cut-off point does not exceed two-thirds that permitted, including the shear strength of web reinforcement provided.

b) Stirrup area in excess of that required for shear and torsion is provided along each terminated bar over a distance from the cut-off point equal to three-fourths the effective depth of the member. The excess stirrup area shall be not less than $0.4\ bs/f_y$, where b is the breadth of beam, s is the spacing and f_y is the characteristic strength of reinforcement in N/mm^2. The resulting spacing shall not exceed $d/8\beta_b$ where β_b is the ratio of the area of bars cut-off to the total area of bars at the section, and d is the effective depth.

c) For 36 mm and smaller bars, the continuing bars provide double the area required for flexure at the cut-off point and the shear does not exceed three-fourths that permitted.

25.2.3.3 *Positive moment reinforcement*

a) At least one-third the positive moment reinforcement in simple members and one-fourth the positive moment reinforcement in continuous members shall extend along the same face of the member into the support, to a length equal to $L_d/3$.

b) When a flexural member is part of the primary lateral load resisting system, the positive reinforcement required to be extended into the support as described in (a) shall be anchored to develop its design stress in tension at the face of the support.

c) At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that L_d computed for f_d by **25.2.1** does not exceed:

$$\frac{M_1}{V} + L_0$$

where

M_1 = moment of resistance of the section assuming all reinforcement at the section to be stressed to f_d;

f_d = $0.87 f_y$ in the case of limit state design and the permissible stress σ_{st} in the case of working stress design;

V = shear force at the section due to design loads;

L_0 = sum of the anchorage beyond the centre of the support and the equivalent anchorage value of any hook or mechanical anchorage at simple support; and at a point of inflection, L_0 is limited to the effective depth of the members or 12ϕ, whichever is greater; and

ϕ = diameter of bar.

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The value of M_1/V in the above expression may be increased by 30 percent when the ends of the reinforcement are confined by a compressive reaction.

25.2.3.4 *Negative moment reinforcement*

At least one-third of the total reinforcement provided for negative moment at the support shall extend beyond the point of inflection for a distance not less than the effective depth of the member of 12ϕ or one-sixteenth of the clear span, whichever is greater.

25.2.3.5 *Curtailment of bundled bars*

Bars in a bundle shall terminate at different points spaced apart by not less than 40 times the bar diameter except for bundles stopping at a support.

25.2.4 *Special Members*

Adequate end anchorage shall be provided for tension reinforcement in flexural members where reinforcement stress is not directly proportional to moment, such as sloped, stepped, or tapered footings; brackets; deep beams; and members in which the tension reinforcement is not parallel to the compression face.

25.2.5 *Reinforcement Splicing*

Where splices are provided in the reinforcing bars, they shall as far as possible be away from the sections of maximum stress and be staggered. It is recommended that splices in flexural members should not be at sections where the bending moment is more than 50 percent of the moment of resistance; and not more than half the bars shall be spliced at a section.

Where more than one-half of the bars are spliced at a section or where splices are made at points of maximum stress, special precautions shall be taken such as increasing the length of lap and/or using spirals or closely-spaced stirrups around the length of the splice.

25.2.5.1 *Lap splices*

a) Lap splices shall not be used for bars larger than 32 mm. Bars larger than 32 mm shall be welded (*see* **11.4**) or mechanically spliced.

b) Lap splices shall be considered as staggered if the centre-to-centre distance of the splices is not less than 1.3 times the lap length calculated as described in (c).

c) Lap length including anchorage value of hooks for bars in flexural tension shall be L_d (*see* **25.2.1**) or 30 ϕ, whichever is greater. The straight length of the lap shall not be less than 15 ϕ or 200 mm. The following provisions shall also apply:

   Where lap occurs for a tension bar located at,

   1) top of a section as cast and the minimum cover is less than twice the diameter of the lapped bar, the lap length shall be increased by a factor of 1.4.

   2) corner of a section and the minimum cover to either face is less than twice the diameter of the lapped bar or where the clear distance between adjacent laps is less than 75 mm or 6 times the diameter of lapped bar, whichever is greater, the lap length should be increased by a factor of 1.4.

   Where both condition (1) and (2) apply, the lap length should be increased by a factor of 2.0.

   NOTE — Splices in tension members shall be enclosed in spirals made of bars not less than 6 mm diameter with pitch not more than 100 mm.

d) The lap length in compression shall be equal to the development length in compression, calculated as described in **25.2.1**, but not less than 24 ϕ.

e) When bars of two different diameters are to be spliced, the lap length shall be calculated on the basis of diameter of the smaller bar.

f) When splicing of welded wire fabric is to be carried out, lap splices of wires shall be made so that overlap measured between the extreme cross wires shall be not less than the spacing of cross wires plus 100 mm.

g) In case of bundled bars, lapped splices of bundled bars shall be made by splicing one bar at a time; such individual splices within a bundle shall be staggered.

Reinforcement couplers for mechanical splices of bars for concrete reinforcement, used, shall be in accordance with accepted standard [6-5A(38)].

25.2.5.2 *Strength of welds*

The following values may be used where the strength of the weld has been proved by tests to be at least as great as that of the parent bar.

a) *Splices in compression* — For welded splices and mechanical connection, 100 percent of the design strength of joined bars.

b) *Splices in tension*

1) 80 percent of the design strength of welded bars (100 percent if welding is strictly supervised and if at any cross-section of the member not more than 20 percent of the tensile reinforcement is welded).

2) 100 percent of design strength of mechanical connection.

25.2.5.3 *End-bearing splices*

End-bearing splices shall be used only for bars in

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compression. The ends of the bars shall be square cut and concentric bearing ensured by suitable devices.

25.3 Spacing of Reinforcement

25.3.1 For the purpose of this clause, the diameter of a round bar shall be its nominal diameter, and in the case of bars which are not round or in the case of deformed bars or crimped bars, the diameter shall be taken as the diameter of a circle giving an equivalent effective area. Where spacing limitations and minimum concrete cover (*see* **25.4**) are based on bar diameter, a group of bars bundled in contact shall be treated as a single bar of diameter derived from the total equivalent area.

25.3.2 *Minimum Distance Between Individual Bars*

The following shall apply for spacing of bars:

a) The horizontal distance between two parallel main reinforcing bars shall usually be not less than the greatest of the following :
   1) The diameter of the bar if the diameters are equal.
   2) The diameter of the larger bar if the diameters are unequal, and
   3) 5 mm more than the nominal maximum size of coarse aggregate.

   NOTE — This does not preclude the use of larger size of aggregates beyond the congested reinforcement in the same member; the size of aggregates may be reduced around congested reinforcement to comply with this provision.

b) Greater horizontal distance than the minimum specified in (a) should be provided, wherever possible. However, when needle vibrators are used the horizontal distance between bars of a group may be reduced to two-thirds the nominal maximum size of the coarse aggregate, provided that sufficient space is left between groups of bars to enable the vibrator to be immersed.

c) Where there are two or more rows of bars, the bars shall be vertically in line and the minimum vertical distance between the bars shall be 15 mm, two-thirds the nominal maximum size of aggregate or the maximum size of bars, whichever is greater.

25.3.3 *Maximum Distance Between Bars in Tension*

Unless the calculation of crack widths shows that a greater spacing is acceptable, the following rules shall be applied to flexural members in normal internal or external conditions of exposure:

a) *Beams* — The horizontal distance between parallel reinforcement bars, or groups, near the tension face of a beam shall not be greater than the value given in Table 15 depending on the amount of redistribution carried out in analysis and the characteristic strength of the reinforcement.

b) *Slabs*
   1) The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm, whichever is smaller.
   2) The horizontal distance between parallel reinforcement bars provided against shrinkage and temperature shall not be more than five times the effective depth of a solid slab or 300 mm, whichever is smaller.

Table 15 Clear Distance Between Bars

(*Clause* 25.3.3)

Sl No.	f_y	Percentage Redistribution to or from Section Considered				
		–30	–15	0	+15	+ 30
		Clear Distance Between Bars				
	N/mm^2	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	250	215	260	300	300	300
ii)	415	125	155	180	210	235
iii)	500	105	130	150	175	195

NOTE — The spacings given in table are not applicable to members subjected to particularly aggressive environments unless in the calculation of the moment of resistance f_y has been limited to 300 N/mm^2 in limit state design and σ_{st} limited to 165 N/mm^2 in working stress design.

25.4 Nominal Cover to Reinforcement

25.4.1 *Nominal Cover*

Nominal cover is the design depth of concrete cover to all steel reinforcements, including links. It is the dimension used in design and indicated in the drawings. It shall be not less than the diameter of the bar.

25.4.2 *Nominal Cover to Meet Durability Requirement*

Minimum values for the nominal cover of normal-weight aggregate concrete which should be provided to all reinforcement, including links depending on the condition of exposure described in **7.2.2** shall be as given in Table 16.

25.4.2.1 However, for a longitudinal reinforcing bar in a column nominal cover shall in any case not be less than 40 mm, or less than the diameter of such bar. In the case of columns of minimum dimension of 200 mm or under, whose reinforcing bars do not exceed 12 mm, a nominal cover of 25 mm may be used.

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Table 16 Nominal Cover to Meet Durability Requirements

(*Clause* 25.4.2)

Sl No.	Exposure	Nominal Concrete Cover not Less Than mm
(1)	(2)	(3)
i)	Mild	20
ii)	Moderate	30
iii)	Severe	45
iv)	Very severe	50
v)	Extreme	75

NOTES

1 For main reinforcement up to 12 mm diameter bar for mild exposure the nominal cover may be reduced by 5 mm.

2 Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by $^{+10}_{-0}$ mm.

3 For exposure condition 'severe' and 'very severe', reduction of 5 mm may be made, where concrete grade is M 35 and above.

25.4.2.2 For footings minimum cover shall be 50 mm.

25.4.3 *Nominal Cover to Meet Specified Period of Fire Resistance*

Minimum values of nominal cover of normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance shall be given in Table 16A.

25.5 Requirements of Reinforcement for Structural Members

25.5.1 *Beams*

25.5.1.1 *Tension reinforcement*

a) *Minimum reinforcement* – The minimum area of tension reinforcement shall be not less than that given by the following:

$$\frac{A_s}{bd} = \frac{0.85}{f_y}$$

where

A_s = minimum area of tension reinforcement;

b = breadth of beam or the breadth of the web of T-beam;

d = effective depth, and

f_y = characteristic strength of reinforcement, in N/mm^2.

b) *Maximum reinforcement* – The maximum area of tension reinforcement shall not exceed 0.04 *bD*.

where

D = overall depth of beam or slab or diameter of column; dimension of a rectangular column in the direction under consideration.

NOTE — The use of 4 percent reinforcement may involve practical difficulty in placing and compacting concrete; hence lower percentage is recommended.

25.5.1.2 *Compression reinforcement*

The maximum area of compression reinforcement shall not exceed 0.04 *bD*. Compression reinforcement in beams shall be enclosed by stirrups for effective lateral restraint. The arrangement of stirrups shall be as specified in **25.5.3.2**.

NOTE — The use of 4 percent reinforcement may involve practical difficulty in placing and compacting concrete; hence lower percentage is recommended.

25.5.1.3 *Side face reinforcement*

Where the depth of the web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall be not

Table 16A Nominal Cover to Meet Specified Period of Fire Resistance

(*Clauses* 20.4, 25.4.3 *and* Fig. 1)

Sl No.	Fire Resistance	Nominal Cover						
		Beams		Slabs		Ribs		Columns
		Simply Supported	Continuous	Simply Supported	Continuous	Simply Supported	Continuous	
	h	mm	mm	mm	mm	mm	mm	mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	0.5	20	20	20	20	20	20	40
ii)	1	20	20	20	20	20	20	40
iii)	1.5	20	20	25	20	35	20	40
iv)	2	40	30	35	25	45	35	40
v)	3	60	40	45	35	55	45	40
vi)	4	70	50	55	45	65	55	40

NOTES

1 The nominal covers given relate specifically to the minimum member dimensions given in Fig. 1.

2 Cases that lie below the bold line require attention to the additional measures necessary to reduce the risks of spalling (*see* **20.3.1**).

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less than 0.1 percent of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness, whichever is less.

25.5.1.4 *Transverse reinforcement in beams for shear and torsion*

The transverse reinforcement in beams shall be taken around the outer-most tension and compression bars. In T-beams and I-beams, such reinforcement shall pass around longitudinal bars located close to the outer face of the flange.

25.5.1.5 *Maximum spacing of shear reinforcement*

The maximum spacing of shear reinforcement measured along the axis of the member shall not exceed 0.75 d for vertical stirrups and d for inclined stirrups at 45°, where d is the effective depth of the section under consideration. In no case shall the spacing exceed 300 mm.

25.5.1.6 *Minimum shear reinforcement*

Minimum shear reinforcement in the form of stirrups shall be provided such that,

$$\frac{A_{sv}}{bs_v} \geq \frac{0.4}{0.87 f_y}$$

where

A_{sv} = total cross-sectional area of stirrups legs effective in shear,

s_v = stirrup spacing along the length of the member,

b = breadth of the beam or breadth of the web of flanged beam, and

f_y = characteristic strength of the stirrup reinforcement, in N/mm^2, which shall not be taken greater than 415 N/mm^2.

Where the maximum shear stress calculated is less than half the permissible value and in members of minor structural importance such as lintels, this provision need not be complied with.

25.5.1.7 *Distribution of torsion reinforcement*

When a member is designed for torsion (*see* **40** or **B-6**) torsion reinforcement shall be provided as below:

a) The transverse reinforcement for torsion shall be rectangular closed stirrups placed perpendicular to the axis of the member. The spacing of the stirrups shall not exceed the least of x_1, $\frac{x_1 + y_1}{4}$, and 300 mm, where x_1 and y_1 are respectively the short and long dimensions of the stirrup.

b) Longitudinal reinforcement shall be placed as close as is practicable to the corners of the cross-section and in all cases, there shall be at least one longitudinal bar in each corner of the ties. When the cross-sectional dimension of the member exceeds 450 mm, additional longitudinal bars shall be provided to satisfy the requirements of minimum reinforcement and spacing given in **25.5.1.3**.

25.5.1.8 Reinforcement in flanges of T-beams and L-beams shall satisfy the requirements in **22.1.1**(b). Where flanges are in tension, a part of the main tension reinforcement shall be distributed over the effective flange width or a width equal to one-tenth of the span, whichever is smaller. If the effective flange width exceeds one-tenth of the span, nominal longitudinal reinforcement shall be provided in the outer portions of the flange.

25.5.2 *Slabs*

The rules given in **25.5.2.1** and **25.5.2.2** shall apply to slabs in addition to those given in the appropriate clauses.

25.5.2.1 *Minimum reinforcement*

The mild steel reinforcement in either direction in slabs shall not be less than 0.15 percent of the total cross-sectional area. However, this value can be reduced to 0.12 percent when high strength deformed bars or welded wire fabric are used.

25.5.2.2 *Maximum diameter*

The diameter of reinforcing bars shall not exceed one-eighth of the total thickness of the slab.

25.5.3 *Columns*

25.5.3.1 *Longitudinal reinforcement*

a) The cross-sectional area of longitudinal reinforcement, shall be not less than 0.8 percent nor more than 6 percent of the gross cross-sectional area of the column.

NOTE — The use of 6 percent reinforcement may involve practical difficulties in placing and compacting of concrete; hence lower percentage is recommended. Where bars from the columns below have to be lapped with those in the column under consideration, the percentage of steel shall usually not exceed 4 percent.

b) In any column that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based upon the area of concrete required to resist the direct stress and not upon the actual area.

c) The minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

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d) The bars shall not be less than 12 mm in diameter.

e) A reinforced concrete column having helical reinforcement shall have at least six bars of longitudinal reinforcement within the helical reinforcement.

f) In a helically reinforced column, the longitudinal bars shall be in contact with the helical reinforcement and equidistant around its inner circumference.

g) Spacing of longitudinal bars measured along the periphery of the column shall not exceed 300 mm.

h) In case of pedestals in which the longitudinal reinforcement is not taken in account in strength calculations, nominal longitudinal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.

NOTE — Pedestal is a compression member, the effective length of which does not exceed three times the least lateral dimension.

25.5.3.2 *Transverse reinforcement*

a) *General* — A reinforced concrete compression member shall have transverse or helical reinforcement so disposed that every longitudinal bar nearest to the compression face has effective lateral support against buckling subject to provisions in (b). The effective lateral support is given by transverse reinforcement either in the form of circular rings capable of taking up circumferential tension or by polygonal links (lateral ties) with internal angles not exceeding 135°. The ends of the transverse reinforcement shall be properly anchored [*see* **25.2.2.4**(b)].

b) *Arrangement of transverse reinforcement*

1) If the longitudinal bars are not spaced more than 75 mm on either side, transverse reinforcement need only to go round corner and alternate bars for the purpose of providing effective lateral supports (*see* Fig. 8).

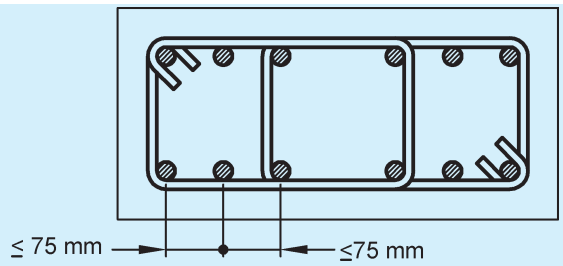


FIG. 8

2) If the longitudinal bars spaced at a distance of not exceeding 48 times the diameter of the tie are effectively tied in two directions, additional longitudinal bars in between these bars need to be tied in one direction by open ties (*see* Fig. 9).

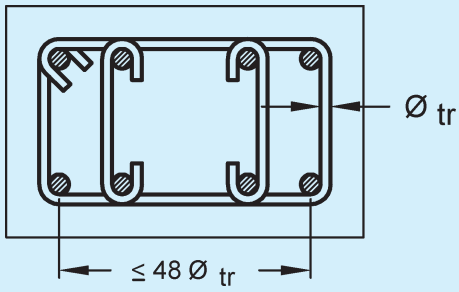


FIG. 9

3) Where the longitudinal reinforcing bars in a compression member are placed in more than one row, effective lateral support to the longitudinal bars in the inner rows may be assumed to have been provided, if

i) transverse reinforcement is provided for the outer-most row in accordance with **25.5.3.2**; and

ii) no bar of the inner row is closer to the nearest compression face than three times the diameter of the largest bar in the inner row (*see* Fig. 10).

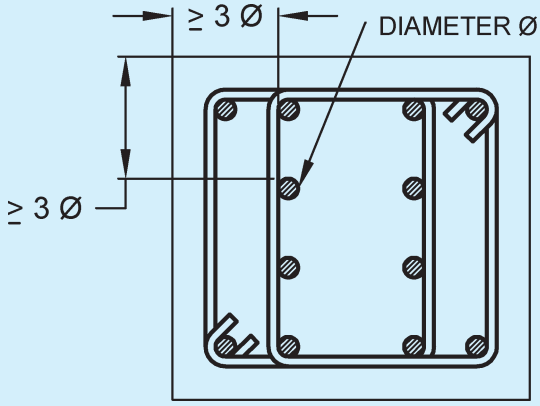


FIG. 10

4) Where the longitudinal bars in a compression member are grouped (not in contact) and each group adequately tied with transverse reinforcement in accordance with **25.5.3.2**, the transverse reinforcement for the compression member as a whole may be provided on the assumption that each group is a single longitudinal bar for purpose of determining the pitch and diameter of the transverse reinforcement in accordance with **25.5.3.2**. The diameter of such

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transverse reinforcement need not, however, exceed 20 mm (*see* Fig. 11).

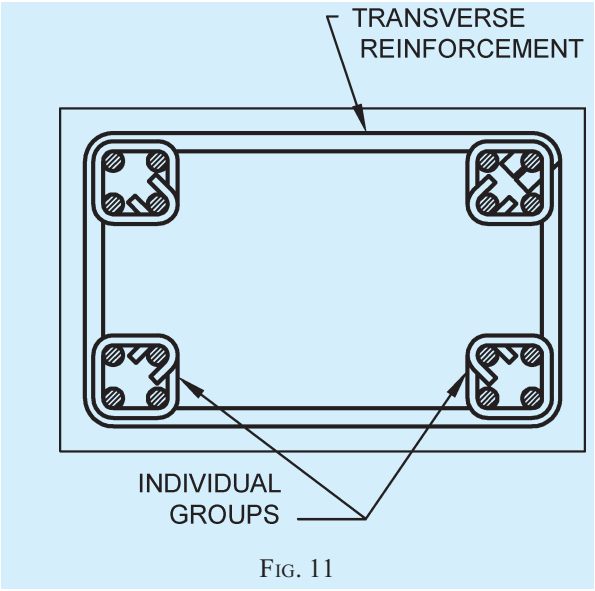


FIG. 11

c) *Pitch and diameter of lateral ties*

1) *Pitch* — The pitch of transverse reinforcement shall be not more than the least of the following distances:

i) The least lateral dimension of the compression members;

ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied; and

iii) 300 mm.

2) *Diameter* — The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest longitudinal bar, and in no case less than 6 mm.

d) *Helical reinforcement*

1) *Pitch* — Helical reinforcement shall be of regular formation with the turns of the helix spaced evenly and its ends shall be anchored properly by providing one and a half extra turns of the spiral bar. Where an increased load on the column on the strength of the helical reinforcement is allowed for, the pitch of helical turns shall be not more than 75 mm, nor more than one-sixth of the core diameter of the column, nor less than 25 mm, nor less than three times the diameter of the steel bar forming the helix. In other cases, the requirements of **25.5.3.2** shall be complied with.

2) The diameter of the helical reinforcement shall be in accordance with **25.5.3.2** (c) (2).

25.5.3.3 In columns where longitudinal bars are offset at a splice, the slope of the inclined portion of the bar with the axis of the column shall not exceed 1 in 6, and the portions of the bar above and below the offset shall be parallel to the axis of the column. Adequate horizontal support at the offset bends shall be treated as a matter of design, and shall be provided by metal ties, spirals, or parts of the floor construction. Metal ties or spirals so designed shall be placed near (not more than eight-bar diameters from) the point of bend. The horizontal thrust to be resisted shall be assumed as one and half times the horizontal components of the nominal stress in the inclined portion of the bar. Offset bars shall be bent before they are placed in the forms. Where column faces are offset 75 mm or more, splices of vertical bars adjacent to the offset face shall be made by separate dowels overlapped as specified in **25.2.5.1**.

26 EXPANSION JOINTS

26.1 Structures in which marked changes in plan dimensions take place abruptly shall be provided with expansion joints at the section where such changes occur. Expansion joints shall be so provided that the necessary movement occurs with a minimum resistance at the joint. The structures adjacent to the joint should preferably be supported on separate columns or walls but not necessarily on separate foundations. Reinforcement shall not extend across an expansion joint and the break between the sections shall be complete.

26.2 The details as to the length of a structure where expansion joints have to be provided can be determined after taking into consideration various factors, such as temperature, exposure to weather, the time and season of the laying of the concrete, etc. Normally structures exceeding 45 m in length are designed with one or more expansion joints. However, in view of the large number of factors involved in deciding the location, spacing and nature of expansion joints, the provision of expansion joint in reinforced cement concrete structures should be left to the discretion of the designer. Good practice [6-5A(39)] gives the design considerations, which need to be examined and provided for.

SECTION 5A (D) SPECIAL DESIGN REQUIREMENTS FOR STRUCTURAL MEMBERS AND SYSTEMS

27 CONCRETE CORBELS

27.1 General

A corbel is a short cantilever projection which supports a load bearing member and where,

a) the distance a_v between the line of the reaction to the supported load and the root of the corbel

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is less than *d* (the effective depth of the root of the corbel); and

b) the depth at the outer edge of the contact area of the supported load is not less than one-half of the depth at the root of the corbel.

The depth of the corbel at the face of the support is determined in accordance with **39.5.1**.

27.2 Design

27.2.1 *Simplifying Assumptions*

The concrete and reinforcement may be assumed to act as elements of a simple strut-and-tie system, with the following guidelines:

a) The magnitude of the resistance provided to horizontal force should be not less than one-half of the design vertical load on the corbel (*see also* **27.2.4**).

b) Compatibility of strains between the strut-and-tie at the corbel root should be ensured.

It should be noted that the horizontal link requirement described in **27.2.3** will ensure satisfactory serviceability performance.

27.2.2 *Reinforcement Anchorage*

At the front face of the corbel, the reinforcement should be anchored either by:

a) *Welding to a transverse bar of equal strength* — In this case the bearing area of the load should stop short of the face of the support by a distance equal to the cover of the tie reinforcement, or

b) Bending back the bars to form a loop — In this case the bearing area of the load should not project beyond the straight portion of the bars forming the main tension reinforcement.

27.2.3 *Shear Reinforcement*

Shear reinforcement should be provided in the form of horizontal links distributed in the upper two-third of the effective depth of root of the corbel; this reinforcement should be not less than one-half of the area of the main tension reinforcement and should be adequately anchored.

27.2.4 *Resistance to Applied Horizontal Force*

Additional reinforcement connected to the supported member should be provided to transmit this force in its entirety.

28 DEEP BEAMS

28.1 General

a) A beam shall be deemed to be a deep beam when the ratio of effective span to overall depth, $\frac{l}{D}$ is less than,

1) 2.0 for a simply supported beam; and

2) 2.5 for a continuous beam.

b) A deep beam complying with the requirements of **28.2** and **28.3** shall be deemed to satisfy the provisions for shear.

28.2 Lever Arm

The lever arm *z* for a deep beam shall be determined as below:

a) *For simply supported beams* :

$z = 0.2\ (l + 2\ D)$ when $1 \le \frac{l}{D} \le 2$

or

$z = 0.6l$ when $\frac{l}{D} < 1$

b) *For continuous beams* :

$z = 0.2(l + 1.5D)$ when $1 \le \frac{l}{D} \le 2.5$

or

$z = 0.5l$ when $\frac{l}{D} < 1$

where *l* is the effective span taken as centre-to-centre distance between supports or 1.15 times the clear span, whichever is smaller, and *D* is the overall depth.

28.3 Reinforcement

28.3.1 *Positive Reinforcement*

The tensile reinforcement required to resist positive bending moment in any span of a deep beam shall,

a) extend without curtailment between supports;

b) be embedded beyond the face of each support, so that at the face of the support it shall have a development length not less than 0.8 L_d ; where L_d is the development length (*see* **25.2.1**), for the design stress in the reinforcement; and

c) be placed within a zone of depth equal to (0.25 *D* – 0.05 *l*) adjacent to the tension face of the beam where *D* is the overall depth and *l* is the effective span.

28.3.2 *Negative Reinforcement*

a) *Termination of reinforcement* — For tensile reinforcement required to resist negative bending moment over a support of a deep beam:

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1) It shall be permissible to terminate not more than half of the reinforcement at a distance of 0.5 D from the face of the support, where D is as defined in **29.2**; and
2) The remainder shall extend over the full span.

b) *Distribution* – When ratio of clear span to overall depth is in the range 1.0 to 2.5, tensile reinforcement over a support of a deep beam shall be placed in two zones comprising,
1) a zone of depth 0.2 D, adjacent to the tension face, which shall contain a proportion of the tension steel given by:

$$0.5\left(\frac{l}{D}-0.5\right)$$

where

l = clear span, and

D = overall depth.

2) a zone measuring 0.3 D on either side of the mid-depth of the beam, which shall contain the remainder of the tension steel, evenly distributed.

For span to depth ratios less than unity, the steel shall be evenly distributed over a depth of 0.8 D measured from the tension face.

28.3.3 *Vertical Reinforcement*

If forces are applied to a deep beam in such a way that hanging action is required, bars or suspension stirrups shall be provided to carry all the forces concerned.

28.3.4 *Side Face Reinforcement*

Side face reinforcement shall comply with requirements of minimum reinforcement of wall (*see* **31.5**).

29 RIBBED, HOLLOW BLOCK OR VOIDED SLAB

29.1 General

This covers the slabs constructed in one of the ways described below:

a) As a series of concrete ribs with topping cast on forms which may be removed after the concrete has set;
b) As a series of concrete ribs between precast blocks which remain part of the completed structure; the top of the ribs may be connected by a topping of concrete of the same strength as that used in the ribs; and
c) With a continuous top and bottom face but containing voids of rectangular, oval or other shape.

29.2 Analysis of Structure

The moments and forces due to design loads on continuous slabs may be obtained by the methods given in Section 5A (C) for solid slabs. Alternatively, the slabs may be designed as a series of simply supported spans provided they are not exposed to weather or corrosive conditions; wide cracks may develop at the supports and the engineer shall satisfy himself that these will not impair finishes or lead to corrosion of the reinforcement.

29.3 Shear

Where hollow blocks are used, for the purpose of calculating shear stress, the rib width may be increased to take account of the wall thickness of the block on one side of the rib; with narrow precast units, the width of the jointing mortar or concrete may be included.

29.4 Deflection

The recommendations for deflection in respect of solid slabs may be applied to ribbed, hollow block or voided construction. The span to effective depth ratios given in **22.2** for a flanged beam are applicable but when calculating the final reduction factor for web width, the rib width for hollow block slabs may be assumed to include the walls of the blocks on both sides of the rib. For voided slabs and slabs constructed of box or I-section units, an effective rib width shall be calculated assuming all material below the upper flange of the unit to be concentrated in a rectangular rib having the same cross-sectional area and depth.

29.5 Size and Position of Ribs

In-situ ribs shall be not less than 65 mm wide. They shall be spaced at centres not greater than 1.5 m apart and their depth, excluding any topping, shall be not more than four times their width. Generally ribs shall be formed along each edge parallel to the span of one way slabs. When the edge is built into a wall or rests on a beam, a rib at least as wide as the bearing shall be formed along the edge.

29.6 Hollow Blocks and Formers

Blocks and formers may be of any suitable material. Hollow clay tiles for the filler type shall conform to accepted standard [6-5A(40)]. When required to contribute to the structural strength of a slab they shall,

a) be made of concrete or burnt clay; and
b) have a crushing strength of at least 14 N/mm^2 measured on the net section when axially

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loaded in the direction of compressive stress in the slab.

29.7 Arrangement of Reinforcement

The recommendations given in **25.3** regarding maximum distance between bars apply to areas of solid concrete in this form of construction. The curtailment, anchorage and cover to reinforcement shall be as described below:

a) At least 50 percent of the total main reinforcement shall be carried through at the bottom on to the bearing and anchored in accordance with **25.2.3.3**.

b) Where a slab, which is continuous over supports, has been designed as simply supported, reinforcement shall be provided over the support to control cracking. This reinforcement shall have a cross-sectional area of not less than one-quarter that required in the middle of the adjoining spans and shall extend at least one-tenth of the clear span into adjoining spans.

c) In slabs with permanent blocks, the side cover to the reinforcement shall not be less than 10 mm. In all other cases, cover shall be provided according to **25.4**.

29.8 Precast Joists and Hollow Filler Blocks

The construction with precast joists and hollow filler blocks of concrete or clay shall conform to good practice [6-5A(41)].

30 FLAT SLABS

30.1 General

The term flat slab means a reinforced concrete slab with or without drops, supported generally without beams, by columns with or without flared column heads (*see* Fig. 12). A flat slab may be solid slab or may have recesses formed on the soffit so that the soffit comprises a series of ribs in two directions. The recesses may be formed by removable or permanent filler blocks.

30.1.1 For the purpose of this clause, the following definitions shall apply:

a) *Column strip* — Column strip means a design strip having a width of $0.25\,l_2$, but not greater than $0.25\,l_1$ on each side of the column centre-line, where l_1 is the span in the direction moments are being determined, measured centre-to-centre of supports and l_2 is the span transverse to l_1, measured centre-to-centre of supports.

b) *Middle strip* — Middle strip means a design strip bounded on each of its opposite sides by the column strip.

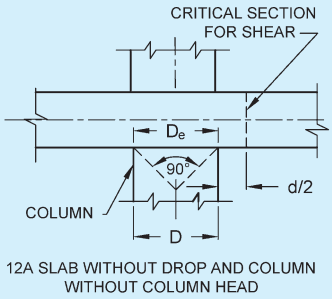
c) *Panel* — Panel means that part of a slab bounded on each of its four sides by the centre-line of a column or centre-lines of adjacent spans.

30.2 Proportioning

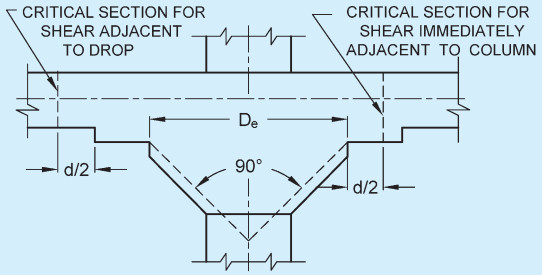
30.2.1 *Thickness of Flat Slab*

The thickness of the flat slab shall be generally controlled by considerations of span to effective depth ratios given in **22.2**.

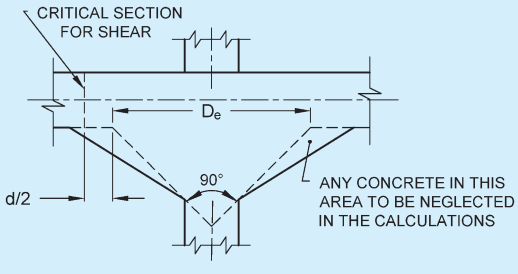
For slabs with drops conforming to **30.2.2**, span to effective depth ratios given in **22.2** shall be applied directly; otherwise the span to effective depth ratios



12A SLAB WITHOUT DROP AND COLUMN WITHOUT COLUMN HEAD



12B SLAB WITH DROP AND COLUMN WITH COLUMN HEAD



12C SLAB WITHOUT DROP AND COLUMN WITH COLUMN HEAD

NOTE — D_e is the diameter of column or column head to be considered for design and d is effective depth of slab or drop as appropriate.

FIG. 12 CRITICAL SECTIONS FOR SHEAR IN FLAT SLABS

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obtained in accordance with provisions in **22.2** shall be multiplied by 0.9. For this purpose, the longer span shall be considered. The minimum thickness of slab shall be 125 mm.

30.2.2 *Drop*

The drops when provided shall be rectangular in plan, and have a length in each direction not less than one-third of the panel length in that direction. For exterior panels, the width of drops at right angles to the non-continuous edge and measured from the centre-line of the columns shall be equal to one-half the width of drop for interior panels.

30.2.3 *Column Heads*

Where column heads are provided, that portion of a column head which lies within the largest right circular cone or pyramid that has a vertex angle of 90° and can be included entirely within the outlines of the column and the column head, shall be considered for design purposes (*see* Fig. 12).

30.3 Determination of Bending Moment

30.3.1 *Methods of Analysis and Design*

It shall be permissible to design the slab system by one of the following methods:

a) The direct design method as specified in **30.4**, and

b) The equivalent frame method as specified in **30.5**.

In each case the applicable limitations given in **30.4** and **30.5** shall be met.

30.3.2 *Bending Moments in Panels with Marginal Beams or Walls*

Where the slab is supported by a marginal beam with a depth greater than 1.5 times the thickness of the slab, or by a wall, then,

a) the total load to be carried by the beam or wall shall comprise those loads directly on the wall or beam plus a uniformly distributed load equal to one-quarter of the total load on the slab; and

b) the bending moments on the half-column strip adjacent to the beam or wall shall be one-quarter of the bending moments for the first interior column strip.

30.3.3 *Transfer of Bending Moments to Columns*

When unbalanced gravity load, wind, earthquake, or other lateral loads cause transfer of bending moment between slab and column, the flexural stresses shall be investigated using a fraction, α of the moment given by:

$$\alpha = \frac{1}{1+\frac{2}{3}\sqrt{a_1/a_2}}$$

where

a_1 = overall dimension of the critical section for shear in the direction in which moment acts, and

a_2 = overall dimension of the critical section for shear transverse to the direction in which moment acts.

A slab width between lines that are one and one-half slab or drop panel thickness; 1.5 *D*, on each side of the column or capital may be considered effective, *D* being the size of the column.

Concentration of reinforcement over column head by closer spacing or additional reinforcement may be used to resist the moment on this section.

30.4 Direct Design Method

30.4.1 *Limitations*

Slab system designed by the direct design method shall fulfill the following conditions:

a) There shall be minimum of three continuous spans in each direction,

b) The panels shall be rectangular, and the ratio of the longer span to the shorter span within a panel shall not be greater than 2.0,

c) It shall be permissible to offset columns to a maximum of 10 percent of the span in the direction of the offset notwithstanding the provision in (b),

d) The successive span lengths in each direction shall not differ by more than one-third of the longer span. The end spans may be shorter but not longer than the interior spans, and

e) The design live load shall not exceed three times the design dead load.

30.4.2 *Total Design Moment for a Span*

30.4.2.1 In the direct design method, the total design moment for a span shall be determined for a strip bounded laterally by the centre-line of the panel on each side of the centre-line of the supports.

30.4.2.2 The absolute sum of the positive and average negative bending moments in each direction shall be taken as :

$$M_o = \frac{Wl_n}{8}$$

where

M_o = total moment;

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W = design load on an area $l_2\ l_n$;

l_n = clear span extending from face to face of columns, capitals, brackets or walls, but not less than 0.65 l_1;

l_1 = length of span in the direction of M_o; and

l_2 = length of span transverse to l_1.

30.4.2.3 Circular supports shall be treated as square supports having the same area.

30.4.2.4 When the transverse span of the panels on either side of the centre-line of supports varies, l_2 shall be taken as the average of the transverse spans.

30.4.2.5 When the span adjacent and parallel to an edge is being considered, the distance from the edge to the centre-line of the panel shall be substituted for l_2 in **30.4.2.2**.

30.4.3 *Negative and Positive Design Moments*

30.4.3.1 The negative design moment shall be located at the face of rectangular supports, circular supports being treated as square supports having the same area.

30.4.3.2 In an interior span, the total design moment M_o shall be distributed in the following proportions:

a) Negative design moment : 0.65

b) Positive design moment : 0.35

30.4.3.3 In an end span, the total design moment M_o shall be distributed in the following proportions:

a) *Interior negative design moment*:

$$0.75-\frac{0.10}{1+\frac{1}{\alpha_c}}$$

b) *Positive design moment*:

$$0.63-\frac{0.28}{1+\frac{1}{\alpha_c}}$$

c) *Exterior negative design moment*:

$$\frac{0.65}{1+\frac{1}{\alpha_c}}$$

α_c is the ratio of flexural stiffness of the exterior columns to the flexural stiffness of the slab at a joint taken in the direction moments are being determined and is given by:

$$\alpha_c=\frac{\sum K_c}{K_s}$$

where

K_c = sum of the flexural stiffness of the columns meeting at the joint; and

K_s = flexural stiffness of the slab, expressed as moment per unit rotation.

30.4.3.4 It shall be permissible to modify these design moments by up to 10 percent, so long as the total design moment, M_o for the panel in the direction considered is not less than that required by **30.4.2.2**.

30.4.3.5 The negative moment section shall be designed to resist the larger of the two interior negative design moments determined for the spans framing into a common support unless an analysis is made to distribute the unbalanced moment in accordance with the stiffness of the adjoining parts.

30.4.4 *Distribution of Bending Moments Across the Panel Width*

Bending moments at critical cross-section shall be distributed to the column strips and middle strips as specified in **30.5.5** as applicable.

30.4.5 *Moments in Columns*

30.4.5.1 Columns built integrally with the slab system shall be designed to resist moments arising from loads on the slab system.

30.4.5.2 At an interior support, the supporting members above and below the slab shall be designed to resist the moment M given by the following equation, in direct proportion to their stiffnesses unless a general analysis is made:

$$M=0.08\left(\frac{(w_d+0.5w_l)l_2l_n^{\ 2}-w_d'l_2'l_n'^{\ 2}}{1+\frac{1}{\alpha_c}}\right)$$

where

w_d, w_l = design dead and live loads respectively, per unit area;

l_2 = length of span transverse to the direction of M;

l_n = length of the clear span in the direction of M, measured face to face of supports;

$\alpha_c=\dfrac{\sum K_c}{\sum K_s}$ where K_c and K_s are as defined in **30.4.3.3**; and

w_d', l_2' and l_n' refer to the shorter span.

30.4.6 *Effects of Pattern Loading*

In the direct design method, when the ratio of live load to dead load exceeds 0.5,

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a) the sum of the flexural stiffness of the columns above and below the slab, $\sum K_c$, shall be such that α_c is not less than the appropriate minimum value $\alpha_{c\,min}$ specified in Table 17; or

b) if the sum of the flexural stiffnesses of the columns, $\sum K_c$, does not satisfy (a), the positive design moments for the panel shall be multiplied by the coefficient β_s given by the following equation :

$$\beta_s = 1 + \left[\frac{2 - \frac{w_d}{w_l}}{4 + \frac{w_d}{w_l}}\right]\left(1 - \frac{\alpha_c}{\alpha_{c\,min}}\right)$$

α_c is the ratio of flexural stiffness of the columns above and below the slab to the flexural stiffness of the slabs at a joint taken in the direction moments are being determined and is given by:

$$\alpha_c = \frac{\sum K_c}{\sum K_s}$$

where K_c and K_s are flexural stiffnesses of column and slab respectively.

Table 17 Minimum Permissible Values of α_c

(*Clause* 30.4.6)

Sl No.	Imposed Load/ Dead Load	Ratio $\frac{l_1}{l_2}$	Value of $\alpha_{c\,min}$
(1)	(2)	(3)	(4)
i)	0.5	0.5 to 2.0	0
ii)	1.0	0.5	0.6
iii)	1.0	0.8	0.7
iv)	1.0	1.0	0.7
v)	1.0	1.25	0.8
vi)	1.0	2.0	1.2
vii)	2.0	0.5	1.3
viii)	2.0	0.8	1.5
ix)	2.0	1.0	1.6
x)	2.0	1.25	1.9
xi)	2.0	2.0	4.9
xii)	3.0	0.5	1.8
xiii)	3.0	0.8	2.0
xiv)	3.0	1.0	2.3
xv)	3.0	1.25	2.8
xvi)	3.0	2.0	13.0

30.5 Equivalent Frame Method

30.5.1 *Assumptions*

The bending moments and shear forces may be determined by an analysis of the structure as a continuous frame and the following assumptions may be made:

a) The structure shall be considered to be made up of equivalent frames on column lines taken longitudinally and transversely through the building. Each frame consists of a row of equivalent columns or supports, bounded laterally by the centre-line of the panel on each side of the centre-line of the columns or supports. Frames adjacent and parallel to an edge shall be bounded by the edge and the centre-line of the adjacent panel.

b) Each such frame may be analysed in its entirety, or, for vertical loading, each floor thereof and the roof may be analysed separately with its columns being assumed fixed at their remote ends. Where slabs are thus analysed separately, it may be assumed in determining the bending moment at a given support that the slab is fixed at any support two panels distant therefrom provided the slab continuous beyond the point.

c) For the purpose of determining relative stiffness of members, the moment of inertia of any slab or column may be assumed to be that of the gross cross-section of the concrete alone.

d) Variations of moment of inertia along the axis of the slab on account of provision of drops shall be taken into account. In the case of recessed or coffered slab which is made solid in the region of the columns, the stiffening effect may be ignored provided the solid part of the slab does not extend more than 0.15 l_{ef}, into the span measured from the centre-line of the columns. The stiffening effect of flared column heads may be ignored.

30.5.2 *Loading Pattern*

30.5.2.1 When the loading pattern is known, the structure shall be analysed for the load concerned.

30.5.2.2 When the live load is variable but does not exceed three-quarters of the dead load, or the nature of the live load is such that all panels will be loaded simultaneously, the maximum moments may be assumed to occur at all sections when full design live load is on the entire slab system.

30.5.2.3 For other conditions of live load/dead load ratio and when all panels are not loaded simultaneously,

a) maximum positive moment near midspan of a panel may be assumed to occur when three-quarters of the full design live load is on the panel and on alternate panels; and

b) maximum negative moment in the slab at a support may be assumed to occur when three-quarters of the full design live load is on the adjacent panels only.

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30.5.2.4 In no case shall design moments be taken to be less than those occurring with full design live load on all panels.

30.5.3 *Negative Design Moment*

30.5.3.1 At interior supports, the critical section for negative moment, in both the column strip and middle strip, shall be taken at the face of rectilinear supports, but in no case at a distance greater than 0.175 l_1 from the centre of the column where l_1 is the length of the span in the direction moments are being determined, measured centre-to-centre of supports.

30.5.3.2 At exterior supports provided with brackets or capitals, the critical section for negative moment in the direction perpendicular to the edge shall be taken at a distance from the face of the supporting element not greater than one-half the projection of the bracket or capital beyond the face of the supporting element.

30.5.3.3 Circular or regular polygon shaped supports shall be treated as square supports having the same area.

30.5.4 *Modification of Maximum Moment*

Moments determined by means of the equivalent frame method, for slabs which fulfil the limitations of **30.4** may be reduced in such proportion that the numerical sum of the positive and average negative moments is not less than the value of total design moment M_o specified in **30.4.2.2**.

30.5.5 *Distribution of Bending Moment Across the Panel Width*

30.5.5.1 *Column strip : Negative moment at an interior support*

At an interior support, the column strip shall be designed to resist 75 percent of the total negative moment in the panel at that support.

30.5.5.2 *Column strip : Negative moment at a exterior support*

a) At an exterior support, the column strip shall be designed to resist the total negative moment in the panel at that support.

b) Where the exterior support consists of a column or a wall extending for a distance equal to or greater than three-quarters of the value of l_2, the length of span transverse to the direction moments are being determined, the exterior negative moment shall be considered to be uniformly distributed across the length l_2.

30.5.5.3 *Column strip : Positive moment for each span*

For each span, the column strip shall be designed to resist 60 percent of the total positive moment in the panel.

30.5.5.4 *Moments in the middle strip*

The middle strip shall be designed on the following bases:

a) That portion of the design moment not resisted by the column strip shall be assigned to the adjacent middle strips.

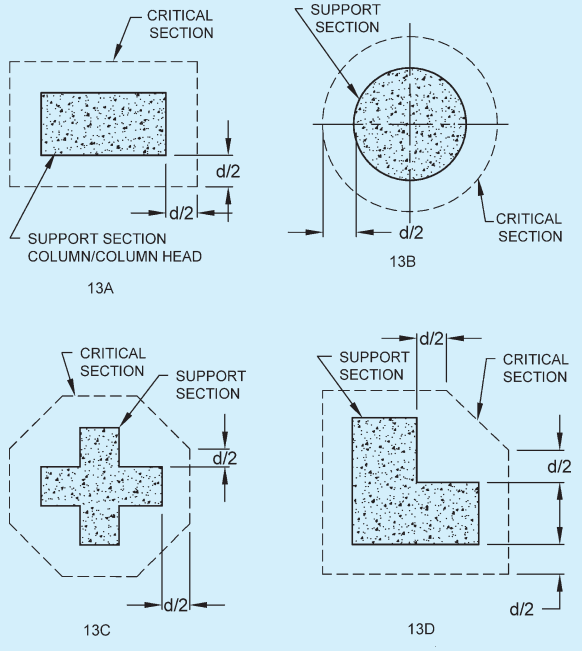
b) Each middle strip shall be proportioned to resist the sum of the moments assigned to its two half middle strips.

c) The middle strip adjacent and parallel to an edge supported by a wall shall be proportioned to resist twice the moment assigned to half the middle strip corresponding to the first row of interior columns.

30.6 Shear in Flat Slab

30.6.1 The critical section for shear shall be at a distance $d/2$ from the periphery of the column/capital/drop panel, perpendicular to the plane of the slab where d is the effective depth of the section (*see* Fig. 12). The shape in plan is geometrically similar to the support immediately below the slab (*see* Fig. 13A and Fig.13B).

NOTE — For column sections with re-entrant angles, the critical section shall be taken as indicated in Fig. 13C and Fig. 13D.



NOTE — d is the effective depth of the flat slab/drop.

FIG. 13 CRITICAL SECTIONS IN PLAN FOR SHEAR IN FLAT SLABS

30.6.1.1 In the case of columns near the free edge of a slab, the critical section shall be taken as shown in Fig. 14.

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30.6.1.2 When openings in flat slabs are located at a distance less than ten times the thickness of the slab from a concentrated reaction or when the openings are located within the column strips, the critical sections specified in **30.6.1** shall be modified so that the part of the periphery of the critical section which is enclosed by radial projections of the openings to the centroid of the reaction area shall be considered ineffective (*see* Fig. 15), and openings shall not encroach upon column head.

30.6.2 *Calculation of Shear Stress*

The shear stress τ_v shall be the sum of the values calculated according to **30.6.2.1** and **30.6.2.2.**

30.6.2.1 The nominal shear stress in flat slabs shall be taken as $V/b_o d$ where V is the shear force due to design load, b_o is the periphery of the critical section and d is the effective depth.

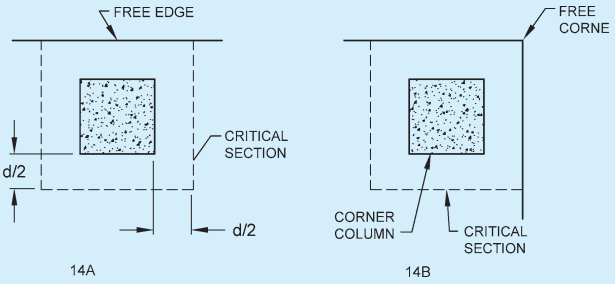


FIG. 14 EFFECT OF FREE EDGES ON CRITICAL SECTION FOR SHEAR

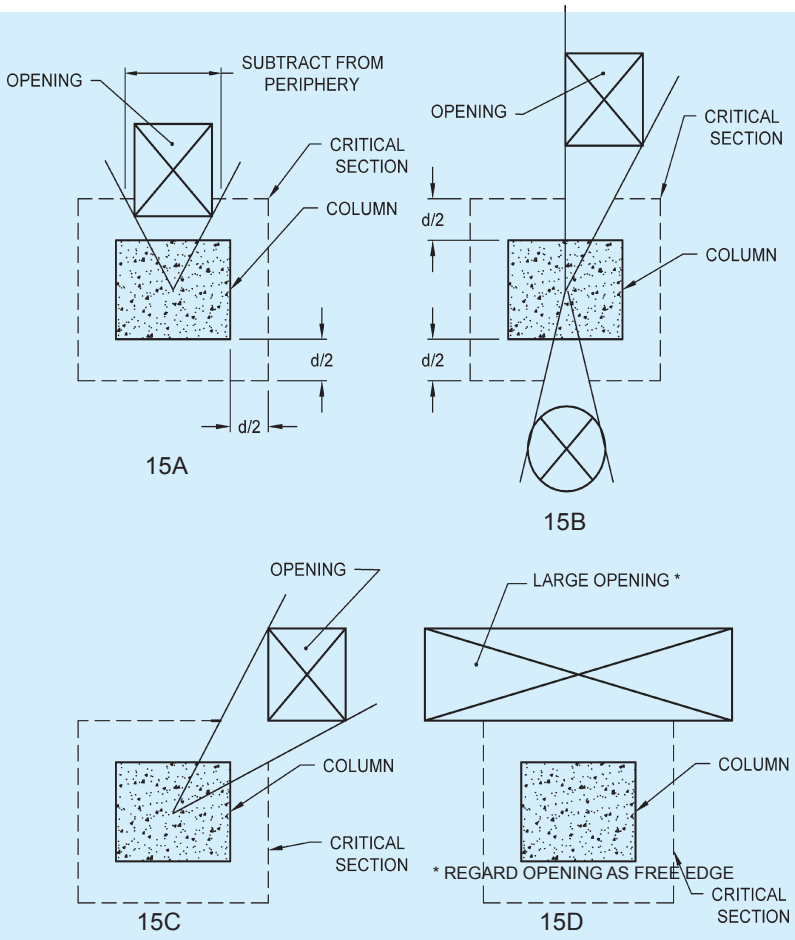


FIG. 15 EFFECT OF OPENINGS ON CRITICAL SECTION FOR SHEAR

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30.6.2.2 When unbalanced gravity load, wind, earthquake or other forces cause transfer of bending moment between slab and column, a fraction $(1 - \alpha)$ of the moment shall be considered transferred by eccentricity of the shear about the centroid of the critical section. Shear stresses shall be taken as varying linearly about the centroid of the critical section. The value of á shall be obtained from the equation given in **30.3.3**.

30.6.3 *Permissible Shear Stress*

30.6.3.1 When shear reinforcement is not provided, the calculated shear stress at the critical section shall not exceed $k_s\tau_c$,

where

k_s = $(0.5 + \beta_c)$ but not greater than 1, β_c being the ratio of short side to long side of the column/capital; and

τ_c = $0.25\sqrt{f_{ck}}$ in limit state method of design, and $0.16\sqrt{f_{ck}}$ in working stress method of design.

30.6.3.2 When the shear stress at the critical section exceeds the value given in **30.6.3.1**, but less than $1.5\tau_c$ shear reinforcement shall be provided. If the shear stress exceeds $1.5\tau_c$, the flat slab shall be redesigned. Shear stresses shall be investigated at successive sections more distant from the support and shear reinforcement shall be provided up to a section where the shear stress does not exceed $0.5\tau_c$. While designing the shear reinforcement, the shear stress carried by the concrete shall be assumed to be $0.5\tau_c$ and reinforcement shall carry the remaining shear.

30.7 Slab Reinforcement

30.7.1 *Spacing*

The spacing of bars in a flat slab, shall not exceed 2 times the slab thickness, except where a slab is of cellular or ribbed construction.

30.7.2 *Area of Reinforcement*

When drop panels are used, the thickness of drop panel for determination of area of reinforcement shall be the lesser of the following:

a) Thickness of drop, and
b) Thickness of slab plus one quarter the distance between edge of drop and edge of capital.

30.7.3 *Minimum Length of Reinforcement*

a) Reinforcement in flat slabs shall have the minimum lengths specified in Fig. 16. Larger lengths of reinforcement shall be provided when required by analysis.
b) Where adjacent spans are unequal, the extension of negative reinforcement beyond each face of the common column shall be based on the longer span.
c) The length of reinforcement for slabs in frames not braced against sideways and for slabs resisting lateral loads shall be determined by analysis but shall not be less than those prescribed in Fig. 16.

30.7.4 *Anchoring Reinforcement*

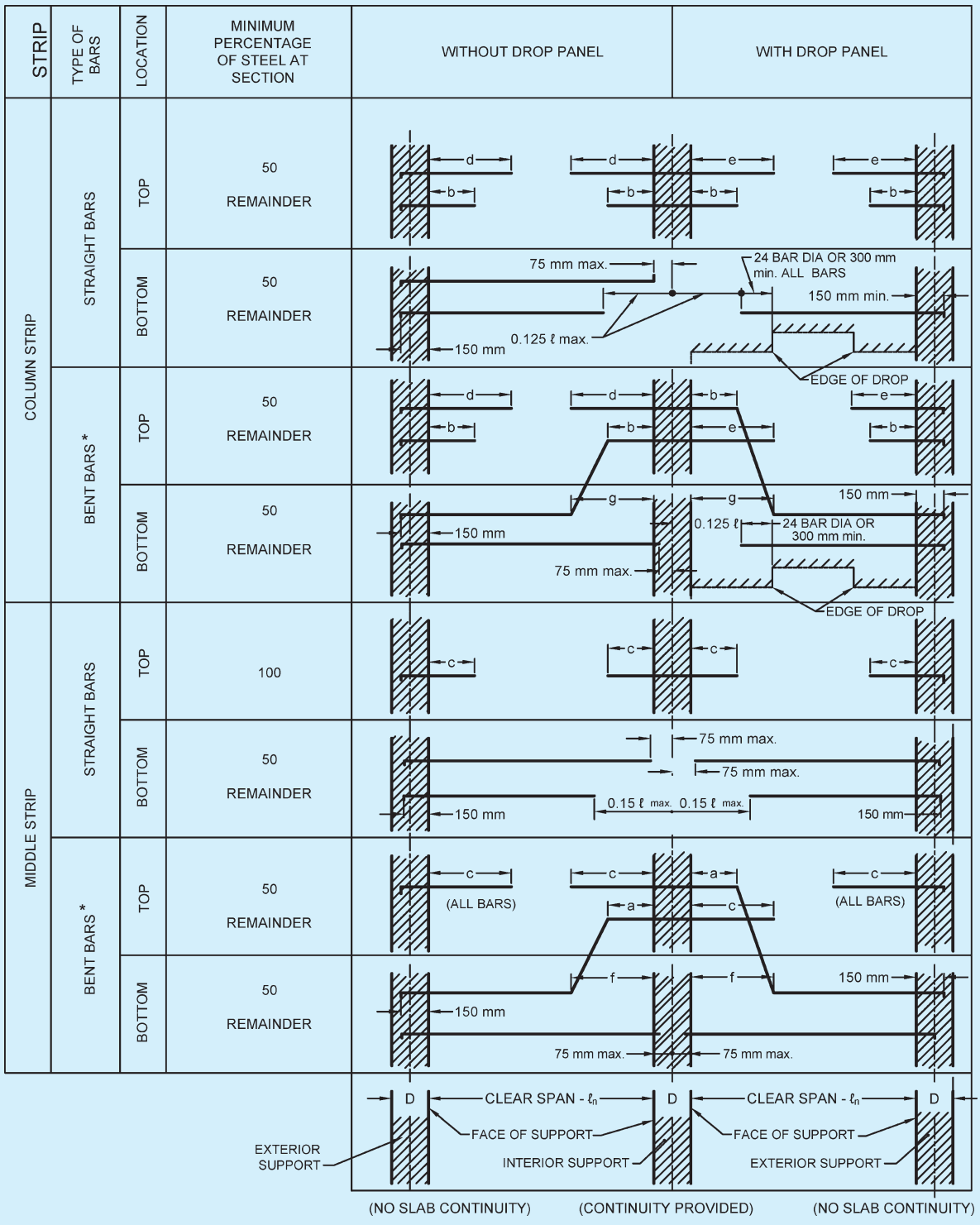
a) All slab reinforcement perpendicular to a discontinuous edge shall have an anchorage (straight, bent or otherwise anchored) past the internal face of the spandrel beam, wall or column, of an amount :
   1) *For positive reinforcement* – Not less than 150 mm except that with fabric reinforcement having a fully welded transverse wire directly over the support, it shall be permissible to reduce this length to one-half of the width of the support or 50 mm, whichever is greater; and
   2) *For negative reinforcement* – Such that the design stress is developed at the internal face, in accordance with Section 5A (C).
b) Where the slab is not supported by a spandrel beam or wall, or where the slab cantilevers beyond the support, the anchorage shall be obtained within the slab.

30.8 Openings in Flat Slabs

Openings of any size may be provided in the flat slab, if it is shown by analysis that the requirements of strength and serviceability are met. However, for openings conforming to the following, no special analysis is required.

a) Openings of any size may be placed within the middle half of the span in each direction, provided the total amount of reinforcement required for the panel without the opening is maintained.
b) In the area common to two column strips, not more than one-eighth of the width of strip in either span shall be interrupted by the openings. The equivalent of reinforcement interrupted shall be added on all sides of the openings.
c) In the area common to one column strip and one middle strip, not more than one-quarter of the reinforcement in either strip shall be interrupted by the openings. The equivalent

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	Bar Length from face of Support						
	Minimum Length					*Maximum Length*	
Mark	a	b	c	d	e	f	g
Length	0.14 l_n	0.20 l_n	0.22 l_n	0.30 l_n	0.33 l_n	0.20 l_n	0.24 l_n

* Bent bars at exterior supports may be used, if a general analysis is made.

NOTE — D is the diameter of the column and the dimension of the rectangular column in the direction under consideration.

FIG. 16 MINIMUM BEND JOINT LOCATION AND EXTENSION FOR REINFORCEMENT IN FLAT SLABS

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of reinforcement interrupted shall be added on all sides of the openings.

d) The shear requirements of **30.6** shall be satisfied.

31 WALLS

31.1 General

Reinforced concrete walls subjected to direct compression or combined flexure and direct compression should be designed in accordance with Section 5 or Annex B provided the vertical reinforcement is provided in each face. Braced walls subjected to only vertical compression may be designed as per empirical procedure given in **31.2**. The minimum thickness of walls shall be 100 mm.

31.1.1 Guidelines or design of walls subjected to horizontal and vertical loads are given in **31.3**.

31.2 Empirical Design Method for Walls Subjected to In-Plane Vertical Loads

31.2.1 *Braced Walls*

Walls shall be assumed to be braced if they are laterally supported by a structure in which all the following apply:

a) Walls or vertical braced elements are arranged in two directions so as to provide lateral stability to the structure as a whole.

b) Lateral forces are resisted by shear in the planes of these walls or by braced elements.

c) Floor and roof systems are designed to transfer lateral forces.

d) Connections between the wall and the lateral supports are designed to resist a horizontal force not less than,

1) the simple static reactions to the total applied horizontal forces at the level of lateral support; and

2) 2.5 percent of the total vertical load that the wall is designed to carry at the level of lateral support.

31.2.2 *Eccentricity of Vertical Load*

The design of a wall shall take account of the actual eccentricity of the vertical force subject to a minimum value of 0.05 *t*.

The vertical load transmitted to a wall by a discontinuous concrete floor or roof shall be assumed to act at one-third the depth of the bearing area measured from the span face of the wall. Where there is an *in-situ* concrete floor continuous over the wall, the load shall be assumed to act at the centre of the wall.

The resultant eccentricity of the total vertical load on a braced wall at any level between horizontal lateral supports, shall be calculated on the assumption that the resultant eccentricity of all the vertical loads above the upper support is zero.

31.2.3 *Maximum Effective Height to Thickness Ratio*

The ratio of effective height to thickness, H_{we}/t shall not exceed 30.

31.2.4 *Effective Height*

The effective height of a braced wall shall be taken as follows:

a) Where restrained against rotation at both ends by:

1) floors : 0.75 H_w or

2) intersecting walls or similar members, whichever is the lesser. : 0.75 L_1

b) Where not restrained against rotation at both ends by:

1) floors : 1.0 H_w or

2) intersecting walls or similar members, whichever is the lesser. : 1.0 L_1

where

H_w = unsupported height of the wall.

L_1 = horizontal distance between centres of lateral restraint.

31.2.5 *Design Axial Strength of Wall*

The design axial strength P_{uw} per unit length of a braced wall in compression may be calculated from the following equation:

$$P_{uw} = 0.3\left(t - 1.2e - 2e_a\right) f_{ck}$$

where

t = thickness of the wall,

e = eccentricity of load measured at right angles to the plane of the wall determined in accordance with **31.2.2**, and

e_a = additional eccentricity due to slenderness effect taken as $H_{we}^2/2\ 500t$.

31.3 Walls Subjected to Combined Horizontal and Vertical Forces

31.3.1 When horizontal forces are in the plane of the wall, it may be designed for vertical forces in accordance with **31.2** and for horizontal shear in accordance with **31.4**. In plane bending may be neglected in case a horizontal cross-section of the wall is always under compression due to combined effect

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of horizontal and vertical loads.

31.3.2 Walls subjected to horizontal forces perpendicular to the wall and for which the design axial load does not exceed $0.04 f_{ck} A_g$, shall be designed as slabs in accordance with the appropriate provisions under **23**, where A_g is gross area of the section.

31.4 Design for Horizontal Shear

31.4.1 *Critical Section for Shear*

The critical section for maximum shear shall be taken at a distance from the base of 0.5 L_w or 0.5 H_w, whichever is less.

31.4.2 *Nominal Shear Stress*

The nominal shear stress τ_{vw} in walls shall be obtained as follows:

$$\tau_{vw} = \frac{V_u}{t.d}$$

where

V_u = shear force due to design loads,

t = wall thickness,

d = $0.8 \times L_w$, where L_w is the length of the wall.

31.4.2.1 Under no circumstances shall the nominal shear stress τ_{cw} in walls exceed $0.17 f_{ck}$ in limit state method and $0.12 f_{ck}$ in working stress method.

31.4.3 *Design Shear Strength of Concrete*

The design shear strength of concrete in walls, τ_{cw}, without shear reinforcement shall be taken as below :

a) For $H_w / L_w \leq 1$

$$\tau_{cw} = (3.0 - H_w / L_w) K_1 \sqrt{f_{ck}}$$

where K_1 is 0.2 in limit state method and 0.13 in working stress method.

b) For $H_w / L_w > 1$

Lesser of the values calculated from (a) above and from,

$$\tau_{cw} = K_2 \sqrt{f_{ck}} \frac{(H_w / L_w + 1)}{(H_w / L_w - 1)}$$

where K_2 is 0.045 in limit state method and 0.03 in working stress method, but τ_{cw} shall be not less than $K_3 \sqrt{f_{ck}}$ in any case where K_3 is 0.15 in limit state method and 0.10 in working stress method.

31.4.4 *Design of Shear Reinforcement*

Shear reinforcement shall be provided to carry a shear equal to $V_u - \tau_{cw} . t \ (0.8 L_w)$. In case of working stress method V_u is replaced by V. The strength of shear reinforcement shall be calculated as per **39.4** or **B-5.4** with A_{av} defined as below:

$$A_{av} = P_w (0.8 L_w) t$$

where P_w is determined as follows :

a) For walls where $H_w / L_w \leq 1$, P_w shall be the lesser of the ratios of either the vertical reinforcement area or the horizontal reinforcement area to the cross-sectional area of wall in the respective direction.

b) For walls where $H_w / L_w > 1$, P_w shall be the ratio of the horizontal reinforcement area to the cross-sectional area of wall per vertical metre.

31.5 Minimum Requirements for Reinforcement in Walls

The reinforcement for walls shall be provided as below:

a) The minimum ratio of vertical reinforcement to gross concrete area shall be:
   1) 0.001 2 for deformed bars not larger than 16 mm in diameter and with a characteristic strength of 415 N/mm^2 or greater.
   2) 0.001 5 for other types of bars.
   3) 0.001 2 for welded wire fabric not larger than 16 mm in diameter.

b) Vertical reinforcement shall be spaced not farther apart than three times the wall thickness nor 450 mm.

c) The minimum ratio of horizontal reinforcement to gross concrete area shall be:
   1) 0.002 0 for deformed bars not larger than 16 mm in diameter and with a characteristic strength of 415 N/mm^2 or greater.
   2) 0.002 5 for other types of bars.
   3) 0.002 0 for welded wire fabric not larger than 16 mm in diameter.

d) Horizontal reinforcement shall be spaced not farther apart than three times the wall thickness nor 450 mm.

NOTE — The minimum reinforcement may not always be sufficient to provide adequate resistance to the effects of shrinkage and temperature.

31.5.1 For walls having thickness more than 200 mm, the vertical and horizontal reinforcement shall be provided in two grids, one near each face of the wall.

31.5.2 Vertical reinforcement need not be enclosed by

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transverse reinforcement as given in **25.5.3.2** for column, if the vertical reinforcement is not greater than 0.01 times the gross sectional area or where the vertical reinforcement is not required for compression.

32 STAIRS

32.1 Effective Span of Stairs

The effective span of stairs without stringer beams shall be taken as the following horizontal distances :

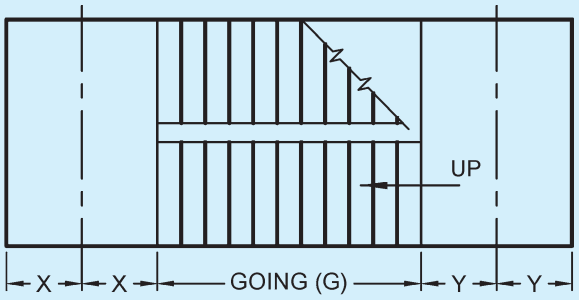
a) Where supported at top and bottom risers by beams spanning parallel with the risers, the distance centre-to-centre of beams ;

b) Where spanning on to the edge of a landing slab, which spans parallel, with the risers (*see* Fig. 17), a distance equal to the going of the stairs plus at each end either half the width of the landing or one metre, whichever is smaller; and

c) Where the landing slab spans in the same direction as the stairs, they shall be considered as acting together to form a single slab and the span determined as the distance centre-to-centre of the supporting beams or walls, the going being measured horizontally.

32.2 Distribution of Loading on Stairs

In the case of stairs with open wells, where spans partly crossing at right angles occur, the load on areas common to any two such spans may be taken as one-half in each direction as shown in Fig. 18. Where flights or landings are embedded into walls for a length of not less than 110 mm and are designed to span in the direction of the flight, a 150 mm strip may be deducted from the loaded area and the effective breadth of the section increased by 75 mm for purposes of design (*see* Fig. 19).



X	Y	SPAN (m)
< 1 m	< 1 m	G + X + Y
< 1 m	≥ 1 m	G + X + 1
≥ 1 m	< 1 m	G + Y + 1
≥ 1 m	≥ 1 m	G + 1 + 1

FIG. 17 EFFECTIVE SPAN FOR STAIRS SUPPORTED AT EACH END BY LANDINGS SPANNING PARALLEL WITH THE RISERS

32.3 Depth of Section

The depth of section shall be taken as the minimum thickness perpendicular to the soffit of the staircase.

33 FOOTINGS

33.1 General

Footings shall be designed to sustain the applied loads, moments and forces and the induced reactions and to ensure that any settlement which may occur shall be as nearly uniform as possible, and the safe bearing

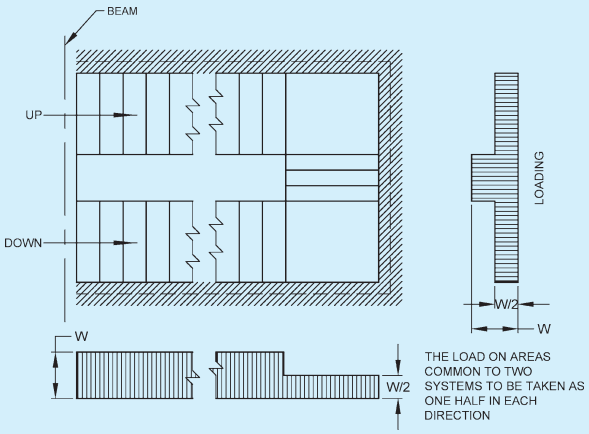


FIG. 18 LOADING ON STAIRS WITH OPEN WELLS

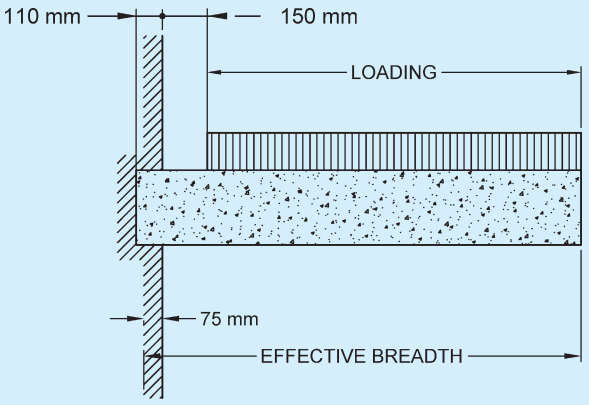


FIG. 19 LOADING ON STAIRS BUILT INTO WALLS

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capacity of the soil is not exceeded (*see* Part 6 'Structural Design, Section 2 Soils and Foundations' of the Code).

33.1.1 In sloped or stepped footings the effective cross-section in compression shall be limited by the area above the neutral plane, and the angle of slope or depth and location of steps shall be such that the design requirements are satisfied at every section. Sloped and stepped footings that are designed as a unit shall be constructed to assure action as a unit.

33.1.2 *Thickness at the Edge of Footing*

In reinforced and plain concrete footings, the thickness at the edge shall be not less than 150 mm for footings on soils, nor less than 300 mm above the tops of piles for footings on piles.

33.1.3 In the case of plain concrete pedestals, the angle between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and the horizontal plane (*see* Fig. 20) shall be governed by the expression :

$$\tan\alpha \not< 0.9\sqrt{\frac{100q_o}{f_{ck}}+1}$$

where

q_o = calculated maximum bearing pressure at the base of the pedestal, in N/mm^2; and

f_{ck} = characteristic strength of concrete at 28 days, in N/mm^2.

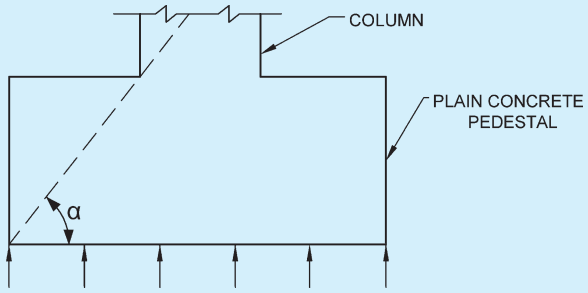


FIG. 20

33.2 Moments and Forces

33.2.1 In the case of footings on piles, computation for moments and shears may be based on the assumption that the reaction from any pile is concentrated at the centre of the pile.

33.2.2 For the purpose of computing stresses in footings which support a round or octagonal concrete column or pedestal, the face of the column or pedestal shall be taken as the side of a square inscribed within the perimeter of the round or octagonal column or pedestal.

33.2.3 *Bending Moment*

33.2.3.1 The bending moment at any section shall be determined by passing through the section a vertical plane which extends completely across the footing, and computing the moment of the forces acting over the entire area of the footing on one side of the said plane.

33.2.3.2 The greatest bending moment to be used in the design of an isolated concrete footing which supports a column, pedestal or wall, shall be the moment computed in the manner prescribed in **33.2.3.1** at sections located as follows:

a) At the face of the column, pedestal or wall, for footings supporting a concrete column, pedestal or wall ;

b) Halfway between the centre-line and the edge of the wall, for footings under masonry walls; and

c) Halfway between the face of the column or pedestal and the edge of the gusseted base, for footings under gusseted bases.

33.2.4 *Shear and Bond*

33.2.4.1 The shear strength of footings is governed by the more severe of the following two conditions:

a) Footing acting essentially as a wide beam, with a potential diagonal crack extending in a plane across the entire width; the critical section for this condition shall be assumed as a vertical section located from the face of the column, pedestal or wall at a distance equal to the effective depth of footing in case of footings on soils, and at a distance equal to half the effective depth of footing for footings on piles.

b) Two-way action of the footing, with potential diagonal cracking along the surface of truncated cone or pyramid around the concentrated load; in this case, the footing shall be designed for shear in accordance with appropriate provisions specified in **30.6**.

33.2.4.2 In computing the external shear on any section through a footing supported on piles, the entire reaction from any pile of diameter D_p whose centre is located $D_p/2$ or more outside the section shall be assumed as producing shear on the section; the reaction from any pile whose centre is located $D_p/2$ or more inside the section shall be assumed as producing no shear on the section. For intermediate positions of the pile centre, the portion of the pile reaction to be assumed as producing shear on the

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section shall be based on straight line interpolation between full value at $D_p/2$ outside the section and zero value at $D_p/2$ inside the section.

33.2.4.3 The critical section for checking the development length in a footing shall be assumed at the same planes as those described for bending moment in **33.2.3** and also at all other vertical planes where abrupt changes of section occur. If reinforcement is curtailed, the anchorage requirements shall be checked in accordance with **25.2.3**.

33.3 Tensile Reinforcement

The total tensile reinforcement at any section shall provide a moment of resistance at least equal to the bending moment on the section calculated in accordance with **33.2.3**.

33.3.1 Total tensile reinforcement shall be distributed across the corresponding resisting section as given below:

a) In one-way reinforced footing, the reinforcement shall be distributed uniformly across the full width of the footing;

b) In two-way reinforced square footing, the reinforcement extending in each direction shall be distributed uniformly across the full width of the footing; and

c) In two-way reinforced rectangular footing, the reinforcement in the long direction shall be distributed uniformly across the full width of the footing. For reinforcement in the short direction, a central band equal to the width of the footing shall be marked along the length of the footing and portion of the reinforcement determined in accordance with the equation given below shall be uniformly distributed across the central band:

$$\frac{\text{Reinforcement in central band width}}{\text{Total reinforcement in short direction}} = \frac{2}{\beta+1}$$

where β is the ratio of the long side to the short side of the footing. The remainder of the reinforcement shall be uniformly distributed in the outer portions of the footing.

33.4 Transfer of Load at the Base of Column

The compressive stress in concrete at the base of a column or pedestal shall be considered as being transferred by bearing to the top of the supporting pedestal or footing. The bearing pressure on the loaded area shall not exceed the permissible bearing stress in direct compression multiplied by a value equal to $\sqrt{\frac{A_1}{A_2}}$

but not greater than 2;

where

A_1 = supporting area for bearing of footing, which inE sloped or stepped footing may be taken as the area of the lower base of the largest frustum of a pyramid or cone contained wholly within the footing and having for its upper base, the area actually loaded and having side slope of one vertical to two horizontal; and

A_2 = loaded area at the column base.

For working stress method of design the permissible bearing stress on full area of concrete shall be taken as $0.25 f_{ck}$; for limit state method of design the permissible bearing stress shall be $0.45 f_{ck}$.

33.4.1 Where the permissible bearing stress on the concrete in the supporting or supported member would be exceeded, reinforcement shall be provided for developing the excess force, either by extending the longitudinal bars into the supporting member, or by dowels (*see* **33.4.3**).

33.4.2 Where transfer of force is accomplished by reinforcement, the development length of the reinforcement shall be sufficient to transfer the compression or tension to the supporting member in accordance with **25.2**.

33.4.3 Extended longitudinal reinforcement or dowels of at least 0.5 percent of the cross-sectional area of the supported column or pedestal and a minimum of four bars shall be provided. Where dowels are used, their diameter shall not exceed the diameter of the column bars by more than 3 mm.

33.4.4 Column bars of diameters larger than 36 mm, in compression only can be dowelled at the footings with bars of smaller size of the necessary area. The dowel shall extend into the column, a distance equal to the development length of the column bar and into the footing, a distance equal to the development length of the dowel.

33.5 Nominal Reinforcement

33.5.1 Minimum reinforcement and spacing shall be as per the requirements of solid slab.

33.5.2 The nominal reinforcement for concrete sections of thickness greater than 1 m shall be 360 mm^2 per metre length in each direction on each face. This provision does not supersede the requirement of minimum tensile reinforcement based on the depth of the section.

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SECTION 5A (E) STRUCTURAL DESIGN (LIMIT STATE METHOD)

34 SAFETY AND SERVICEABILITY REQUIREMENTS

34.1 General

In the method of design based on limit state concept, the structure shall be designed to withstand safely all loads liable to act on it throughout its life; it shall also satisfy the serviceability requirements, such as limitations on deflection and cracking. The acceptable limit for the safety and serviceability requirements before failure occurs is called a 'limit state'. The aim of design is to achieve acceptable probabilities that the structure will not become unfit for the use for which it is intended, that is, that it will not reach a limit state.

34.1.1 All relevant limit states shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

34.1.2 For ensuring the above objective, the design should be based on characteristic values for material strengths and applied loads, which take into account the variations in the material strengths and in the loads to be supported. The characteristic values should be based on statistical data, if available; where such data are not available they should be based on experience. The 'design values' are derived from the characteristic values through the use of partial safety factors, one for material strengths and the other for loads. In the absence of special considerations these factors should have the values given in **35** according to the material, the type of loading and the limit state being considered.

34.2 Limit State of Collapse

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from buckling due to elastic or plastic instability (including the effects of sway where appropriate) or overturning. The resistance to bending, shear, torsion and axial loads at every section shall not be less than the appropriate value at that section produced by the probable most unfavourable combination of loads on the structure using the appropriate partial safety factors.

34.3 Limit States of Serviceability

34.3.1 *Deflection*

Limiting values of deflections are given in **22.2**.

34.3.2 *Cracking*

Cracking of concrete should not adversely affect the appearance or durability of the structure; the acceptable limits of cracking would vary with the type of structure and environment. Where specific attention is required to limit the designed crack width to a particular value, crack width calculation may be done using formula given in Annex G.

The practical objective of calculating crack width is merely to give guidance to the designer in making appropriate structural arrangements and in avoiding gross errors in design, which might result in concentration and excessive width of flexural crack.

The surface width of the cracks should not, in general, exceed 0.3 mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. In members where cracking in the tensile zone is harmful either because they are exposed to the effects of the weather or continuously exposed to moisture or in contact soil or ground water, an upper limit of 0.2 mm is suggested for the maximum width of cracks. For particularly aggressive environment, such as 'very severe' and 'extreme' categories given in Table 3, the assessed surface width of cracks should not in general, exceed 0.1 mm.

34.4 Other Limit States

Structures designed for unusual or special functions shall comply with any relevant additional limit state considered appropriate to that structure.

35 CHARACTERISTIC AND DESIGN VALUES AND PARTIAL SAFETY FACTORS

35.1 Characteristic Strength of Materials

The term 'characteristic strength' means that value of the strength of the material below which not more than 5 percent of the test results are expected to fall. The characteristic strength for concrete shall be in accordance with Table 2. Until the relevant Indian Standard Specifications for reinforcing steel are modified to include the concept of characteristic strength, the characteristic value shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard Specifications.

35.2 Characteristic Loads

The term 'characteristic load' means that value of load which has a 95 percent probability of not being exceeded during the life of the structure. Since data are not available to express loads in statistical terms, for the purpose of this standard, dead loads, imposed loads, wind loads, snow load and seismic forces in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code shall be assumed as the characteristic loads.

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35.3 Design Values

35.3.1 *Materials*

The design strength of the materials, f_d is given by:

$$f_d = \frac{f}{\gamma_m}$$

where

f = characteristic strength of the material (*see* **35.1**), and

γ_m = partial safety factor appropriate to the material and the limit state being considered.

35.3.2 *Loads*

The design load, F_d is given by:

$$F_d = F\gamma_f$$

where

F = characteristic load (*see* **35.2**), and

γ_f = partial safety factor appropriate to the nature of loading and the limit state being considered.

35.3.3 *Consequences of Attaining Limit State*

Where the consequences of a structure attaining a limit state are of a serious nature such as huge loss of life and disruption of the economy, higher values for γ_f and γ_m than those given under **35.4.1** and **35.4.2** may be applied.

35.4 Partial Safety Factors

35.4.1 *Partial Safety Factor γ_f for Loads*

The values γ_f given in Table 18 shall normally be used.

Table 18 Values of Partial Safety Factor γ_f for Loads

(*Clauses* 17.2.3.1, 35.4.1 *and* B-4.3)

Sl No.	Load Combination	Limit State of Collapse			Limit States of Serviceability		
		DL	*IL*	*WL*	*DL*	*IL*	*WL*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	*DL*+ *IL*	1.5	1.5	–	1.0	1.0	–
ii)	*DL*+ *WL*	1.5 or 0.9[1)]	–	1.5	1.0	–	1.0
iii)	*DL*+ *IL*+ *WL*	1.2	1.2	1.2	1.0	0.8	0.8

NOTES

1 While considering earthquake effects, substitute *EL* for *WL*.

2 For the limit states of serviceability, the values of γ_f given in this table are applicable for short term effects. While assessing the long term effects due to creep the dead load and that part of the imposed load likely to be permanent may only be considered.

[1)] This value is to be considered when stability against overturning or stress reversal is critical.

35.4.2 *Partial Safety Factor γ_m for Material Strength*

35.4.2.1 When assessing the strength of a structure or structural member for the limit state of collapse, the values of partial safety factor, γ_m should be taken as 1.5 for concrete and 1.15 for steel.

NOTE — γ_m values are already incorporated in the equations and tables given in this standard for limit state design.

35.4.2.2 When assessing the deflection, the material properties such as modulus of elasticity should be taken as those associated with the characteristic strength of the material.

36 ANALYSIS

36.1 Analysis of Structure

Method of analysis as in **21** shall be used. The material strength to be assumed shall be characteristic values in the determination of elastic properties of members irrespective of the limit state being considered. Redistribution of the calculated moments may be made as given in **36.1.1**.

36.1.1 *Redistribution of Moments in Continuous Beams and Frames*

The redistribution of moments may be carried out satisfying the following conditions:

a) Equilibrium between the internal forces and the external loads is maintained.

b) The ultimate moment of resistance provided at any section of a member is not less than 70 percent of the moment at the section obtained from an elastic maximum moment diagram covering all appropriate combinations of loads.

c) The elastic moment at any section in a member due to a particular combination of loads shall not be reduced by more than 30 percent of the numerically largest moment given anywhere by the elastic maximum moments diagram for the particular member, covering all appropriate combination of loads.

d) At sections where the moment capacity after redistribution is less than that from the elastic maximum moment diagram, the following relationship shall be satisfied:

$$\frac{x_u}{d} + \frac{\delta M}{100} \leq 0.6$$

where

x_u = depth of neutral axis,

d = effective depth, and

δM = percentage reduction in moment.

e) In structures in which the structural frame

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provides the lateral stability, the reduction in moment allowed by condition given in **36.1.1** (c) shall be restricted to 10 percent for structures over 4 storeys in height.

36.1.2 *Analysis of Slabs Spanning in Two Directions at Right Angles*

Yield line theory or any other acceptable method may be used. Alternatively the provisions given in Annex D may be followed.

37 LIMIT STATE OF COLLAPSE: FLEXURE

37.1 Assumptions

Design for the limit state of collapse in flexure shall be based on the assumptions given below:

a) Plane sections normal to the axis remain plane after bending.

b) The maximum strain in concrete at the outermost compression fibre is taken as 0.003 5 in bending.

c) The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola or any other shape which result in prediction of strength in substantial agreement with the results of test. An acceptable stress strain curve is given in Fig. 21. For design purposes, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor $\gamma_m = 1.5$ shall be applied in addition to this.

NOTE — For the stress-strain curve in Fig. 21 the design stress block parameters are as follows (*see* Fig. 22):

Area of stress block = $0.36 f_{ck}. x_u$

Depth of centre of compressive force from the extreme fibre in compression = $0.42 x_u$

where

f_{ck} = characteristic compressive strength of concrete, and

x_u = depth of neutral axis.

d) The tensile strength of the concrete is ignored.

e) The stresses in the reinforcement are derived from representative stress-strain curve for the type of steel used. Typical curves are given in Fig. 23. For design purposes the partial safety factor γ_m, equal to 1.15 shall be applied.

f) The maximum strain in the tension reinforcement in the section at failure shall not be less than:

$$\frac{f_y}{1.15E_s} + 0.002$$

where

f_y = characteristic strength of steel, and

E_s = modulus of elasticity of steel.

NOTE — The limiting values of depth of neutral axis for different grades of steel based on the assumptions in **37.1** are as follows:

f_y	$x_{u,max}/d$
250	0.53
415	0.48
500	0.46

The expression for obtaining the moments of resistance for rectangular and T-Sections, based on the assumptions of **37.1**, are given in Annex H.

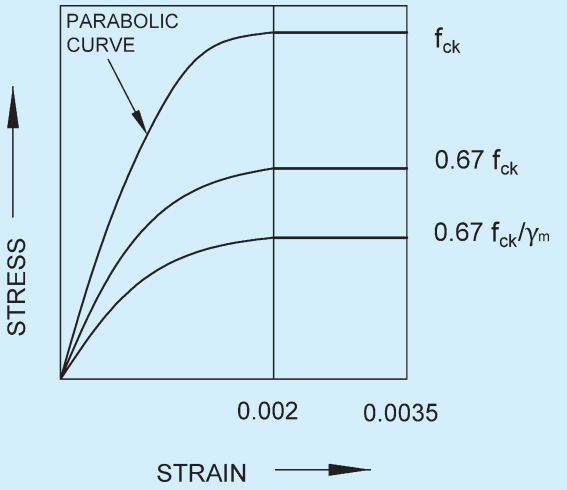


FIG. 21 STRESS-STRAIN CURVE FOR CONCRETE

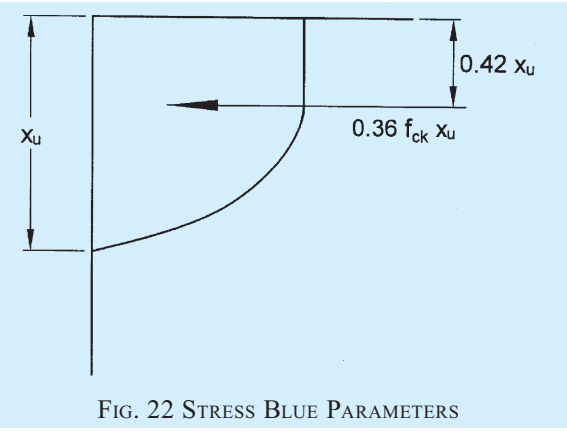


FIG. 22 STRESS BLUE PARAMETERS

38 LIMIT STATE OF COLLAPSE: COMPRESSION

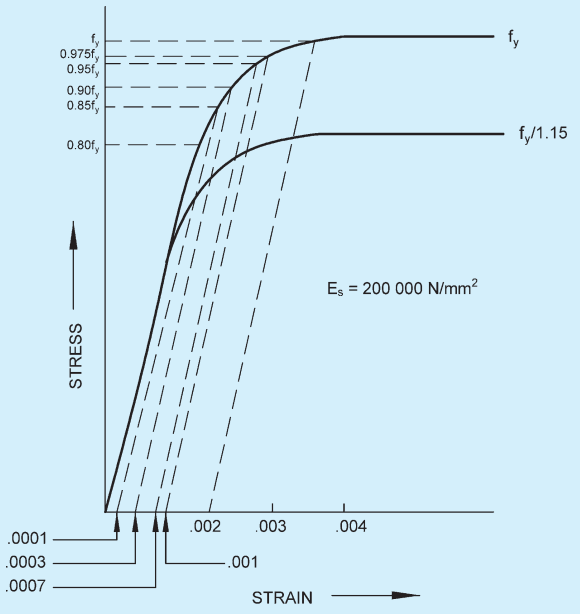
38.1 Assumptions

In addition to the assumptions given in **37.1** (a) to **37.1** (e) for flexure, the following shall be assumed:

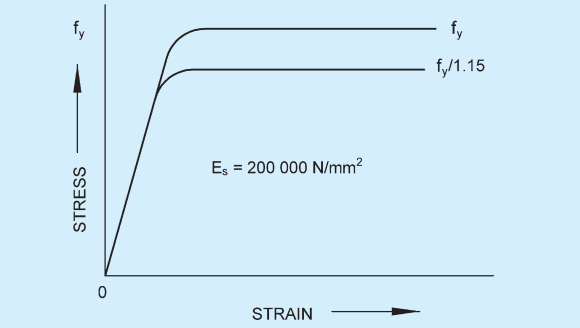
a) Maximum compressive strain in concrete in axial compression is taken as 0.002.

b) Maximum compressive strain at the highly compressed extreme fibre in concrete

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23A COLD WORKED DEFORMED BAR



23B STEEL BAR WITH DEFINITE YIELD POINT

FIG. 23 REPRESENTATIVE STRESS-STRAIN CURVES FOR REINFORCEMENT

subjected to axial compression and bending and when there is no tension on the section shall be 0.003 5 minus 0.75 times the strain at the least compressed extreme fibre.

38.2 Minimum Eccentricity

All members in compression shall be designed for the minimum eccentricity in accordance with **24.4**. Where calculated eccentricity is larger, the minimum eccentricity should be ignored.

38.3 Short Axially Loaded Members in Compression

The member shall be designed by considering the assumptions given in **38.1** and the minimum eccentricity. When the minimum eccentricity as per **24.4** does not exceed 0.05 times the lateral dimension, the members may be designed by the following equation:

$$P_u = 0.4 f_{ck} A_c + 0.067 f_y A_{sc}$$

where

P_u = axial load on the member,

f_{ck} = characteristic compressive strength of the concrete,

A_c = area of concrete

f_y = characteristic strength of the compression reinforcement, and

A_{sc} = area of longitudinal reinforcement for columns.

38.4 Compression Members with Helical Reinforcement

The strength of compression members with helical reinforcement satisfying the requirement of **38.4.1** shall be taken as 1.05 times the strength of similar member with lateral ties.

38.4.1 The ratio of the volume of helical reinforcement to the volume of the core shall not be less than:

$$0.36\left(A_g / A_c - 1\right) f_{ck} / f_y$$

where

A_g = gross area of the section,

A_c = area of the core of the helically reinforced column measured to the outside diameter of the helix,

f_{ck} = characteristic compressive strength of the concrete, and

f_y = characteristic strength of the helical reinforcement but not exceeding 415 N/mm^2.

38.5 Members Subjected to Combined Axial Load and Uniaxial Bending

A member subjected to axial force and uniaxial bending shall be designed on the basis of **38.1** and **38.2**.

NOTE — The design of member subjected to combined axial load and uniaxial bending will involve lengthy calculation by trial and error. In order to overcome these difficulties interaction diagrams may be used.

38.6 Members Subjected to Combined Axial Load and Biaxial Bending

The resistance of a member subjected to axial force and biaxial bending shall be obtained on the basis of assumptions given in **38.1** and **38.2** with neutral axis so chosen as to satisfy the equilibrium of load and moments about two axes. Alternatively, such members may be designed by the following equation:

$$\left[\frac{M_{ux}}{M_{ux1}}\right]^{\alpha_n} + \left[\frac{M_{uy}}{M_{uy1}}\right]^{\alpha_n} \leq 1.0$$

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where

M_{ux}, M_{uy} = moments about x and y axes due to design loads;

M_{ux1}, M_{uy1} = maximum uniaxial moment capacity for an axial load of P_u, bending about x and y axes, respectively; and

α_n is related to P_u/P_{uz}

where

$$P_{uz} = 0.45 f_{ck} \cdot A_c + 0.75 f_y \cdot A_{sc}$$

For values of $P_u/P_{uz} = 0.2$ to 0.8, the values of α_n vary linearly from 1.0 to 2.0. For values less than 0.2, α_n is 1.0; for values greater than 0.8, α_n is 2.0.

38.7 Slender Compression Members

The design of slender compression members (*see* **24.1.1**) shall be based on the forces and the moments determined from an analysis of the structure, including the effect of deflections on moments and forces. When the effect of deflections are not taken into account in the analysis, additional moment given in **38.7.1** shall be taken into account in the appropriate direction.

38.7.1 The additional moments M_{ax} and M_{ay} shall be calculated by the following formulae:

$$M_{ax} = \frac{P_u D}{2\,000}\left[\frac{l_{ex}}{D}\right]^2$$

$$M_{ay} = \frac{P_u b}{2\,000}\left[\frac{l_{ey}}{b}\right]^2$$

where

P_u = axial load on the member,

l_{ex} = effective length in respect of the major axis,

l_{ey} = effective length in respect of the minor axis,

D = depth of the cross-section at right angles to the major axis, and

b = width of the member.

For design of section, **38.5** or **38.6** as appropriate shall apply.

NOTES

1 A column may be considered braced in a given plane if lateral stability to the structure as a whole is provided by walls or bracing or buttressing designed to resist all lateral forces in that plane. It should otherwise be considered as unbraced.

2 In the case of a braced column without any transverse loads occurring in its height, the additional moment shall be added to an initial moment equal to sum of 0.4 M_{u1} and 0.6 M_{u2} where M_{u2} is the larger end moment and M_{u1} is the smaller end moment (assumed negative if the column is bent in double curvature). In no case shall the initial moment be less than 0.4 M_{u2} nor the total moment including the initial moment be less than M_{u2}. For unbraced columns, the additional moment shall be added to the end moments.

3 Unbraced compression members, at any given level or storey, subject to lateral load are usually constrained to deflect equally. In such cases slenderness ratio for each column may be taken as the average for all columns acting in the same direction.

38.7.1.1 The values given by equation **38.7.1** may be multiplied by the following factor:

$$k = \frac{P_{uz} - P_u}{P_{uz} - P_b} \leq 1$$

where

P_u = axial load on compression member,

P_{uz} = as defined in **38.6**, and

P_b = axial load corresponding to the condition of maximum compressive strain of 0.003 5 in concrete and tensile strain of 0.002 in outer most layer of tension steel.

39 LIMIT STATE OF COLLAPSE: SHEAR

39.1 Nominal Shear Stress

The nominal shear stress, t_v, in beams of uniform depth shall be obtained by the following equation:

$$\tau_v = \frac{V_u}{bd}$$

where

V_u = shear force due to design loads;

b = breadth of the member, which for flanged section shall be taken as the breadth of the web, b_w; and

d = effective depth.

39.1.1 *Beams of Varying Depth*

In the case of beams of varying depth the equation shall be modified as:

$$\tau_v = \frac{V_u \pm \frac{M_u}{d}\tan\beta}{bd}$$

where

τ_v, V_u, b and d are the same as in **39.1**,

M_u = bending moment at the section, and

β = angle between the top and the bottom edges of the beam.

The negative sign in the formula applies when the bending moment M_u increases numerically in the same direction as the effective depth d increases, and the positive sign when the moment decreases numerically in this direction.

39.2 Design Shear Strength of Concrete

39.2.1 The design shear strength of concrete in beams without shear reinforcement is given in Table 19.

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Table 19 Design Shear Strength of Concrete, τ_c, N/mm²

(*Clauses* 39.2.1, 39.2.2, 39.3, 39.4, 39.5.3, 40.3.2, 40.3.3 *and* 40.4.3)

Sl No.	$100\frac{A_s}{bd}$	Concrete Grade					
		M 15	M 20	M 25	M 30	M 35	M 40 and Above
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30
ii)	0.25	0.35	0.36	0.36	0.37	0.37	0.38
iii)	0.50	0.46	0.48	0.49	0.50	0.50	0.51
iv)	0.75	0.54	0.56	0.57	0.59	0.59	0.60
v)	1.00	0.60	0.62	0.64	0.66	0.67	0.68
vi)	1.25	0.64	0.67	0.70	0.71	0.73	0.74
vii)	1.50	0.68	0.72	0.74	0.76	0.78	0.79
viii)	1.75	0.71	0.75	0.78	0.80	0.82	0.84
ix)	2.00	0.71	0.79	0.82	0.84	0.86	0.88
x)	2.25	0.71	0.81	0.85	0.88	0.90	0.92
xi)	2.50	0.71	0.82	0.88	0.91	0.93	0.95
xii)	2.75	0.71	0.82	0.90	0.94	0.96	0.98
xiii)	3.00 and above	0.71	0.82	0.92	0.96	0.99	1.01

NOTE — The term A_g is the area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at support where the full area of tension reinforcement may be used provided the detailing conforms to **25.2.2** and **25.2.3**.

39.2.1.1 For solid slabs, the design shear strength for concrete shall be $\tau_c k$, where k has the values given below:

Overall Depth of Slab mm	300 or more	275	250	225	200	175	150 or less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

NOTE — This provision shall not apply to flat slabs for which **30.6** shall apply.

39.2.2 *Shear Strength of Members Under Axial Compression*

For members subjected to axial compression P_u, the design shear strength of concrete, given in Table 19, shall be multiplied by the following factor:

$$\delta = 1 + \frac{3P_u}{A_g f_{ck}} \quad \text{but not exceeding 1.5}$$

where

P_u = axial compressive force, in N;

A_g = gross area of the concrete section, in mm²; and

f_{ck} = characteristic compressive strength of concrete.

Table 20 Maximum Shear Stress, τ_{cmax}, N/mm²

(*Clauses* 39.2.3, 39.2.3.1, 39.5.1 *and* 40.3.1)

Concrete Grade	M 15	M 20	M 25	M 30	M 35	M 40 and Above
$\tau_{c\,max}$, N/mm²	2.5	2.8	3.1	3.5	3.7	4.0

39.2.3 *With Shear Reinforcement*

Under no circumstances, even with shear reinforcement, shall be nominal shear stress in beams τ_v exceed $\tau_{c\,max}$ given in Table 20.

39.2.3.1 For solid slabs, the nominal shear stress shall not exceed half the appropriate values given in Table 20.

Maximum shear stress, τ_{cmax} given in Table 20 is valid for all load cases including earthquake except the following:

a) For coupled beams only, under earthquake forces, the limiting value of τ_{cmax} given in Table 20 shall be superseded by **F-9.**

b) Coupled shear walls shall be connected by ductile coupling beams. If the earthquake induced shear stress in the coupling beam exceeds,

$$\frac{0.1\, l_2 \sqrt{f_{ck}}}{D}$$

where l_s is the clear span of the coupling beam and D is its overall depth, the entire earthquake induced shear and flexure shall, preferably, be resisted by diagonal reinforcement.

The area of reinforcement to be provided along each diagonal in a diagonally reinforced coupling beam shall be,

$$A_{sd} = \frac{V_u}{1.74 f_y \sin\alpha}$$

where V_u is the factored shear force and α is the angle made by the diagonal reinforcement with the horizontal. At least 4 bars of 8 mm diameter shall be provided along each diagonal. The reinforcement along each diagonal shall be enclosed by special confining reinforcement, as per **F-7**. The pitch of spiral or spacing of ties shall not exceed 100 mm.

The diagonal or horizontal bars of a coupling beam shall be anchored in the adjacent walls with an anchorage length of 1.5 times the development length in tension.

39.3 Minimum Shear Reinforcement

When τ_v is less than τ_c given in Table 19, minimum shear reinforcement shall be provided in accordance with **25.5.1.6**.

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39.4 Design of Shear Reinforcement

When τ_v exceeds τ_c given in Table 19, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,
b) Bent-up bars along with stirrups, and
c) Inclined stirrups

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.

Shear reinforcement shall be provided to carry a shear equal to $V_u - \tau_c bd$. The strength of shear reinforcement V_{us} shall be calculated as below:

1) For vertical stirrups:

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}$$

2) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_{us} = \frac{0.87 f_y A_{sv} d}{S_v}(\sin\alpha + \cos\alpha)$$

3) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_{us} = 0.87 f_y A_{sv} \sin\alpha$$

where

A_{sv} = total cross-sectional area of stirrup legs or bent-up bars within a distance s_v,
s_v = spacing of the stirrups or bent-up bars along with the length of the member,
τ_v = nominal shear stress,
τ_c = design shear strength of the concrete,
b = breadth of the member which for flanged beams, shall be taken as the breadth of the web b_w,
f_y = characteristic strength of the stirrup or bent-up reinforcement which shall not be taken greater than 415 N/mm^2,
α = angle between the inclined stirrup or bent-up bar and the axis of the member, not less than 45°, and
d = effective depth.

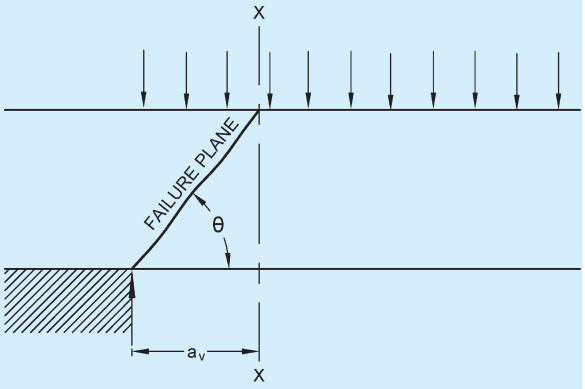
NOTES

1 Where more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately.

2 The area of the stirrups shall not be less than the minimum specified in **25.5.1.6**.

39.5 Enhanced Shear Strength of Sections Close to Supports

39.5.1 *General*



NOTE — The shear causing failure is that acting on section X-X.

FIG. 24 SHEAR FAILURE NEAR SUPPORTS

Shear failure at sections of beams and cantilevers without shear reinforcement will normally occur on plane inclined at an angle 30° to the horizontal. If the angle of failure plane is forced to be inclined more steeply than this [because the section considered ($X-X$) in Fig. 24 is close to a support or for other reasons], the shear force required to produce failure is increased.

The enhancement of shear strength may be taken into account in the design of sections near a support by increasing design shear strength of concrete to $2d\,\tau_c/a_v$ provided that design shear stress at the face of the support remains less than the values given in Table 20. Account may be taken of the enhancement in any situation where the section considered is closer to the face of a support or concentrated load than twice the effective depth, d. To be effective, tension reinforcement should extend on each side of the point where it is intersected by a possible failure plane for a distance at least equal to the effective depth, or be provided with an equivalent anchorage.

39.5.2 *Shear Reinforcement for Sections Close to Supports*

If shear reinforcement is required, the total area of this is given by:

$$\sum A_{sv} = a_v b(\tau_v - 2d\,\tau_c/a_v)/0.87 f_y \geq 0.4 a_v b/0.87 f_y$$

This reinforcement should be provided within the middle three quarters of a_v, where a_v is less than d, horizontal shear reinforcement will be effective than vertical.

39.5.3 *Enhanced Shear Strength Near Supports (Simplified Approach)*

The procedure given in **39.5.1** and **39.5.2** may be used for all beams. However, for beams carrying generally uniform load or where the principal load is located farther than $2d$ from the face of support, the shear stress

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may be calculated at a section a distance d from the face of support. The value of τ_c is calculated in accordance with Table 19 and appropriate shear reinforcement is provided at sections closer to the support, no further check for shear at such sections is required.

40 LIMIT STATE OF COLLAPSE: TORSION

40.1 General

In structures, where torsion is required to maintain equilibrium, members shall be designed for torsion in accordance with **40.2** to **40.4**. However, for such indeterminate structures where torsion can be eliminated by releasing redundant restraints, no specific design for torsion is necessary, provided torsional stiffness is neglected in the calculation of internal forces. Adequate control of any torsional cracking is provided by the shear reinforcement as per **39**.

NOTE — The approach to design in this clause is as follows:

Torsional reinforcement is not calculated separately from that required for bending and shear. Instead the total longitudinal reinforcement is determined for a fictitious bending moment which is a function of actual bending moment and torsion; similarly web reinforcement is determined for a fictitious shear which is a function of actual shear and torsion.

40.1.1 The design rules laid down in **40.3** and **40.4** shall apply to beams of solid rectangular cross-section. However, these clauses may also be applied to flanged beams, by substituting b_w for b in which case they are generally conservative; therefore specialist literature may be referred to.

40.2 Critical Section

Sections located less than a distance d, from the face of the support may be designed for the same torsion as computed at a distance d, where d is the effective depth.

40.3 Shear and Torsion

40.3.1 *Equivalent Shear*

Equivalent shear V_e, shall be calculated from the formula:

$$V_e = V_u + 1.6\frac{T_u}{b}$$

where

V_e = equivalent shear,
V_u = shear,
T_u = torsional moment, and
b = breadth of beam.

The equivalent nominal shear stress τ_{ve} in this case shall be calculated as given in **39.1**, except for substituting V_u by V_e. The values of τ_{ve} shall not exceed the values of $\tau_{c\,max}$ given in Table 20.

40.3.2 If the equivalent nominal shear stress τ_{ve} does not exceed τ_c given in Table 19, minimum shear reinforcement shall be provided as per **25.5.1.6**.

40.3.3 If τ_{ve} exceeds τ_c given in Table 19, both longitudinal and transverse reinforcement shall be provided in accordance with **40.4**.

40.4 Reinforcement in Members Subjected to Torsion

40.4.1 Reinforcement for torsion, when required, shall consist of longitudinal and transverse reinforcement.

40.4.2 *Longitudinal Reinforcement*

The longitudinal reinforcement shall be designed to resist an equivalent bending moment, M_{e1}, given by:

$$M_{e1} = M_u + M_t$$

where

M_u = bending moment at the cross-section, and

$$M_t = T_u\frac{(1+D/b)}{1.7}$$

where

T_u is the torsional moment, D is the overall depth of the beam and b is the breadth of the beam.

40.4.2.1 If the numerical value of M_t as defined in **40.4.2** exceeds the numerical value of the moment M_u, longitudinal reinforcement shall be provided on the flexural compression face, such that the beam can also withstand an equivalent M_{e2} given by $M_{e2} = M_t - M_u$, the moment M_{e2} being taken as acting in the opposite sense to the moment M_u.

40.4.3 *Transverse Reinforcement*

Two legged closed hoops enclosing the corner longitudinal bars shall have an area of cross-section A_{sv}, given by:

$$A_{sv} = \frac{T_u s_v}{b_1 d_1\left(0.87 f_y\right)} + \frac{V_u s_v}{2.5 d_1\left(0.87 f_y\right)}$$

but the total transverse reinforcement shall not be less than

$$\frac{\left(\tau_{ve}-\tau_c\right)b.s_v}{\left(0.87 f_y\right)}$$

where

T_u = torsional moment,
V_u = shear force,
s_v = spacing of the stirrup reinforcement,
b_1 = centre-to-centre distance between corner bars in the direction of the width,
d_1 = centre-to-centre distance between corner bars,

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b = breadth of the member,

f_y = characteristic strength of the stirrup reinforcement,

τ_{ve} = equivalent shear stress as specified in **40.3.1**, and

τ_c = shear strength of the concrete as per Table 19.

41 LIMIT STATE OF SERVICEABILITY: DEFLECTION

41.1 Flexural Members

In all normal cases, the deflection of a flexural member will not be excessive if the ratio of its span to its effective depth is not greater than appropriate ratios given in **22.2.1**. When deflections are calculated according to Annex C, they shall not exceed the permissible values given in **22.2**.

42 LIMIT STATE OF SERVICEABILITY: CRACKING

42.1 Flexural Members

In general, compliance with the spacing requirements of reinforcement given in **25.3.2** should be sufficient to control flexural cracking. If greater spacing are required, the expected crack width should be checked by formula given in Annex G.

42.2 Compression Members

Cracks due to bending in a compression member subjected to a design axial load greater than $0.2f_{ck}A_c$, where f_{ck} is the characteristic compressive strength of concrete and A_c is the area of the gross section of the member, need not be checked. A member subjected to lesser load than $0.2f_{ck}A_c$ may be considered as flexural member for the purpose of crack control (*see* **42.1**).

ANNEX A

(*Clause* 16B.2.4.1)

DESIGN OF STEEL FIBRE REINFORCED CONCRETE

A-1 GENERAL

This annex shall apply where steel fibres are used to improve the performance and capacity of reinforced and prestressed concrete structures.

The design of steel fibre reinforced concrete (SFRC) at both the ultimate and serviceability limit states shall be based on the stress (σ) ≠ strain (ε) relationships for SFRC as specified in **A-3.3** (*see* Note 1).

Steel fibres shall not be relied upon in plastic hinge regions for strength requirements (*see* Note 2).

Steel fibres shall not be relied upon at constructions joints for either serviceability or strength requirements. Design procedure in this clause is for steel-fibre-reinforced concrete with a softening classification only (*see* Fig. 25). Hardening SFRC and the use of synthetic fibres is beyond the scope of this annex.

NOTES

1 When using brittle fibres that rely on a fibre pullout failure mechanism to obtain member ductility, care is required for cases where a significant number of fibres fracture or where fibres result in local crushing of the concrete due to the local forces imposed on the matrix by the fibres. Fibre fracture may occur where the bond between the fibre and the matrix is high, and this is more likely in a high strength concrete combined with fibres of high bond capacity and of lower strength steels.

2 The anchorage capacity of steel fibres may be lost in areas where crack widths exceed about 3.5 mm. Cracking of this magnitude can be expected in regions where plastic rotations are expected.

A-2 DEFINITIONS

For the purpose of this annex the following definitions shall apply.

A-2.1 Crack Mouth Opening Displacement (CMOD) — The width of a crack shall be measured at its mouth in a flexural tensile test. To measure the CMOD, a displacement transducer/clip gauge shall be mounted along the longitudinal axis at the mid width of the test specimen (beam with nominal size of 150 mm × 150 mm and length L so that 550 mm < L < 700 mm).

A-2.2 Crack Opening Displacement (COD) — The width of a single localized crack, taken as an average on four sides, for a direct tensile test on a strain softening SFRC dog-bone shaped specimen in accordance with **A-3.3.7**.

A-2.3 Steel Fibre Reinforced Concrete (SFRC) — A mixture of concrete and steel fibres.

A-2.4 Hardening Behaviour — A material that displays an enhanced strength with increasing crack widths beyond that measured at the point of initial cracking of the cementitious matrix.

A-2.5 Softening Behaviour A material that exhibits a loss of strength upon cracking.

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A-2.6 Target Dosage — The specified quantity of fibres in kilograms per cubic metre of concrete (kg/m^3).

A-3 PROPERTIES OF SFRC

A-3.1 General

SFRC shall be classified in terms of both its characteristic compressive (cylinder) strength (f'_c) (*see* **A-3.2**) and its characteristic residual tensile strength ($f'_{1.5}$) (*see* **A-3.3.3**).

A-3.2 Compressive Strength

The characteristic compressive strength of SFRC at 28 days (f'_c) shall be determined in accordance with good practice [6-5A(14)].

In the absence of more accurate data, the mean value of the in situ compressive strength (f_{cmi}) shall be taken as 90 percent of the mean value of the cylinder strength (f_{cm}).

NOTE — The compressive strength of steel fibre reinforced concrete (SFRC) should be determined by means of standard tests on concrete cylinders. The addition of steel fibres to concrete in conventional dosages (less than 100 kg/m^3) does not change the compressive properties of the concrete.

A-3.3 Tensile Properties

A-3.3.1 *Classification*

SFRC shall be classified as either softening or hardening as shown in Fig. 25. Hardening SFRC is outside the scope of this annex.

NOTES

1 A hardening material is defined as one with a tensile strength equal to or greater than 1.1 times the strength of the matrix without fibres and taken at a crack opening displacement (COD) of equal to or greater than 0.3 mm.

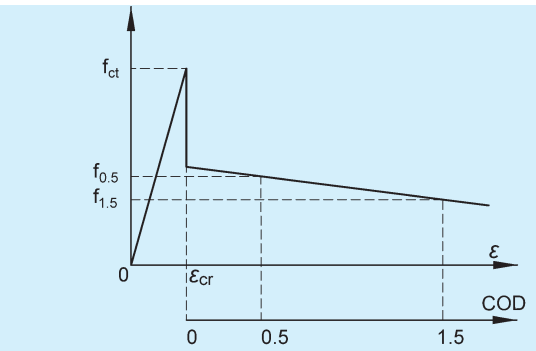
2 A hardening material is one where multiple cracks can occur prior to crack localization. For material hardening to occur, the fibre dosage is typically such that the strength of the SFRC is at least 10 percent greater than the strength of the same concrete mix without fibres. The value of COD of 0.3 is sufficiently high such that matrix contribution to the strength of the composite is minimal and the tension at this point is substantially taken by the fibres alone. Hardening SFRC is outside of the scope of this annex.

A-3.3.2 *Matrix Tensile Strength*

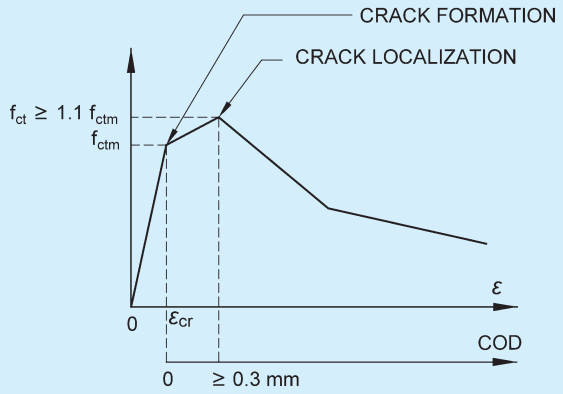
The matrix tensile strength of the softening SFRC (f_{ct}) shall be obtained using flexural tensile testing, in accordance with good practice [6-5A(14)].

When only the characteristic compressive (cylinder) strength (f'_c) has been determined, the mean and characteristic flexural tensile strength of SFRC shall be calculated in accordance with **5.2.2**.

NOTE — For strain softening SFRC, the peak strength of the composite may be approximated as the strength of the concrete mix without fibres.



25A STRAIN SOFTENING SFRC



25B STRAIN HARDENING SFRC

FIG. 25 CLASSIFICATION OF SFRC

A-3.3.3 *Residual Tensile Strength*

The standard characteristic residual tensile strength grades ($f'_{1.5}$) are 0.4 MPa, 0.6 MPa, 0.8 MPa, 1.2 MPa, 1.6 MPa and 2.0 MPa.

The characteristic residual tensile strengths of concrete at 28 days ($f'_{1.5}$) shall be determined statistically from tests carried out in accordance **A-3.3.4** or **A-3.3.5.**

NOTE — The characteristic residual tensile strength depends on the fibre-matrix bond strength, which is usually a function of the compressive strength of the parent concrete, as well as the fibre content. It may be unrealistic to specify a high value of $f'_{1.5}$ when using a relatively low value of f'_c.

A-3.3.4 *Determination of Strength by Direct Testing*

The characteristic residual tensile strength ($f'_{1.5}$) shall be obtained using direct tensile tests as specified in **A-3.3.7**.

Alternatively, where matched direct and indirect testing has been undertaken in accordance with **A-3.3.6** for similar SFRC mixtures, the characteristic residual tensile may be determined as:

$$f'_{1.5} = k_{R,4} f'_{R,4}$$

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Where $f'_{R,4}$ is determined in accordance with **A-3.3.8** and calculated statistically, and the factor $k_{R,4}$ determined from **A-3.3.6**.

For the purposes of this clause, similar SFRC mixtures are defined as having the same,

a) fibre type and content,
b) water to cementitious material ratio,
c) maximum aggregate particle size, and
d) compressive strength (f'_c).

NOTES

1 In calculating the characteristic strength, the population may be treated normally distributed and the strength determined in accordance with accepted standard. A confidence level of 75 percent shall be used such that 95 percent of the population exceeds the characteristic value.

2 The sample standard deviation shall not exceed 25 percent.

A-3.3.5 *Determination of Strength by Indirect Testing*

The characteristic residual tensile strength ($f'_{1.5}$) may be obtained using indirect tests as specified in **A-3.3.8** and calculated as:

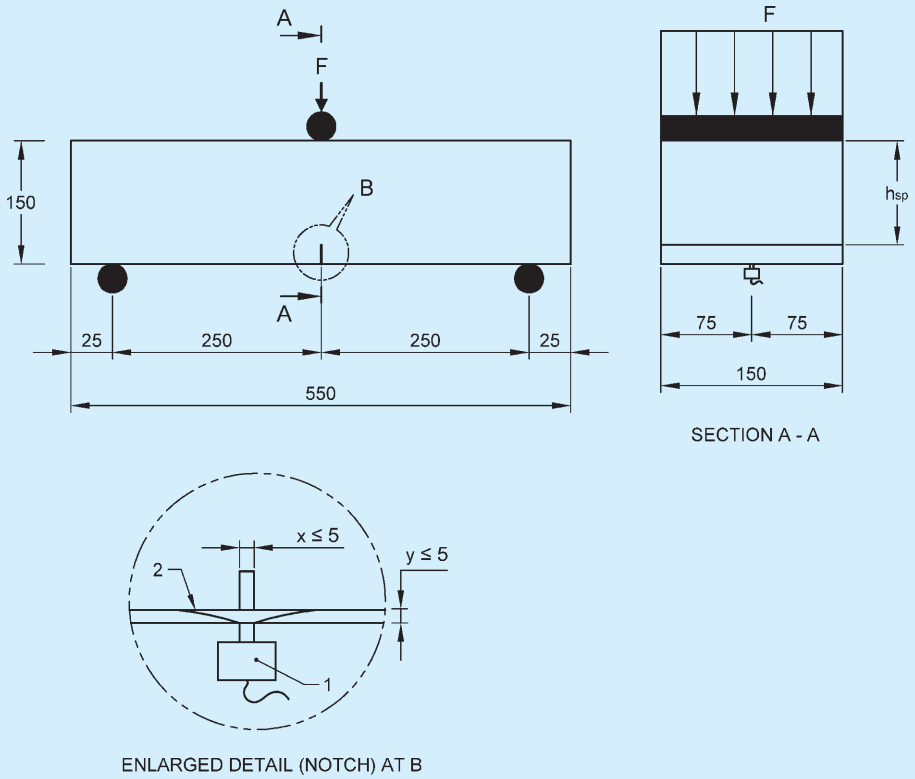
$$f'_{1.5} = 0.4f'_{R,4} - 0.07 f'_{R,2}$$

A-3.3.6 *Residual Tensile Strength-Residual Flexural Strength Relationship*

The relationship between residual tensile strength and the residual flexural strength shall be obtained by matched using the same SFRC mixture. Residual tensile strength specimens shall be prepared and tested in accordance with **A-3.3.7**. Residual flexural tensile tests shall be in accordance with the procedure as mentioned below:

The average width of the specimen and distance between the tip of the notch and the top of the specimen in the mid-span section shall be determined from two measurement to nearest 0.1 mm width and distance in the notch port of the specimen using calipers.

When the CMOD is measured, the displacement transducer shall be mounted along the longitudinal axis at mid width of test specimen such that the distance 'y' between the bottom of specimen and line of measurement is 5 mm or less as mentioned in Fig. 26.



All dimensions in millimetres.

FIG. 26 ARRANGEMENT FOR RESIDUAL FLEXURAL TENSILE TEST

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

a) The concrete mix shall be batched to ensure a uniform distribution of fibres, the SFRC shall be placed in the moulds in a manner that does not interfere with the distribution of the fibres and, the SFRC shall be compacted using lightly applied external vibration; and

b) A minimum of 12 specimens shall be tested.

The reference factor $k_{R,4}$ shall be determined as:

$$k_{R,4} = f_{1.5m}/f_{R,4m}$$

where

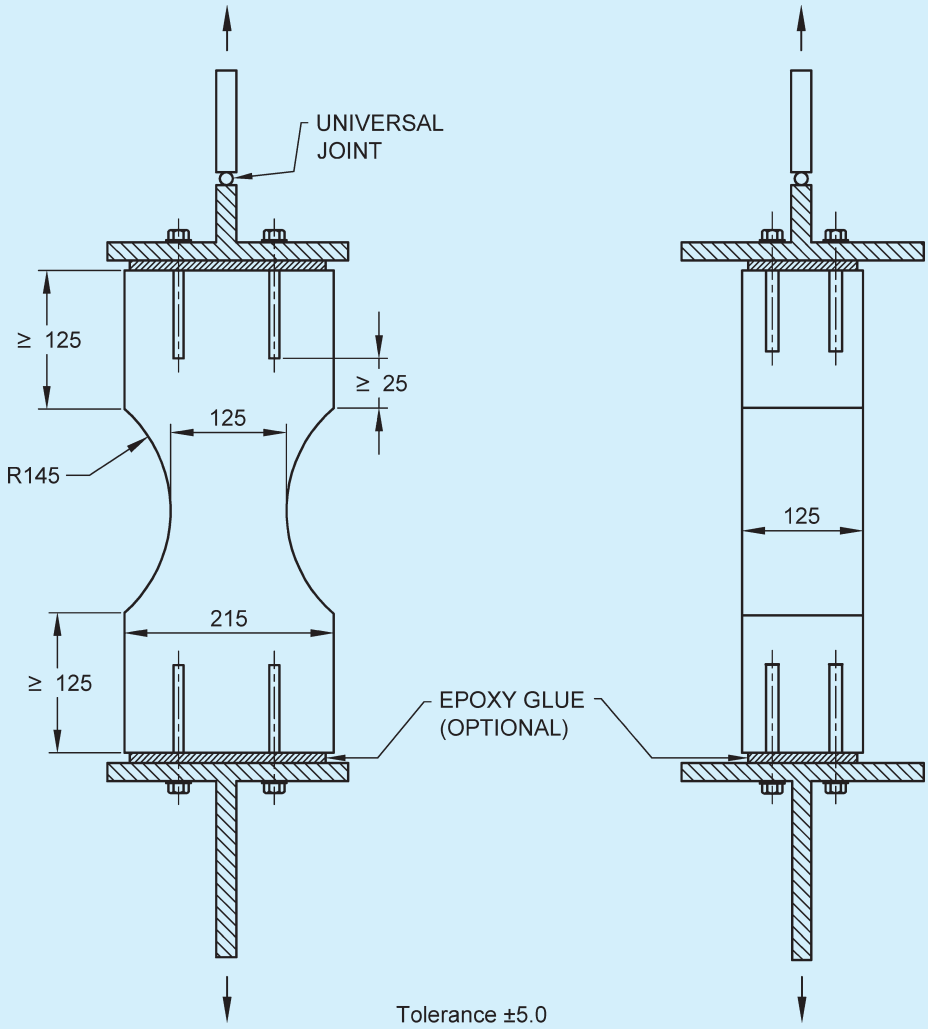
$f_{1.5m}$ = mean residual tensile strengths corresponding to a COD of 1.5 mm, determined in accordance with **A-3.3.7**.

$f_{R,4m}$ = mean residual flexural tensile strengths corresponding to a CMOD of 3.5 mm, determined in accordance with **A-3.3.8**.

NOTE — The residual tensile strength (as obtained from a direct tensile test) is a fundamental material property of SFRC. This clause allows the concrete producer and steel fibre manufacturer to correlate the direct tensile strength of their particular SFRC mix design with the flexural tensile strength.

A-3.3.7 *Residual Tensile Strength Test*

The residual tensile strength shall be obtained using the testing arrangement shown in Fig. 27 and with the following criteria:



All dimensions in millimetres.

NOTE — There is considerable discussion in the literature on whether the ends of the specimens should be fixed at each end, pinned at each end or fixed at one end and pinned at the other. The adoption of one pinned and one fixed end is a pragmatic decision between the ideal condition (fixed at each end) and limitations in manufacturing of specimens that are perfectly square at their ends for alignment within the testing machine. With both ends fixed any misalignment induces a moment in the specimen during gripping. This moment can induce a tensile stress on one side of the specimen, weakening the specimen. In some situations, the moment induced may be sufficient to crack the concrete. The inclusion of the universal joint at one end eliminates residual tensions that may result from the gripping procedure.

FIG. 27 TESTING ARRANGEMENT FOR DIRECT TENSION

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a) The critical section shall be where the cross-sectional area is a minimum.

b) The SFRC mix shall be batched to ensure a uniform distribution of fibres, and shall be placed in the moulds in a manner that does not interfere with the distribution of the fibres. The SFRC shall be compacted using lightly applied external vibration.

c) The specimen shall be connected to the testing machine in such a manner that the machine does not apply a load to the specimen during the process of tightening of the grips and prior to testing.

d) One end of the specimen shall be connected to the testing machine through a universal joint such that no moment is applied to the end of the specimen.

e) Displacement measurements shall be taken on each of the four sides with the COD taken as the average of these measurements.

f) A minimum of twelve specimens shall be tested.

g) Tests where the failure of the specimen is outside of the testing region, or where the results are influenced by the test specimen boundaries, shall be retested.

h) The characteristic values of the tensile strength $f_{0.5}$ and $f_{1.5}$, corresponding to CODs of 0.5 mm and 1.5 mm, respectively, shall be determined statistically as the 95 percentile confidence value assuming the population is normally distributed.

j) The mean values of $f_{0.5m}$ and $f_{1.5m}$, corresponding to CODs of 0.5 mm and 1.5 mm, respectively, shall be determined statistically as the 50th percentile confidence value assuming the population is normally distributed.

The stress results obtained from the test shall be multiplied by the three-dimensional orientation factor k_1, where,

$$k_1 = \frac{1}{0.94 + 0.6\ell_f/b} \leq 1$$

And ℓ_f is the length and b is taken as the average of the width and depth of the specimen taken at the critical section.

NOTE — The factor k_1 removes the influence of the boundaries on the fibre distribution and converts the results of the test to a state where the fibres can be considered to be randomly orientated in three-dimensional space.

A-3.3.8 *Residual Flexural Tensile Strength*

The residual flexural tensile strength $f_{R,j}$ shall be determined from 3 point notched bending tests on 150 mm square section prisms. The notch depth shall be 25 mm and the test conducted in accordance with **A-3.3.6.** The force F shall be plotted against the crack mouth opening displacement (CMOD), as shown in Fig. 28, and the residual flexural stress calculated as:

$$\frac{3F_jL}{2bh_{sp}^{\ 2}}$$

where

b = width of the specimen, in mm;

h_{sp} = distance between tip of the notch and top of cross-section, in mm;

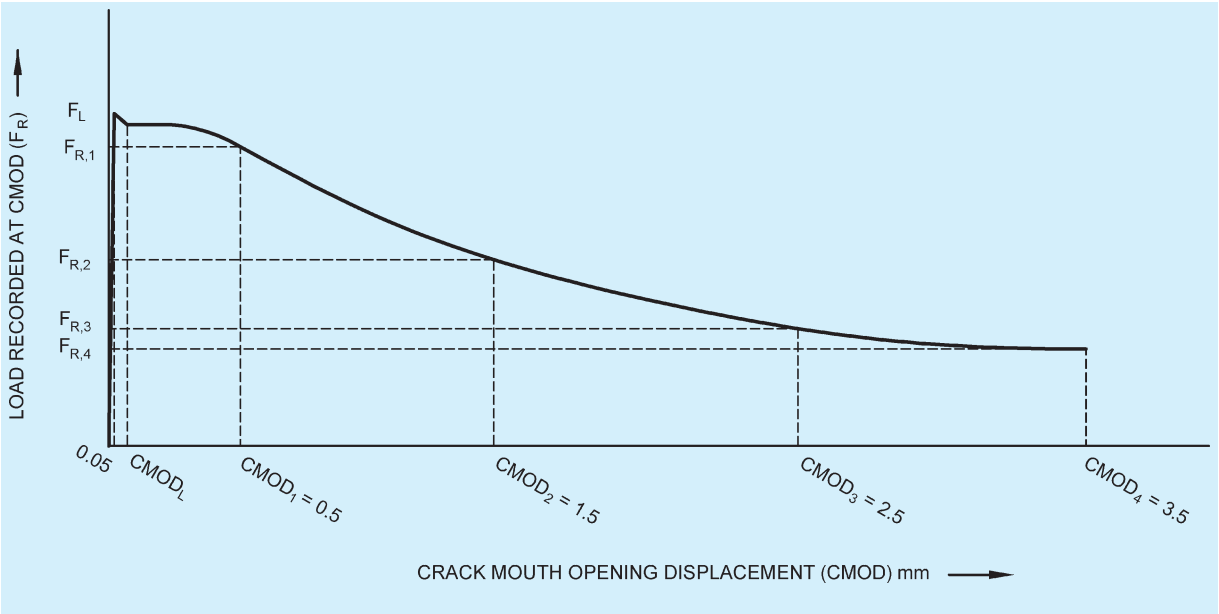


FIG. 28 LOAD *VERSUS* CMOD FOR RESIDUAL FLEXURAL TENSION

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L = span, in mm; and

F_{Rj} = load recorded at $CMOD_j$ (*see* Fig. 28).

A-3.4 Modulus of Elasticity

The mean modulus of elasticity at the appropriate age (E_{cj}) shall be determined in accordance with good practice [6-5A(14)].

NOTE — The addition of steel fibres to concrete in conventional dosages (100 kg/m³ and less) does not change the elastic modulus of the concrete.

A-4 DESIGN OF REINFORCED SFRC MEMBERS

A-4.1 General

This clause applied to reinforced and prestressed beams subjected to any combination of shear force, bending moment and axial force. This clause does not apply when torsion acts in conjunction with shear or to non-flexural members.

A-4.2 Strength of Beams in Bending and Combined Bending and Axial Force

Calculations for strength of cross-sections in bending shall incorporate equilibrium and strain-compatibility considerations and be consistent with the following assumptions:

a) Plane sections normal to the axis shall remain plane after bending.
b) Stress in the fibre reinforced concrete in that part of the cross-section in tension shall be taken to be $f'_{1.5,}$ where $f'_{1.5}$ is the characteristic residual tensile stress determined in accordance with **A-3.3.3**.
c) Distribution of compressive stress shall be determined from a stess-strain relationship for the concrete.

The strength of a section in bending, or in combined bending and axial force, shall be determined using rectangular stress blocks for the concrete in compression and concrete in tension, as shown in Fig. 29.

A-4.3 Minimum Reinforcement Requirements for Bending

The minimum tensile reinforcement shall be not less than that determined using the principles given in this annex, excluding fibres.

A-4.4 Strength of Beams in Shear

A-4.4.1 *Design Shear Strength of a Beam*

The design shear strength of a beam shall be taken as ϕV_u

where

$$V_u = V_{uc} + V_{uf} + V_{us}$$

Where V_{uc} is determined from **39**, V_{us} is determined from **39** and V_{ufc} is determined from **A-4.4.2**.

Notwithstanding the above equations, the fibres component to the shear strength of a beam, V_{uf}, shall not exceed the greater of $0.3V_u$ and that determined by **A-4.4.3** with V_{us} taken as zero.

A-4.4.2 *Contribution to Shear Strength by Steel Fibres*

The contribution of the fibres to the ultimate shear strength V_{uf} of an SFRC beam shall be calculated from the following equation:

$$V_{uf} = 0.7\, k_\theta b_v d_0 f'_{1.5}$$

where

$$k_\theta = \cos\theta_v \le 1.28$$

θ_v = angle between the axis of the concrete compression strut and the longitudinal axis of the member and shall be taken as not less than 38°

A-4.4.3 *Minimum Shear Reinforcement*

The minimum contribution from the total of the transverse steel reinforcement and fibres shall satisfy the following:

$$(V_{us} + V_{uf})_{min} \ge 0.1 b_v d_0 \sqrt{f'_c} \text{ and} \ge 0.6 b_v d_0$$

A-4.5 Design for Serviceability Limit States

A-4.5.1 *General*

When an SRFC cross-sectional is uncracked, the full cross-section shall be assumed to be active and both concrete and steel are assumed to be elastic in tension as well as in compression.

When an SRFC cross-section is cracked, the SFRC shall be assumed to be elastic in compression, and capable of sustaining a tensile stress equal to $1.1 f'_{1.5}$.

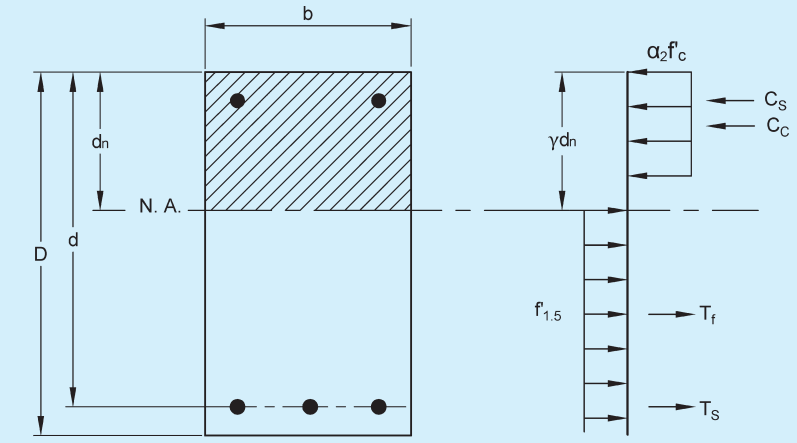
NOTE — Prior to cracking, linear elastic behaviour is assumed for the SFRC, reinforcement and the bonded tendons in both tension and compression. After cracking, the SFRC in tension is assumed to carry a tensile stress of $1.1 f'_{1.5}$, while the SFRC in compression, the reinforcement and the bonded tendons are assumed to be linear elastic.

A-4.5.2 *Stress Limits*

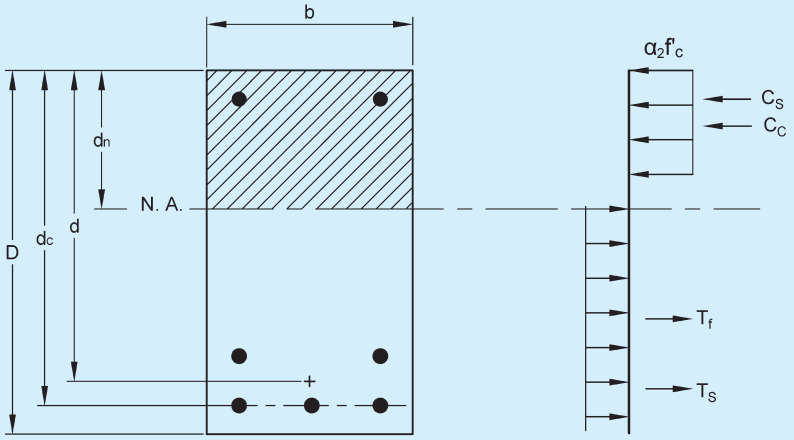
A-4.5.2.1 *Concrete*

The maximum compressive stress in the concrete at the serviceability limit states shall not exceed $0.6 f_{cm}(t)$. Under permanent effect loading, the maximum compressive stress in the concrete shall not exceed $0.4 f_{cm}(t)$.

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29A SINGLE TENSILE REINFORCEMENT LAYER



29B MULTIPLE TENSILE REINFORCEMENT LAYERS

FIG. 29 STRESS BLOCKS AND FORCES ON REINFORCED SFRC SECTION

NOTES

1 The satisfaction of limits on the concrete tensile stress at the serviceability limit state is not necessary if the member performance is satisfactory at the ultimate limit state.

2 Compressive stresses are limited to avoid large time-dependent deformations and to ensure creep behaviour remains linear with respect to stress. Restrictions on the tensile stress in SFRC are not necessary provided the member satisfies all other requirements at the strength and serviceability limit states.

A-4.5.2.2 *Reinforcing steel*

To avoid any inelastic deformation that could lead to large, permanently open cracks, tensile stresses in the reinforcement at the serviceability limit states shall not exceed $0.8 f_{sy.}$

A-4.5.3 *Minimum Reinforcement for Crack Control*

The minimum amount of longitudinal reinforcement required to obtain controlled crack formation shall be:

$$A_{st,min} = k_1 k_c k_p f_{ct,ef} - 1.1 f'_{1.5} \frac{A_{ct}}{f_{s,max}} \geq 0.0 \ (mm^2)$$

where

$A_{s,min}$ = minimum area of reinforcement required within the tensile zone (mm^2). If $Z_{st,min}$ is zero only steel fibres are necessary to control cracking.

A_{ct} = area of concrete within the tensile zone (mm^2). The tensile zone is that part of the cross-section calculated to be in tension just before formation of the first crack.

$f_{s,max}$ = maximum stress permitted in the reinforcement immediately after formation of the crack.

$f_{ct,ef}$ = tensile strength of the concrete effective at the time when the cracks may first be

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expected to occur (MPa). Values of $f_{ct,ef}$ shall be obtained from $0.6\sqrt{f_{cm}}$ but not less than 3.0 MPa and f_{cm} is the mean concrete compressive strength at the time cracking is expected to occur.

k_c = coefficient that takes account of the nature of the stress distribution within the section immediately prior to cracking. The relevant stress distribution is that resulting from the combined effects of loading and restrained imposed deformations:

= 1.0 for pure tension ($e = M/N = 0$).

= 0.6 for pure bending.

k_1 = coefficient which allows for the effect of non-uniform self-equilibrating stresses due to non-linear shrinkage or temperature profiles through the member depth. In the absence of more detailed analysis, k_1 may be taken as 0.8.

k_p = a coefficient that takes account of the level of prestress and is given by:

$$k_p = 1 - \frac{\sigma_{cp}}{k k_c f_{ct,ef}}\left(1 - k_c + 2.4\frac{e}{D} - 6k_c\frac{e}{D}\right)$$

e/D = ratio of the eccentricity of the prestressing force on the cross-section, e, measured from the centroidal axis of the uncracked section to the overall depth of the cross-section, D.

σ_{cp} = average intensity of the effective prestress (P_e/A_g)

A-4.5.4 *Deflection Control*

A-4.5.4.1 *General*

The deflection of an SFRC member shall be calculated using the procedures outlined in **A-4.5.4.2** and **A-4.5.4.3**. Allowance shall be made for the expected load history, the expected construction procedure and any anticipated deflections resulting from deformation of forms or settlement of props.

A-4.5.4.2 *Short-term deflection*

The short-term deflections due to external loads and prestressing, which occur immediately on their application, shall be calculated using the value of E_{cj} determined in accordance with this annex and the value of the effective second moment of area of the member (I_{ef}). The value of I_{ef} may be determined from the values of I_{ef} at nominated cross-sections as follows:

a) For a simply supported span, the value at mid-span.

b) In a continuous beam,

1) For an interior span, half the mid-span value plus one quarter of each support value; or

2) For an end span, half the mid-span value plus half the value at the continuous support.

c) For a cantilever, the value at the support.

For the purpose of the above determinations, the value of I_{ef} at each of the cross-sections nominated in items (a) to (c) is obtained from the instantaneous curvature $k_i = M^*_s/(E_{cj}I_{ef})$ calculated as the slope of the strain diagram in Fig. 30B and obtained by satisfying the requirements for rotational and horizontal equilibrium of the stress distribution in Fig. 30C.

NOTE — The procedure for calculating short-term deflection is consistent with the approach in this annex. Short-term deflection of a cracked section is calculated based on the assumed stress and strain distribution shown in Fig. 30. The assumption of a uniform tensile stress in the cracked region of the SFRC is considered to be reasonable for the determination of the neutral axis location and curvature and, hence, for the determination of the effective second moment of area (I_{ef}).

A-4.5.4.3 *Long-term deflection*

For reinforced and prestressed SFRC flexural members, that part of the deflection that occurs after the short term deflection shall be calculated as the sum of,

a) the shrinkage component of the long-term deflection, determined from the design shrinkage strain of concrete (ε_{cs}) and the principles of mechanics; and

b) the additional long-term creep deflections, determined from the design creep coefficient of concrete (φ_{cc}) and the principles of mechanics.

In the absence of more accurate calculations, the additional long-term deflection of a reinforced SFRC beam due to creep and shrinkage may be calculated by multiplying the short-term deflection caused by the sustained loads by a multiplier, k_{cs}, as follows:

$$k_{cs} = \left[2 - 1.2\left(\frac{A_{sc}}{A_{st}}\right)\right] \geq 0.8$$

NOTE — For the calculation of long-term deflection, two alternative approaches are specified.

For reinforced and prestressed beams, the shrinkage and creep components of the long-term deflection may be calculated separately using the material data specified in the annex and the principles of mechanics. The shrinkage component of the long-term deflection may be readily determined from the shrinkage-induced curvatures calculated at the critical sections along the span of the beam using the design shrinkage strain, (ε_{cs}). The creep component of long-term deflection may be obtained from the creep-induced curvatures at the critical sections under the sustained service loads using the creep coefficient for concrete, (φ_{cc}).

Alternatively, for reinforced concrete beams and slabs, the additional long-term deflection caused by creep and shrinkage may be approximated by multiplying the short-term or

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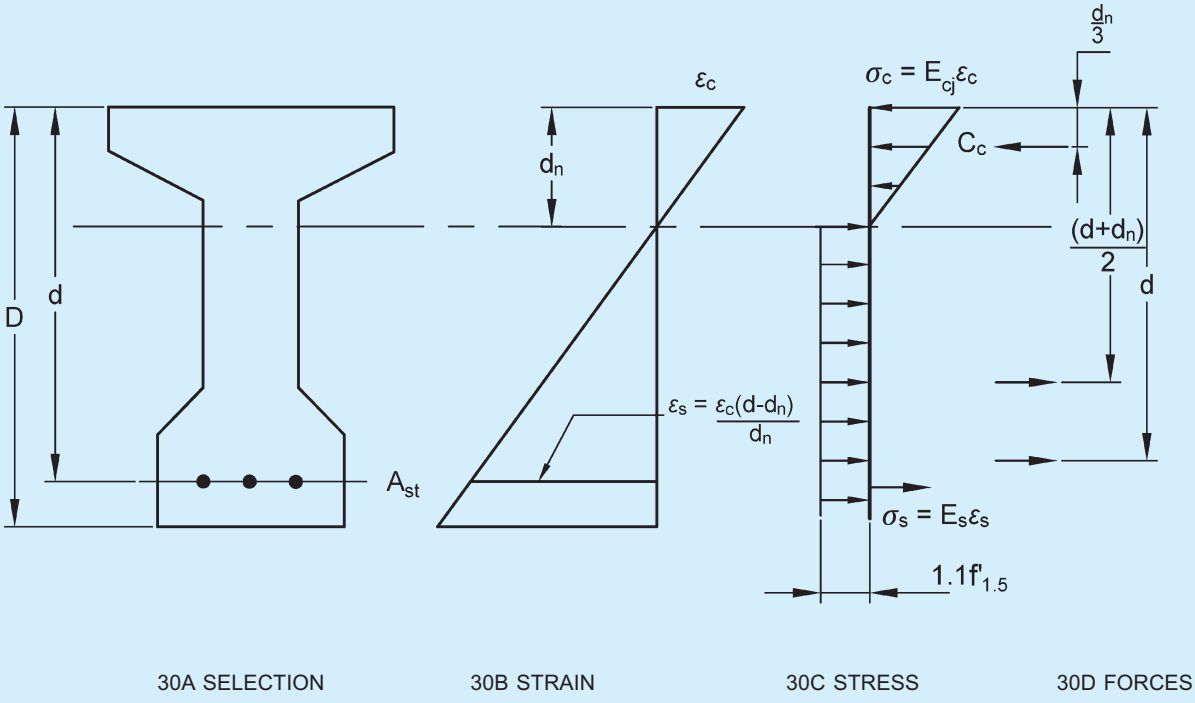


FIG. 30 STRESS AND STRAIN DISTRIBUTION ON A CRACKED SECTION SUBJECTED TO APPLIED IN-SERVICE BENDING MOMENT (M^*_S)

immediate deflection caused by the sustained load by the deflection multiplier k_{cs}. The deflection multiplier depends on the ratio A_{sc}/A_{st}, where A_{sc} is the area of the longitudinal reinforcement in the compressive zone of the cracked section (that is, between the neutral axis and the extreme compressive fibre of the cracked cross-section) and A_{st} is the area of the tensile reinforcement.

A-5 DURABILITY

The minimum concrete grade and cover for SFRC in respective exposure classification shall be as for concrete without fibres and shall apply to the steel reinforcement only. SFRC shall not be used in exposure classification C1 or C2.

NOTES

1 Steel fibres do not require concrete cover as specified for steel reinforcement.

2 SFRC may not be suitable in some exposure classification U environments.

3 Fibres close to the surface are subject to corrosion and may result in surface staining. This will not impact durability.

A-6 FIRE

The structural performance of SFRC for fire shall be determined in accordance with this annex. The material properties for SFRC shall be as specified for concrete in this annex except that to characteristic residual tensile stress of SFRC at elevated temperatures ($f'_{1.52\theta}$) shall be either,

a) taken as ($f'_{1.52\theta}$) = $k_{\theta 1} \times f'_{1.5}$ where $k_{\theta 1}$ is given in Table 21; or

b) determined statistically from tests.

Table 21 Elevated Temperature Coefficient for Residual Tensile Stress of SFRC

(*Clause* A-6)

Temperature of SFRC °C	0	100	500	700	1 200
$k_{\theta 1}$	1.0	1.0	0.6	0.1	0.0

NOTE — Linear interpolation between the values is permitted.

A-7 PRODUCTION OF SFRC

A-7.1 Fibres

Steel fibres shall comply with accepted standard. The 'Certificate of Conformity' shall be supplied on request to the relevant authority.

NOTE — Till the availability of a separate Indian Standard Specification for Steel Fibres, reference may be made to ASTM A820:2016 'Standard Specification for Steel Fibres for Fibre-Reinforced Concrete'.

A-7.2 Mixing of Fibres

Fibres of the type and quantity specified shall be added in a controlled process ensuring that they are dispersed uniformly through the concrete mix. If added after the main mixing process, the concrete shall be remixed until the fibres have been completely dispersed throughout the batch.

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NOTES

1 Balling of fibres should be avoided.

2 A record of fibre content should be recorded for each batch.

A-7.3 Pre-Construction Testing of Materials

Pre-construction testing in the form of initial type tests shall be undertaken in accordance with Table 22.

New initial type tests shall be undertaken when any of the following occur:

a) Concrete composition changes.
b) At least one source material of the concrete changes.
c) Results of compressive tests undertaken as per this annex do not meet the specification.
d) At least once in a period of 12 months.

The pre-construction tests shall be performed with the same personnel, materials and equipment that shall be used during production.

Table 22 Pre-Construction Tests

(*Clause* A-7.3)

Sl No.	Material	Inspection/Test	Purpose
(1)	(2)	(3)	(4)
i)	Steel fibres	a) Check delivery note	Verify that the delivery is in accordance with the order, and is shipped from the correct source
		b) Check conformity label	Verify that the fibres have the correct conformity label which matches the corresponding Certificate of Conformity
ii)	Steel fibre content in the fresh concrete	Testing according to **A-2.5** on the basis of 9 samples	Conformity with the target dosage. Verify homogeneous distribution of the steel fibres in the mix
iii)	Steel fibre concrete performance	Check limit of proportionality, and post-crack flexural strength in accordance with **A-3.3.6** on a minimum of 12 beams	Verify, if the performance is in accordance to the specification The performance level serves as the reference for continuous production control

NOTE — The strength of the population may be treated as normally distributed and the characteristic strength determined in accordance with this annex. A confidence level of 75 percent shall be used such that 95 percent of the population exceeds the characteristic value. For a sample of 12 specimens, the characteristic strength may be calculated from the mean strength using characteristic strength = mean strength ×(1–1.84 × COV). The coefficient of variation (COV as a percentage) shall not exceed 25 percent.

A-7.4 Factory Production control

Factory production control is accordance with Table 23 shall be undertaken to establish a production process for the steel fibre reinforced concrete, and shall include the following:

a) Checking the correct concrete constituents are being used in production.
b) Steel fibres are checked against specified requirements.
c) Compressive tests undertaken in accordance with good practice [6-5A(14)].
d) Fibre content and distribution.

A-7.5 Determining the Steel Fibre Content

Steel fibre content shall be measured from samples taken from the production concrete, by volume of concrete.

In addition,

a) a sample shall be taken from the batch of concrete at unloading from the first third, middle third and final third of the batch;
b) each sample shall be a minimum of 10 litre;
c) the sample container shall be filled in one continuous pour and where possible directly from the discharge chute; and
d) wash out or magnetic separation only shall be used.

The conformity of the correct steel fibre dosage is proven if the criteria in Table 24 are met.

A-7.6 Sampling, Testing and Assessment for Compliance of Hardened SFRC

When concrete is specified by parameters other than strength grade, the method of production control and, if required, project control shall be specified together with the relevant compliance criteria.

Methods of control and assessment shall provide a reliable operating characteristic curve so that,

a) concrete with a proportion defective of 0.05 has a probability of acceptance of at least 50 percent; and
b) concrete with a proportion defective of 0.30 has a probability of rejection of at least 98 percent.

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Table 23 Routine Production Control

(*Clause* A-7.4)

Sl No.	Subject	Inspection/Test	Purpose	Frequency
(1)	(2)	(3)	(4)	(5)
i)	**Equipment inspection**			
	Automatic dosing equipment for steel fibres	a) Visual inspection	Assure correct functioning of dosing device	Once per production day
		b) Control of accuracy	Avoid improper fibre dosage	On installation Periodically In case of doubt
ii)	**Materials inspection**			
	Steel fibres	a) Check delivery note	Verify that the delivery is in accordance with the order, and is shipped from the correct source	Each delivery
		b) Check conformity requirements	Verify that the fibres matches the corresponding Certificate of Conformity	Each delivery
		c) Visual control, measure fibre dimensions	Compare the fibre geometry with the fibres used for ITT	Each delivery
iii)	**Production process inspection**			
	a) Fibres content-record	Record the quantity added	Check the content	Every batch
	b) Fibre content in the fresh concrete	Testing according to **A-7.5**	Conformity with the target dosage Verify homogenous distribution of the steel fibres in the mix	Beginning of each day and every/ $50m^3$ (manual dosing) and/ $150\ m^3$ (auto dosing)
	c) Concrete mix	Visual check	Correct mixing with correct fibre type and even fibre distribution without balling	Daily
iv)	**Finished product inspection**			
	Steel fibre concrete performance	Check limit of proportionality, and post-crack flexural strength in accordance with **A-3.3.6**	Check performance level of the specification	2 beams every other day of production

Table 24 Criteria of Acceptance for Steel Fibre Dosage

(*Clause* A-7.5)

Sl No.	Test Control	Test Control	Criteria
(1)	(2)	(3)	(4)
i)	Each sample	Each partial test	≥ 0.80 of the specified target dosage
ii)	Average of 3 samples from the batch	Each test	≥ 0.85 of the specified target dosage
iii)	Continuous control: average of >3 tests	Continuous control average of >3 tests	≥ 0.90 of the specified target dosage

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ANNEX B

(*Clauses* 17.2.2, 21.3.1, 21.7, 25.2.1.1 *and* 31.1)

STRUCTURAL DESIGN (WORKING STRESS METHOD)

B-1 GENERAL

B-1.1 General Design Requirements

The general design requirements of Section 5A (C) shall apply to this annex.

B-1.2 Redistribution of Moments

Except where the simplified analysis using coefficients (*see* **21.5**) is used, the moments over the supports for any assumed arrangement of loading, including the dead load moments may each be increased or decreased by not more than 15 percent, provided that these modified moments over the supports are used for the calculation of the corresponding moments in the spans.

B-1.3 Assumptions for Design of Members

In the methods based on elastic theory, the following assumptions shall be made:

a) At any cross-section, plane sections before bending remain plain after bending.

b) All tensile stresses are taken up by reinforcement and none by concrete, except as otherwise specifically permitted.

c) The stress-strain relationship of steel and concrete, under working loads, is a straight line.

d) The modular ratio m has the value $\frac{280}{3\sigma_{cbc}}$

where σ_{cbc} is permissible compressive stress due to bending in concrete, in N/mm^2, as specified in Table 25.

NOTE — The expression given for m partially takes into account long-term effects such as creep. Therefore this m is not the same as the modular ratio derived based on the value of E_c given in **5.2.3.1**.

B-2 PERMISSIBLE STRESSES

B-2.1 Permissible Stresses in Concrete

Permissible stresses for the various grades of concrete shall be taken as those given in Tables 25 and 27.

NOTE — For increase in strength with age, **5.2.1** shall be applicable. The values of permissible stress shall be obtained by interpolation between the grades of concrete.

B-2.1.1 *Direct Tension*

For members in direct tension, when full tension is taken by the reinforcement alone, the tensile stress shall be not greater than the values given below:

Grade of Concrete	M10	M15	M20	M25	M30	M35	M40	M45	M50 and Above
Tensile Stress N/mm^2	1.2	2.0	2.8	3.2	3.6	4.0	4.4	4.8	5.2

The tensile stress shall be calculated as:

$$\frac{F_t}{A_e + mA_{st}}$$

where

F_t = total tension on the member minus pretension in steel, if any, before concreting;

A_e = cross-sectional area of concrete excluding any finishing material and reinforcing steel;

m = modular ratio; and

A_{st} = cross-sectional area of reinforcing steel in tension.

B-2.1.2 *Bond Stress for Deformed Bars*

In the case of deformed bars conforming to accepted standard [6-5A(36)], the bond stresses given in Table 25 may be increased by 60 percent.

B-2.2 Permissible Stresses in Steel Reinforcement

Permissible stresses in steel reinforcement shall not exceed the values specified in Table 26.

B-2.2.1 In flexural member the value of σ_{st} given in Table 26 is applicable at the centroid of the tensile reinforcement subject to the condition that when more than one layer of tensile reinforcement is provided, the stress at the centroid of the outermost layer shall not exceed by more than 10 percent the value given in Table 26.

B-2.3 Increase in Permissible Stresses

Where stresses due to wind (or earthquake), temperature and shrinkage effects are combined with those due to dead and imposed load, the stresses specified in Tables 25, 26 and 27 may be exceeded upto a limit of $33\frac{1}{3}$ percent. Wind and seismic forces need not be considered as acting simultaneously.

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Table 25 Permissible Stresses in Concrete

(*Clauses* B-1.3, B-2.1, B-2.1.2, B-2.3 *and* B-4.2)

All values in N/mm^2.

Sl No.	Grade of Concrete	Permissible Stress in Compression		Permissible Stress in Bond (Average) for Plain Bars in Tension
		Bending σ_{cbc}	Direct σ_{cc}	τ_{bd}
(1)	(2)	(3)	(4)	(5)
i)	M 10	3.0	2.5	—
ii)	M 15	5.0	4.0	0.6
iii)	M 20	7.0	5.0	0.8
iv)	M 25	8.5	6.0	0.9
v)	M 30	10.0	8.0	1.0
vi)	M 35	11.5	9.0	1.1
vii)	M 40	13.0	10.0	1.2
viii)	M 45	14.5	11.0	1.3
ix)	M 50	16.0	12.0	1.4
x)	M 55	18.0	13.5	1.5
xi)	M 60	20.0	15.0	1.6

NOTES

1 The values of permissible shear stress in concrete are given in Table 27.

2 The bond stress given in col 4 shall be increased by 25 percent for bars in compression.

B-3 PERMISSIBLE LOADS IN COMPRESSION MEMBERS

B-3.1 Pedestals and Short Columns with Lateral Ties

The axial load P permissible on a pedestal or short column reinforced with longitudinal bars and lateral ties shall not exceed that given by the following equation:

$$P = \sigma_{cc} A_c + \sigma_{sc} A_{sc}$$

where

σ_{cc} = permissible stress in concrete in direct compression,

A_c = cross-sectional area of concrete excluding any finishing material and reinforcing steel,

A_{sc} = cross-sectional area of the longitudinal steel.

NOTE — The minimum eccentricity mentioned in **24.4** may be deemed to be incorporated in the above equation.

B-3.2 Short Columns with Helical Reinforcement

The permissible load for columns with helical reinforcement satisfying the requirement of **38.4.1** shall be 1.05 times the permissible load for similar member with lateral ties or rings.

Table 26 Permissible Stresses in Steel Reinforcement

(*Clauses* B-2.2, B-2.2.1, B-2.3 *and* B-4.2)

Sl No.	Type of Stress in Steel Reinforcement	Permissible Stresses N/mm^2		
		Mild Steel Bars Conforming to Grade 1 of Accepted Standard [6-5A(42)]	Medium Tensile Steel Conforming to Accepted Standard [6-5A(42)]	High Yield Strength Deformed Bars Conforming to Accepted Standard [6-5A(36)] (Grade Fe 415)
(1)	(2)	(3)	(4)	(5)
i)	Tension (σ_{st} or σ_{sv})			
	a) Up to and including 20 mm	140	Half the guaranteed yield stress subject to a maximum of 190	230
	b) Over 20 mm	130		230
ii)	Compression in column bars (σ_{sc})	130	130	190
iii)	Compression in bars in a beam or slab when the compressive resistance of the concrete is taken into account	The calculated compressive stress in the surrounding concrete multiplied by 1.5 times the modular ratio or σ_{sc} whichever is lower		
iv)	Compression in bars in a beam or slab where the compressive resistance of the concrete is not taken into account:			
	a) Up to and including 20 mm	140	Half the guaranteed yield stress subject to a maximum of 190	190
	b) Over 20 mm	130		190

NOTES

1 For high yield strength deformed bars of Grade Fe 500 the permissible stress in direct tension and flexural tension shall be 0.55 f_y. The permissible stresses for shear and compression reinforcement shall be as for Grade Fe 415.

2 For welded wire fabric conforming to accepted standard [6-5A(43)], the permissible value in tension ó$_{st}$ is 230 N/mm^2.

3 For the purpose of this standard, the yield stress of steels for which there is no clearly defined yield point should be taken to be 0.2 percent proof stress.

4 When mild steel conforming to Grade II of accepted standard [6-5A(42)] is used, the permissible stresses shall be 90 percent of the permissible stresses in col 3, or if the design details have already been worked out on the basis of mild steel conforming to Grade 1 of accepted standard [6-5A(42)]; the area of reinforcement shall be increased by 10 percent of that required for Grade 1 steel.

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B-3.3 Long Columns

The maximum permissible stress in a reinforced concrete column or part thereof having a ratio of effective column length to least lateral dimension above 12 shall not exceed that which results from the multiplication of the appropriate maximum permissible stress as specified under **B-2.1** and **B-2.2** by the coefficient C_r given by the following formula:

$$C_r = 1.25 - \frac{l_{ef}}{48b}$$

where

C_r = reduction coefficient;

l_{ef} = effective length of column; and

b = least lateral dimension of column; for column with helical reinforcement, b is the diameter of the core.

For more exact calculations, the maximum permissible stresses in a reinforced concrete column or part thereof having a ratio of effective column length to least lateral radius of gyration above 40 shall not exceed those which result from the multiplication of the appropriate maximum permissible stresses specified under **B-2.1** and **B-2.2** by the coefficient C_r given by the following formula:

$$C_r = 1.25 - \frac{l_{ef}}{160i_{min}}$$

where i_{min} = least radius of gyration.

B-3.4 Composite Columns

a) *Allowable load* — The allowable axial load P on a composite column consisting of structural steel or cast-iron column thoroughly encased in concrete reinforced with both longitudinal and spiral reinforcement, shall not exceed that given by the following formula:

$$P = \sigma_{cc} A_c + \sigma_{sc} A_{sc} + \sigma_{mc} A_m$$

where

σ_{cc} = permissible stress in concrete in direct compression;

A_c = net area of concrete section; which is equal to the gross area of the concrete section $= A_{sc} - A_m$;

A_{sc} = cross-sectional area of longitudinal bar reinforcement;

σ_{mc} = allowable unit stress in metal core, not to exceed 125 N/mm^2 for a steel core, or 70 N/mm^2 for a cast iron core; and

A_m = cross-sectional area of the steel or cast iron core.

b) *Metal core and reinforcement* — The cross-sectional area of the metal core shall not exceed 20 percent of the gross area of the column. If a hollow metal core is used, it shall be filled with concrete. The amount of longitudinal and spiral reinforcement and the requirements as to spacing of bars, details of splices and thickness of protective shell outside the spiral, shall conform to requirements of **25.5.3**. A clearance of at least 75 mm shall be maintained between the spiral and the metal core at all points, except that when the core consists of a structural steel H-column, the minimum clearance may be reduced to 50 mm.

c) *Splices and connections of metal cores* — Metal cores in composite columns shall be accurately milled at splices and positive provisions shall be made for alignment of one core above another. At the column base, provisions shall be made to transfer the load to the footing at safe unit stresses in accordance with **33**. The base of the metal section shall be designed to transfer the load from the entire composite columns to the footing, or it may be designed to transfer the load from the metal section only, provided it is placed in the pier or pedestal as to leave ample section of concrete above the base for the transfer of load from the reinforced concrete section of the column by means of bond on the vertical reinforcement and by direct compression on the concrete. Transfer of loads to the metal core shall be provided for by the use of bearing members, such as billets, brackets or other positive connections, these shall be provided at the top of the metal core and at intermediate floor levels where required. The column as a whole shall satisfy the requirements of formula given under (a) at any point; in addition to this, the reinforced concrete portion shall be designed to carry, according to **B-3.1** or **B-3.2** as the case may be, all floor loads brought into the column at levels between the metal brackets or connections. In applying the formula under **B-3.1** or **B-3.2** the gross area of column shall be taken to be the area of the concrete section outside the metal core, and the allowable load on the reinforced concrete section shall be further limited to 0.28 f_{ck} times gross sectional area of the column.

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d) *Allowable load on metal core only* — The metal core of composite columns shall be designed to carry safely any construction or other loads to be placed upon them prior to their encasement in concrete.

B-4 MEMBERS SUBJECTED TO COMBINED AXIAL LOAD AND BENDING

B-4.1 Design Based on Uncracked Section

A member subjected to axial load and bending (due to eccentricity of load, monolithic construction, lateral forces, etc) shall be considered safe provided the following conditions are satisfied:

a) $$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1$$

where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete,

σ_{cc} = permissible axial compressive stress in concrete,

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete, and

σ_{cbc} = permissible bending compressive stress in concrete.

b) The resultant tension in concrete is not greater than 35 percent and 25 percent of the resultant compression for biaxial and uniaxial bending respectively, or does not exceed three-fourths, the 7 days modulus of rupture of concrete.

NOTES

1 $\sigma_{cc,cal} = \frac{P}{A_c + 1.5mA_{sc}}$ for columns with ties where P, A_c and A_{sc} are defined in **B-3.1** and m is the modular ratio.

2 $\sigma_{cbc,cal} = \frac{M}{Z}$ where M equals the moment and Z equals modulus of section. In the case of sections subject to moments in two directions, the stress shall be calculated separately and added algebraically.

B-4.2 Design Based on Cracked Section

If the requirements specified in **B-4.1** are not satisfied, the stresses in concrete and steel shall be calculated by the theory of cracked section in which the tensile resistance of concrete is ignored. If the calculated stresses are within the permissible stress specified in Tables 25, 26 and 27 the section may be assumed to be safe.

NOTE — The maximum stress in concrete and steel may be found from tables and charts based on the cracked section theory or directly by determining the no-stress line which should satisfy the following requirements:

a) The direct load should be equal to the algebraic sum of the forces on concrete and steel,

b) The moment of the external loads about any reference line should be equal to the algebraic sum of the moment of the forces in concrete (ignoring the tensile force in concrete) and steel about the same line, and

c) The moment of the external loads about any other reference lines should be equal to the algebraic sum of the moment of the forces in concrete (ignoring the tensile force in concrete) and steel about the same line.

B-4.3 Members Subjected to Combined Direct Load and Flexure

Members subjected to combined direct load and flexure shall be designed by limit state method as in **38.5** after applying appropriate load factors as given in Table 18.

B-5 SHEAR

B-5.1 Nominal Shear Stress

The nominal shear stress τ_v in beams or slabs of uniform depth shall be calculated by the following equation:

$$\tau_v = \frac{V}{bd}$$

where

V = shear force due to design loads,

b = breadth of the member, which for flanged sections shall be taken as the breadth of the web, and

d = effective depth.

B-5.1.1 *Beams of Varying Depth*

In the case of beams of varying depth, the equation shall be modified as:

$$\tau_v = \frac{V \pm \frac{M \tan\beta}{d}}{bd}$$

where

τ_v, V, b and d are the same as in **B-5.1**.

M = bending moment at the section, and

β = angle between the top and the bottom edges of the beam.

The negative sign in the formula applies when the bending moment M increases numerically in the same direction as the effective depth d increases, and the positive sign when the moment decreases numerically in this direction.

B-5.2 Design Shear Strength of Concrete

B-5.2.1 The permissible shear stress in concrete in beams without shear reinforcement is given in Table 27.

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Table 27 Permissible Shear Stress in Concrete

(*Clauses* B-2.1, B-2.3, B-4.2, B-5.2.1, B-5.2.2, B-5.3, B-5.4, B-5.5.3, B-6.3.2, B-6.3.3, B-6.4.3 *and* Table 25)

Sl No.	$\frac{100A_s}{bd}$	Permissible Shear Stress in Concrete τ_c, N/mm²					
		Grade of Concrete					
		M 15	M 20	M 25	M 30	M 35	M 40 and Above
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	≤ 0.15	0.18	0.18	0.19	0.20	0.20	0.20
ii)	0.25	0.22	0.22	0.23	0.23	0.23	0.23
iii)	0.50	0.29	0.30	0.31	0.31	0.31	0.32
iv)	0.75	0.34	0.35	0.36	0.37	0.37	0.38
v)	1.00	0.37	0.39	0.40	0.41	0.42	0.42
vi)	1.25	0.40	0.42	0.44	0.45	0.45	0.46
vii)	1.50	0.42	0.45	0.46	0.48	0.49	0.49
viii)	1.75	0.44	0.47	0.49	0.50	0.52	0.52
ix)	2.00	0.44	0.49	0.51	0.53	0.54	0.55
x)	2.25	0.44	0.51	0.53	0.55	0.56	0.57
xi)	2.50	0.44	0.51	0.55	0.57	0.58	0.60
xii)	2.75	0.44	0.51	0.56	0.58	0.60	0.62
xiii)	3.00 and above	0.44	0.51	0.57	0.60	0.62	0.63

NOTE — A_s is that area of longitudinal tension reinforcement which continues at least one effective depth beyond the section being considered except at supports where the full area of tension reinforcement may be used provided the detailing conforms to **25.2.2** and **25.2.3**.

B-5.2.1.1 For solid slabs the permissible shear stress in concrete shall be $k\tau_c$ where k has the value given below:

Overall Depth of Slab mm	300 or More	275	250	225	200	175	150 or Less
k	1.00	1.05	1.10	1.15	1.20	1.25	1.30

NOTE – This does not apply to flat slabs for which **30.6** shall apply.

B-5.2.2 *Shear Strength of Members Under Axial Compression*

For members subjected to axial compression P, the permissible shear stress in concrete τ_c given in Table 27, shall be multiplied by the following factor:

$$\delta = 1 + \frac{5P}{A_g f_{ck}}, \text{ but not exceeding 1.5.}$$

where

P = axial compressive force, in N;

A_g = gross area of the concrete section, in mm²; and

f_{ck} = characteristic compressive strength of concrete.

B-5.2.3 *With Shear Reinforcement*

When shear reinforcement is provided the nominal shear stress $\tau_{c\,max}$ in beams shall not exceed τ_c given in Table 28.

B-5.2.3.1 For slabs, τ_v shall not exceed half the value of $\tau_{c\,max}$ given in Table 28.

Table 28 Maximum Shear Stress $\tau_{c\,max}$, N/mm²

(*Clauses* B-5.2.3, B-5.2.3.1, B-5.5.1 *and* B-6.3.1)

Concrete Grade	M15	M20	M25	M30	M35	M 40 and Above
$\tau_{c\,max}$, N/mm²	1.6	1.8	1.9	2.2	2.3	2.5

B-5.3 Minimum Shear Reinforcement

When τ_v is less than τ_c given in Table 27, minimum shear reinforcement shall be provided in accordance with **25.5.1.6**.

B-5.4 Design of Shear Reinforcement

When τ_v exceeds τ_c given in Table 27, shear reinforcement shall be provided in any of the following forms:

a) Vertical stirrups,

b) Bent-up bars along with stirrups, and

c) Inclined stirrups.

Where bent-up bars are provided, their contribution towards shear resistance shall not be more than half that of the total shear reinforcement.

Shear reinforcement shall be provided to carry a shear equal to $V - \tau_c bd$. The strength of shear reinforcement V_s shall be calculated as below:

a) For vertical stirrups:

$$V_s = \frac{\sigma_{sv} A_{sv} d}{s_v}$$

b) For inclined stirrups or a series of bars bent-up at different cross-sections:

$$V_s = \frac{\sigma_{sv} A_{sv} d}{s_v}(\sin\alpha + \cos\alpha)$$

c) For single bar or single group of parallel bars, all bent-up at the same cross-section:

$$V_s = \sigma_{sv} A_{sv} \sin\alpha$$

where

A_{sv} = total cross-sectional area of stirrup legs or bent-up bars within a distance

s_v = spacing of the stirrups or bent-up bars along the length of the member,

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τ_c = design shear strength of the concrete,

b = breadth of the member which for flanged beams, shall be taken as the breadth of the web b_w,

σ_{sv} = permissible tensile stress in shear reinforcement which shall not be taken greater than 230 N/mm^2,

α = angle between the inclined stirrup or bent-up bar and the axis of the member, not less than 45°, and

d = effective depth.

NOTE — Where more than one type of shear reinforcement is used to reinforce the same portion of the beam, the total shear resistance shall be computed as the sum of the resistance for the various types separately. The area of the stirrups shall not be less than the minimum specified in **25.5.1.6**.

B-5.5 Enhanced Shear Strength of Sections Close to Supports

B-5.5.1 *General*

Shear failure at sections of beams and cantilevers without shear reinforcement will normally occur on plane inclined at an angle 30° to the horizontal. If the angle of failure plane is forced to be inclined more steeply than this [because the section considered (X –X) in Fig. 24 is close to a support or for other reasons], the shear force required to produce failure is increased.

The enhancement of shear strength may be taken into account in the design of sections near a support by increasing design shear strength of concrete, τ_c to $2d\tau_c/a_v$ provided that the design shear stress at the face of support remains less than the values given in Table 28. Account may be taken of the enhancement in any situation where the section considered is closer to the face of a support of concentrated load than twice the effective depth, d. To be effective, tension reinforcement should extend on each side of the point where it is intersected by a possible failure plane for a distance at least equal to the effective depth, or be provided with an equivalent anchorage.

B-5.5.2 *Shear Reinforcement for Sections Close to Supports*

If shear reinforcement is required, the total area of this is given by:

$$A_s = a_v b(\tau_v - 2d\,\tau_c/a_v)/\sigma_{sv} \geq 0.4a_v b/0.87f_y$$

This reinforcement should be provided within the middle three quarters of a_v. Where a_v is less than d, horizontal shear reinforcement will be more effective than vertical.

B-5.5.3 *Enhanced Shear Strength Near Supports (Simplified Approach)*

The procedure given in **B-5.5.1** and **B-5.5.2** may be used for all beams. However, for beams carrying generally uniform load or where the principal load is located further than $2d$ from the face of support, the shear stress may be calculated at a section a distance d from the face of support. The value of τ_c is calculated in accordance with Table 27 and appropriate shear reinforcement is provided at sections closer to the support, no further check for such section is required.

B-6 TORSION

B-6.1 General

In structures where torsion is required to maintain equilibrium, members shall be designed for torsion in accordance with **B-6.2**, **B-6.3** and **B-6.4**. However, for such indeterminate structures where torsion can be eliminated by releasing redundant restraints, no specific design for torsion is necessary provided torsional stiffness is neglected in the calculation of internal forces. Adequate control of any torsional cracking is provided by the shear reinforcement as per **B-5**.

NOTE — The approach to design in this clause for torsion is as follows:

Torsional reinforcement is not calculated separately from that required for bending and shear. Instead the total longitudinal reinforcement is determined for a fictitious bending moment which is a function of actual bending moment and torsion; similarly web reinforcement is determined for a fictitious shear which is a function of actual shear and torsion.

B-6.1.1 The design rules laid down in **B-6.3** and **B-6.4** shall apply to beams of solid rectangular cross-section. However, these clauses may also be applied to flanged beams by substituting b_w for b, in which case they are generally conservative; therefore specialist literature may be referred to.

B-6.2 Critical Section

Sections located less than a distance d, from the face of the support may be designed for the same torsion as computed at a distance d, where d is the effective depth.

B-6.3 Shear and Torsion

B-6.3.1 *Equivalent Shear*

Equivalent shear, V_e shall be calculated from the formula:

$$V_e = V + 1.6\left(\frac{T}{b}\right)$$

where

V_e = equivalent shear,

V = shear,

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T = torsional moment, and

b = breadth of beam.

The equivalent nominal shear stress, τ_{ve}, in this case shall be calculated as given in **B-5.1**, except for substituting V by V_e. The values of τ_{ve} shall not exceed the values of $\tau_{c\,max}$ given in Table 28.

B-6.3.2 If the equivalent nominal shear stress τ_{ve} does not exceed τ_c, given in Table 27, minimum shear reinforcement shall be provided as specified in **25.5.1.6**.

B-6.3.3 If τ_{ve} exceeds τ_c given in Table 27, both longitudinal and transverse reinforcement shall be provided in accordance with **B-6.4**.

B-6.4 Reinforcement in Members Subjected to Torsion

B-6.4.1 Reinforcement for torsion, when required, shall consist of longitudinal and transverse reinforcement.

B-6.4.2 *Longitudinal Reinforcement*

The longitudinal reinforcement shall be designed to resist an equivalent bending moment, M_{e1}, given by:

$$M_{e1} = M + M_t$$

where

M = bending moment at the cross-section, and

$M_t = T\dfrac{(1+D/b)}{1.7}$,

where T is the torsional moment, D is the overall depth of the beam and b is the breadth of the beam.

B-6.4.2.1 If the numerical value of M_t as defined in **B-6.4.2** exceeds the numerical value of the moment M, longitudinal reinforcement shall be provided on the flexural compression face, such that the beam can also withstand an equivalent moment M_{e2} given by $M_{e2} = M_t - M$, the moment M_{e2} being taken as acting in the opposite sense to the moment M.

B-6.4.3 *Transverse Reinforcement*

Two legged closed hoops enclosing the corner longitudinal bars shall have an area of cross-section A_{sv}, given by:

$A_{sv} = \dfrac{T.s_v}{b_1 d_1 \sigma_{sv}} + \dfrac{V.s_v}{2.5 d_1 \sigma_{sv}}$, but the total transverse reinforcement shall not be less than $\dfrac{(\tau_{ve} - \tau_c) b.s_v}{\sigma_{sv}}$

where

T = torsional moment,

V = shear force,

s_v = spacing of the stirrup reinforcement,

b_1 = centre-to-centre distance between corner bars in the direction of the width,

d_1 = centre-to centre distance between corner bars in the direction of the depth,

b = breadth of the member

σ_{sv} = permissible tensile stress in shear reinforcement

τ_{ve} = equivalent shear stress as specified in **B-6.3.1**, and

τ_c = shear strength of the concrete as specified in Table 27.

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ANNEX C

(*Clauses* 21.3.2, 22.2.1 *and* 41.1)

CALCULATION OF DELEFCTION

C-1 TOTAL DEFLECTION

The total deflection shall be taken as the sum of the short-term deflection determined in accordance with **C-2** and the long-term deflection, in accordance with **C-3** and **C-4**.

C-2 SHORT-TERM DEFLECTION

The short-term deflection may be calculated by the usual methods for elastic deflections using the short-term modulus of elasticity of concrete, E_c and an effective moment of inertia I_{eff} given by the following equation:

$$I_{eff} = \frac{I_r}{1.2 - \frac{M_r}{M}\frac{z}{d}\left(1-\frac{x}{d}\right)\frac{b_w}{b}} \text{ ; but}$$

$$I_r \le I_{eff} \le I_{gr}$$

where

I_r = moment of inertia of the cracked section,

M_r = cracking moment, equal to $\frac{f_{cr} I_{gr}}{y_t}$ where

f_{cr} = modulus of rupture of concrete,

I_{gr} = moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and y_t is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fibre in tension,

M = maximum moment under service loads,

z = lever arm,

x = depth of neutral axis,

d = effective depth,

b_w = breadth of web, and

b = breadth of compression face.

For continuous beams, deflection shall be calculated using the values of I_r, I_{gr} and M_r modified by the following equation:

$$X_e = k_1\left[\frac{X_1 + X_2}{2}\right] + (1 - k_1) X_o$$

where

X_e = modified value of X,

X_1, X_2 = values of X at the supports,

X_o = value of X at mid span,

k_1 = coefficient given in Table 29, and

X = value of I_r, I_{gr} or M_r as appropriate.

C-3 DEFLECTION DUE TO SHRINKAGE

The deflection due to shrinkage a_{cs} may be computed from the following equation:

$$a_{cs} = k_3 \psi_{cs} l^2$$

where

k_3 is a constant depending upon the support conditions:

0.5 for cantilevers,

0.125 for simply supported members,

0.086 for members continuous at one end, and

0.063 for fully continuous members,

ψ_{cs} is shrinkage curvature = $k_4 \frac{\varepsilon_{cs}}{D}$

where ε_{cs} is the ultimate shrinkage strain of concrete (*see* **5.2.4**),

$$k_4 = 0.72 \times \frac{P_t - P_c}{\sqrt{P_t}} \le 1.0 \text{ for } 0.25 \le P_t - P_c < 1.0$$

$$= 0.65 \times \frac{P_t - P_c}{\sqrt{P_t}} \le 1.0 \text{ for } P_t - P_c \ge 1.0$$

where

$$P_t = \frac{100 A_{st}}{bd} \text{ and } P_c = \frac{100 A_{sc}}{bd}$$

and D is the total depth of the section, and l is the length of span.

Table 29 Values of Coefficient, k_1

(*Clause* C-2)

k_2	0.5 or less	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
k_1	0	0.03	0.08	0.16	0.30	0.50	0.73	0.91	0.97	1.0

NOTE — k_2 is given by:

$$k_2 = \frac{M_1 + M_2}{M_{F1} + M_{F2}}$$

where

M_1, M_2 = support moments, and

M_{F1}, M_{F2} = fixed end moments.

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C-4 DEFLECTION DUE TO CREEP

The creep deflection due to permanent loads $a_{cc(perm)}$ may be obtained from the following equation:

$$a_{cc(perm)} = a_{i,\,cc(perm)} - a_{i(perm)}$$

where

$a_{i,\,cc(perm)}$ = initial deflection plus creep deflection due to permanent loads obtained using an elastic analysis with an effective modulus of elasticity.

$E_{ce} = \dfrac{E_c}{1+\theta}$; θ being the creep coefficient, and

$a_{i(perm)}$ = short-term deflection due to permanent load using E_c.

ANNEX D

(*Clauses* 23.4 *and* 36.1.2)

SLABS SPANNING IN TWO DIRECTIONS

D-1 RESTRAINED SLABS

D-1.0 When the corners of a slab are prevented from lifting, the slab may be designed as specified in **D-1.1** to **D-1.11**.

D-1.1 The maximum bending moments per unit width in a slab are given by the following equations:

$$M_x = \alpha_x w l_x^2$$

$$M_y = \alpha_y w l_x^2$$

where

α_x and α_y are coefficients given in Table 30;

w = total design load per unit area;

M_x, M_y = moments on strips of unit width spanning l_x and l_y, respectively; and

l_x and l_y = lengths of the shorter span and longer span respectively.

D-1.2 Slabs are considered as divided in each direction into middle strips and edge strips as shown in Fig. 31, the middle strip being three-quarters of the width and each edge strip one-eighth of the width.

D-1.3 The maximum moments calculated as in **D-1.1** apply only to the middle strips and no redistribution shall be made.

D-1.4 Tension reinforcement provided at mid-span in the middle strip shall extend in the lower part of the slab to within 0.25l of a continuous edge, or 0.15l of a discontinuous edge.

D-1.5 Over the continuous edges of a middle strip, the tension reinforcement shall extend in the upper part of the slab a distance of 0.15l from the support, and at least 50 percent shall extend a distance of 0.3l.

D-1.6 At a discontinuous edge, negative moments may arise. They depend on the degree of fixity at the edge of the slab but, in general, tension reinforcement equal to 50 percent of that provided at mid-span extending 0.1l into the span will be sufficient.

D-1.7 Reinforcement in edge strip, parallel to that edge, shall comply with the minimum given in Section 5A(C) and the requirements for torsion given in **D-1.8** to **D-1.10**.

D-1.8 Torsion reinforcement shall be provided at any corner where the slab is simply supported on both edges meeting at that corner. It shall consist of top and bottom reinforcement, each with layers of bars placed parallel to the sides of the slab and extending from the edges a minimum distance of one-fifth of the shorter span. The area of reinforcement in each of these four layers shall be three-quarters of the area required for the maximum mid-span moment in the slab.

D-1.9 Torsion reinforcement equal to half that described in **D-1.8** shall be provided at a corner contained by edges over only one of which the slab is continuous.

D-1.10 Torsion reinforcements need not be provided at any corner contained by edges over both of which the slab is continuous.

D-1.11 Where l_y / l_x is greater than 2, the slabs shall be designed as spanning one way.

D-2 SIMPLY SUPPORTED SLABS

D-2.1 When simply supported slabs do not have adequate provision to resist torsion at corners and to prevent the corners from lifting, the maximum moments per unit width are given by the following equation:

$$M_x = \alpha_x w l_x^2$$

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Table 30 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners

(*Clauses* D-1.1 *and* 23.4.1)

Sl No.	Case No.	Type of Panel and Moments Considered	Short Span Coefficients α_x (Values of l_y/l_x)								Long Span Coefficients α_y for All Values of l_y/l_x
			1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	1	*Interior panels:*									
		Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032
		Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024
ii)	2	*One short edge discontinuous:*									
		Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037
		Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028
iii)	3	*One long edge discontinuous:*									
		Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037
		Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028
iv)	4	*Two adjacent edges discontinuous:*									
		Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047
		Positive moment at mid-span	0.035	0.040	0.045	0.049	0.053	0.056	0.063	0.069	0.035
v)	5	*Two short edges discontinuous:*									
		Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	-
		Positive moment at mid-span	0.035	0.037	0.040	0.043	0.044	0.045	0.049	0.052	0.035
vi)	6	*Two long edges discontinuous:*									
		Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
		Positive moment at mid-span	0.035	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
vii)	7	*Three edges discontinuous (One long edge continuous):*									
		Negative moment at continuous edge	0.057	0.064	0.071	0.076	0.080	0.084	0.091	0.097	—
		Positive moment at mid-span	0.043	0.048	0.053	0.057	0.060	0.064	0.069	0.073	0.043
viii)	8	*Three edges discontinuous (One short edge continuous):*									
		Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.057
		Positive moment at mid-span	0.043	0.051	0.059	0.065	0.071	0.076	0.087	0.096	0.043
ix)	9	*Four edges discontinuous:*									
		Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056

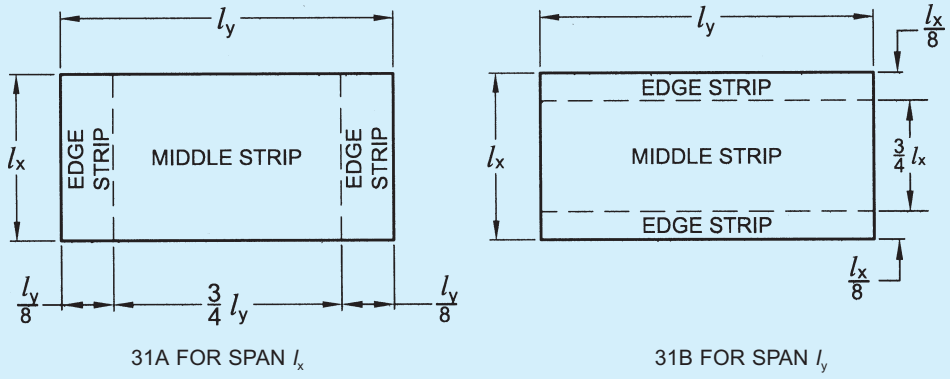


FIG. 31 DIVISION OF SLAB INTO MIDDLE AND EDGE STRIPS

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$$M_y = \alpha_y w l_x^2$$

where

M_x, M_y, l_x, l_y are same as those in **D-1.1**, and α_x and α_y are moment coefficients given in Table 31.

D-2.1.1 At least 50 percent of the tension reinforcement provided at mid-span should extend to the supports. The remaining 50 percent should extend to within $0.1l_x$ or $0.1l_y$ of the support, as appropriate.

Table 31 Bending Moment Coefficients for Slabs Spanning in Two Directions at Right Angles, Simply Supported on Four Sides

(*Clause* D-2.1)

l_y/l_x	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	2.5	3.0
α_x	0.062	0.074	0.084	0.093	0.099	0.104	0.113	0.118	0.122	0.124
α_y	0.062	0.061	0.059	0.055	0.051	0.046	0.037	0.029	0.020	0.014

ANNEX E

(*Clause* 24.2)

EFFECTIVE LENGTH OF COLUMNS

E-1 In the absence of more exact analysis, the effective length of columns in framed structures may be obtained from the ratio of effective length to unsupported length l_{ef}/l given in Fig. 32 when relative displacement of the ends of the column is prevented and in Fig. 33 when relative lateral displacement of the ends is not prevented. In the latter case, it is recommended that the effective length ratio l_{ef}/l may not be taken to be less than 1.2.

NOTES

1 Figures 31 and 32 are reproduced from 'The Structural Engineer' No. 7, Volume 52, July 1974 by the permission of the Council of the Institution of Structural Engineers, U.K.

2 In Figs. 31 and 32, β_1 and β_2 are equal to:

$$\frac{\sum K_c}{\sum K_c + \sum K_b}$$

where the summation is to be done for the members framing into a joint at top and bottom respectively; and K_c and K_b being the flexural stiffness for column and beam, respectively.

E-2 T o determine whether a column is a no sway or a sway column, stability index Q may be computed as given below:

$$Q = \frac{\sum P_u \Delta_u}{H_u h_s}$$

where

$\sum P_u$ = sum of axial loads on all column in the storey,

Δ_u = elastically computed first order lateral deflection,

H_u = total lateral force acting within the storey, and

h_s = height of the storey.

If $Q \leq 0.04$, then the column in the frame may be taken as no sway column, otherwise the column will be considered as sway column.

E-3 For normal usage assuming idealized conditions, the effective length l_{ef} of the compression member in a given plane may be assessed on the basis of Table 32.

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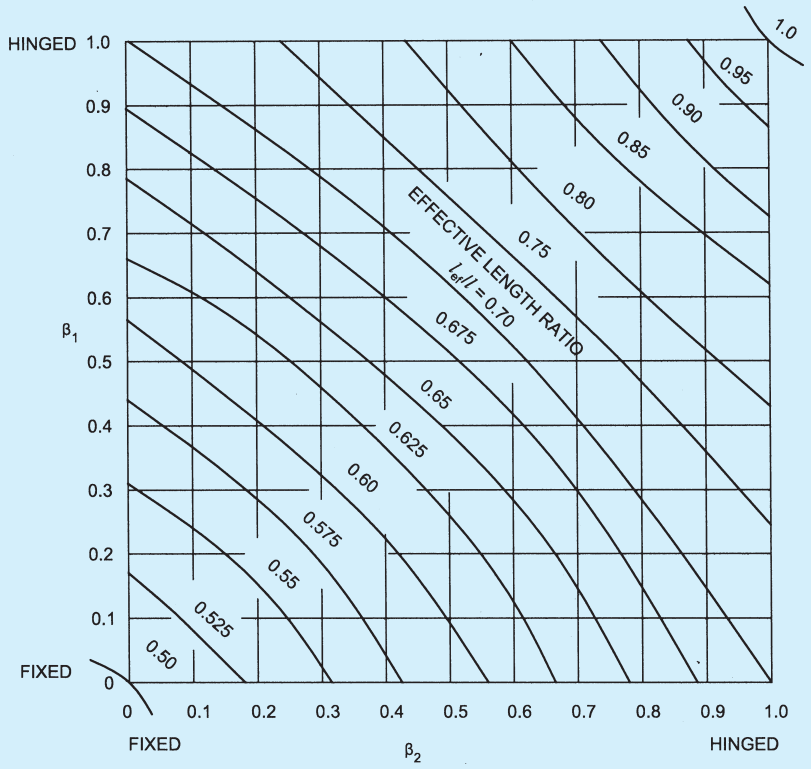


FIG. 32 EFFECTIVE LENGTH RATIOS FOR A COLUMN IN A FRAME WITH NO SWAY

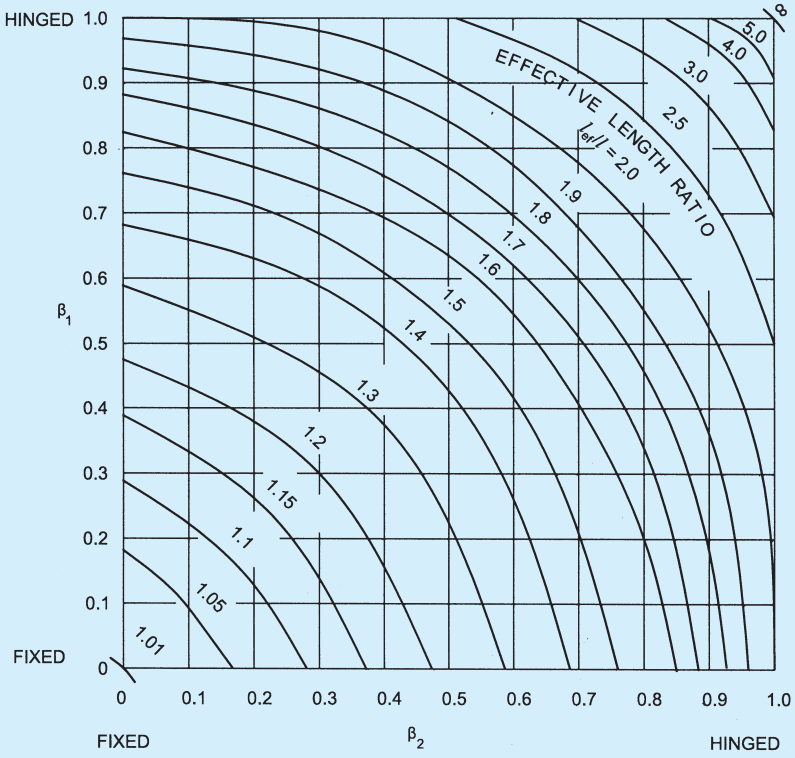
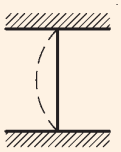
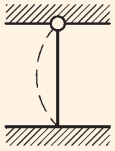
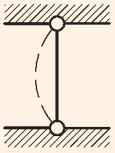
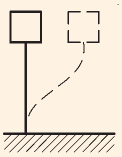
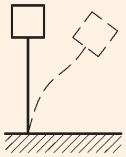
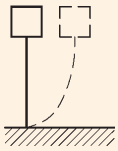
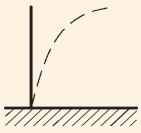


FIG. 33 EFFECTIVE LENGTH RATIOS FOR A COLUMN IN A FRAME WITHOUT RESTRAINT AGAINST SWAY

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Table 32 Effective Length of Compession Members

(*Clause* E-3)

Sl No. (1)	Degree of End Restraint of Compression Members (2)	Symbol (3)	Theoretical Value of Effective Length (4)	Recommended Value of Effective Length (5)
i)	Effectively held in position and restrained against rotation at both ends		0.50 *l*	0.65 *l*
ii)	Effectively held in position at both ends, restrained against rotation at one end		0.70 *l*	0.80 *l*
iii)	Effectively held in position at both ends, but not restrained against rotation		1.00 *l*	1.00 *l*
iv)	Effectively held in position and restrained against rotation at one end, and at the other restrained against rotation but not held in position		1.00 *l*	1.20 *l*
v)	Effectively held in position and restrained against rotation at one end, and at the other partially restrained against rotation but not held in position		–	1.50 *l*
vi)	Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position		2.00 *l*	2.00 *l*
vii)	Effectively held in position and restrained against rotation at one end but not held in position nor restrained against rotation at the other end		2.00 *l*	2.00 *l*

NOTE – *l* is the unsupported length of compression member.

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ANNEX F

(*Clause* 25.1.2)

DUCTILE DESIGN AND DETAILING OF REINFORCED CONCRETE STRUCTURES SUBJECTED TO SEISMIC FORCES

F-1 GENERAL

F-1.1 This annex covers the requirements for designing and detailing of members of reinforced concrete (RC) structures designed to resist lateral effects of earthquake shaking, so as to give them adequate stiffness, strength and ductility to resist severe earthquake shaking without collapse. This annex addresses lateral load resisting structural systems of RC structures composed of,

a) RC moment resisting frames;
b) RC moment resisting frames with unreinforced masonry infill walls;
c) RC moment resisting frames with RC structural walls; and
d) RC structural walls.

F-1.2 Provisions of this annex shall be adopted in all lateral load resisting systems of RC structures located in Seismic Zone III, IV or V. The annex is optional in Seismic Zone II.

F-1.3 The provisions for RC structures given herein apply specifically to monolithic RC construction, and not for precast RC structures. Precast and/or pre stressed concrete members may be used, only if they are designed to provide similar level of ductility as that of monolithic RC structures during or after an earthquake. Likewise, flat slab structures shall have a lateral load resisting system capable of providing similar level of performance as envisioned in this Section and shall be designed for drift compatibility as per **F-10**. Specialist literature shall be referred to for design and construction of such structures. The adequacy of such designs shall be demonstrated by adequate, appropriate experimentation and non-linear dynamic structural analyses.

F-1.4 All RC frames, RC walls and their elements in a structure need not be designed to resist lateral loads and the designer can judiciously identify the lateral load resisting system based on relative stiffness and location in the building and design those members for full lateral force. RC monolithic members assumed not to participate in the lateral force resisting system (*see* **F-2.7**) shall be permitted provided that their effect on the seismic response of the system is accounted for. Consequence of failure of structural and non-structural members not part of the lateral force resisting system shall also be considered in design.

F-2 TERMINOLOGY

For the purpose of this annex, the following definitions shall apply.

F-2.1 Beams — These are members (generally horizontal) of moment resisting frames with flexural and shearing actions.

F-2.2 Boundary Elements — These are portions along the ends of a structural wall that are strengthened by longitudinal and transverse reinforcement. They may have the same thickness as that of the wall web.

F-2.3 Columns — These are members (generally vertical) of moment resisting frames with axial, flexural and shearing actions.

F-2.4 Cover Concrete — It is that concrete which is not confined by transverse reinforcement.

F-2.5 Transverse Reinforcement — It is a continuous bar having a 135° hook with an extension of 6 times diameter (but not < 65 mm) at one end and a hook not less than 90° with an extension of 6 times diameter (but not < 65 mm) at the other end. The hooks shall engage peripheral longitudinal bars. In general, the 90° hooks of two successive crossties engaging the same longitudinal bars shall be alternated end for end. Transverse reinforcement (also called hoops) in columns is typically called stirrups and that in beams is called cross-ties.

F-2.6 Gravity Columns in Buildings — It is a column, which is not part of the lateral load resisting system and designed only for force actions (that is, axial force, shear force and bending moments) due to gravity loads. But, it should be able to resist the gravity loads at lateral displacement imposed by the earthquake forces.

F-2.7 Lateral Force Resisting System — It is that part of the structural system which participates in resisting forces induced by earthquake.

F-2.8 Moment-Resisting Frame — It is a three-dimensional structural system composed of interconnected members, without structural walls, so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor bracing systems, in which the members resist gravity and lateral forces primarily by flexural actions.

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F-2.8.1 *Special Moment Resisting Frame* (*SMRF*) — It is a moment-resisting frame specially detailed to provide ductile behaviour as per the requirements specified in **F-4**, **F-5**, **F-6** and **F-7**.

F-2.8.2 *Ordinary Moment Resisting Frame* (*OMRF*) — It is a moment-resisting frame not meeting special detailing requirements for ductile behaviour.

F-2.9 Link — It is a single steel bar bent into a closed loop having a 135° hook with an extension of 6 times diameter (but not < 65 mm) at each end, which is embedded in the confined core of the section, and placed normal to the longitudinal axis of the RC beam or column.

F-2.10 Shear Wall (also called Structural Wall) — It is a vertically oriented planar element that is primarily designed to resist lateral force effects (axial force, shear force and bending moment) in its own plane.

F-2.11 Special Shear Wall — It is a structural wall meeting special detailing requirements for ductile behaviour specified in **F-9**.

F-3 SYMBOLS

For the purpose of this annex, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place. All dimensions in millimetre, loads in Newton and stresses in MPa, unless otherwise specified.

A_e = Effective cross-sectional area of a joint

A_{ej} = Effective shear area of a joint

A_g = Gross cross-sectional area of column, wall

A_h = Horizontal reinforcement area within spacing s_v

A_k = Area of concrete core of column

A_{sd} = Reinforcement along each diagonal of coupling beam

A_{sh} = Area of cross-section of bar forming spiral or link

A_{st} = Area of uniformly distributed vertical reinforcement

A_v = Vertical reinforcement at a joint

b_b = Width of beam

b_c = Width of column

b_j = Effective width of a joint

D = Overall depth of beam

D_k = Diameter of column core measured to the outside of spiral or link

d = Effective depth of member

d_b = Diameter of longitudinal bar

d_w = Effective depth of wall section

E_s = Elastic modulus of steel

f_{ck} = Characteristic compressive strength of concrete cube, in MPa

f_y = Yield stress of steel reinforcing bars, or 0.2 percent proof strength of reinforcing steel, in MPa

h = Longer dimension of rectangular confining link measured to its outer face

h_c = Depth of column

h_j = Effective depth of a joint

h_{st} = Clear storey height

h_w = Overall height of RC structural wall

L_{AB} = Clear span of beam

L_d = Development length of bar in tension

l_o = Length of member over which special confining reinforcement is to be provided

L_w = Horizontal length of wall/longer cross-section dimension of wall

L_s = Clear span of couplings beam

M_u = Design moment of resistance of entire RC beam, column or wall section

M_{c1} = Design moment of resistance of column section

M_{c2} = Design moment of resistance of column section

M_{g1} = Design moment of resistance of beam section

M_{g2} = Design moment of resistance of beam section

M_u^{Ah} = Hogging design moment of resistance of beam at end A

M_u^{As} = Sagging design moment of resistance of beam at end A

M_u^{Bh} = Hogging design moment of resistance of beam at end B

M_u^{Bs} = Sagging design moment of resistance of beam at end B

M_u^{BL} = Design moment of resistance of beam framing into column from the left

M_u^{BR} = Design moment of resistance of beam framing into column from the right

M_{uw} = Design moment of resistance of web of RC structural wall alone

P_u = Factored axial load

s_v = Spacing of links along the longitudinal direction of beam or column

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t_w = Thickness of web of RC structural wall

$V_{u,a}^{D+L}$ = Factored shear force demand at end A of beam due to dead and live loads

$V_{u,b}^{D+L}$ = Factored shear force demand at end B of beam due to dead and live loads

V_j = Design shear resistance of a joint

V_u = Factored shear force

V_{us} = Design shear resistance offered at a section by steel links

x_u, x_u^* = Depth of neutral axis from extreme compression fibre

α = Inclination of diagonal reinforcement in coupling beam

ρ = Area of longitudinal reinforcement as a fraction of gross area of cross-section in a RC beam, column or structural wall

ρ_c = Area of longitudinal reinforcement on the compression face of a beam as a fraction of gross area of cross-section

$(\rho_h)_{min}$ = Minimum area of horizontal reinforcement of a structural wall as a fraction of gross area of cross-section

$(\rho_{v,be})_{min}$ = Minimum area of vertical reinforcement in each boundary element of a structural wall as a fraction of gross area of cross-section of each boundary element

$(\rho_{v,net})_{min}$ = Minimum area of vertical reinforcement of a structural wall as a fraction of gross area of cross-section of the wall

$(\rho_{v,web})_{min}$ = Minimum area of vertical reinforcement in web of a structural wall as a fraction of gross area of cross-section of web

ρ_{max} = Maximum area of longitudinal reinforcement permitted on the tension face of a beam as a fraction of gross area of cross-section

ρ_{min} = Minimum area of longitudinal reinforcement to be ensured on the tension face of a beam as a fraction of gross area of cross-section

τ_c = Design shear strength of concrete

$\tau_{c,max}$ = Maximum nominal shear stress permitted at a section of RC beam, column or structural wall

τ_v = Nominal shear stress at a section of RC beam, column or structural wall

F-4 GENERAL SPECIFICATIONS

F-4.1 The design and construction of reinforced concrete buildings shall be governed by provisions of this Subsection 5A, except as modified by the provisions of this annex for those elements participating in lateral force resistance.

F-4.2 Minimum grade of structural concrete shall be M 20, but M 25 for buildings,

a) more than 15 m in height in Seismic Zones III, IV and V; and

b) but not less than that required by provisions of Subsection 5A based on exposure conditions.

F-4.3 Steel reinforcement resisting earthquake-induced forces in RC frame members and in boundary elements of RC structural walls shall comply with **F-4.3.1** to **F-4.3.3**.

F-4.3.1 Steel reinforcements used shall be,

a) of grade Fe 415 or less {conforming to accepted standard [6-5A(36)]}; and

b) of grade Fe 500 and Fe 550, that is; high strength deformed steel bars produced by thermo-mechanical treatment process having elongation more than 14.5 percent, and conforming to accepted standard [6-5A(36)].

F-4.3.2 The actual 0.2 percent proof strength of steel bars based on tensile test shall not exceed their characteristic 0.2 percent proof strength by more than 20 percent.

F-4.3.3 The ratio of the actual ultimate strength to the actual 0.2 percent proof strength shall be at least 1.15.

F-4.4 In RC frame buildings, lintel beams shall preferably not be integrated into the columns to avoid short column effect. When integrated, they shall be included in the analytical model for structural analysis. Similarly, plinth beams (where provided), and staircase beams and slabs framing into columns shall be included in the analytical model for structural analysis.

F-4.5 RC regular moment-resisting frame buildings shall have planar frames oriented along the two principal plan directions of buildings. Irregularities listed under **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code shall be avoided. Buildings with any of the listed irregularities perform poorly during earthquake shaking; in addition, buildings with floating columns and set-back columns also perform poorly. When any such irregularities are adopted, detailed nonlinear analyses shall be performed to demonstrate that there is no threat to loss of life and property.

F-5 BEAMS

F-5.1 General

Requirements of this section shall apply to beams resisting earthquake-induced effects, in which the

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factored axial compressive stress does not exceed $0.08 f_{ck}$. Beams, in which the factored axial compressive stress exceeds $0.08 f_{ck}$, shall be designed as per requirements of **F-6**.

F-5.1.1 Beams shall preferably have width-to-depth ratio of more than 0.3.

F-5.1.2 Beams shall not have width less than 200 mm.

F-5.1.3 Beams shall not have depth D more than $1/4^{th}$ of clear span. This may not apply to the floor beam of frame staging of elevated RC water tanks.

F-5.1.4 Width of beam b_w shall not exceed the width of supporting member c_2 plus distance on either side of supporting member equal to the smaller of (a) and (b) below:

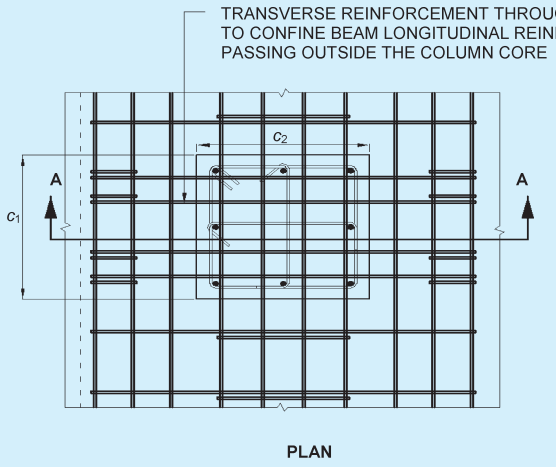
a) Width of supporting member c_2.
b) 0.75 times breadth of supporting member c_1 (*see* Fig. 34A and Fig. 34B).

Transverse reinforcement for the width of a beam that exceeds width of the column c_2 shall be provided as shown in Fig. 34B throughout the beam span including within the beam column joint.

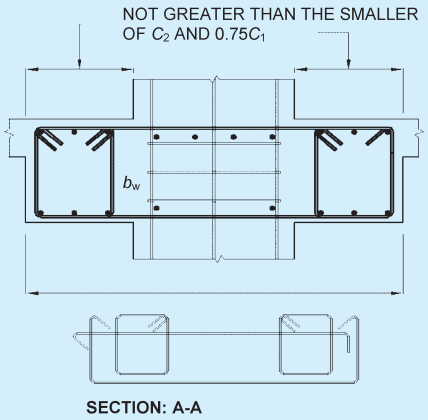
F-5.2 Longitudinal Reinforcement

F-5.2.1 The longitudinal reinforcement in beams shall be as below:

a) Beams shall have at least two 12 mm diameter bars each at the top and bottom faces.
b) Minimum longitudinal steel ratio ρ_{min} required on any face at any section is:



34A PLAN VIEW OF A BEAM COLUMN JOINT SHOWING EFFECTIVE BREADTH AND WIDTH OF JOINT



34B MAXIMUM EFFECTIVE WIDTH OF WIDE BEAM AND REQUIRED TRANSVERSE REINFORCEMENT

FIG. 34 BEAM COLUMN JUNCTIONS

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$$\rho_{min} = 0.24\frac{\sqrt{f_{ck}}}{f_y}$$

F-5.2.2 Maximum longitudinal steel ratio ρ_{max} provided on any face at any section is 0.025.

F-5.2.3 Longitudinal steel on bottom face of a beam framing into a column (at the face of the column) shall be at least half the steel on its top face at the same section. At exterior joints, the anchorage length calculation shall consider this bottom steel to be tension steel.

F-5.2.4 Longitudinal steel in beams at any section on top or bottom face shall be at least 1/4th of longitudinal steel provided at the top face of the beam at the face of the column; when the top longitudinal steel in the beam at the two supporting column faces is different, the larger of the two shall be considered.

F-5.2.5 At an exterior joint, top and bottom bars of beams shall be provided with anchorage length beyond the inner face of the column, equal to development length of the bar in tension plus 10 times bar diameter minus the allowance for 90° bends (*see* Fig. 35).

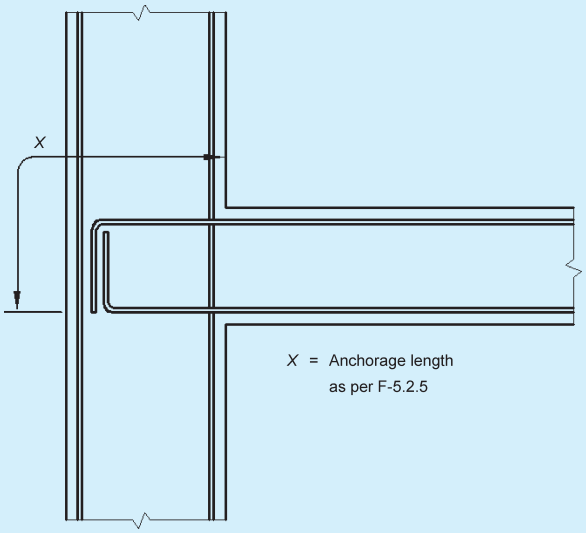


FIG. 35 ANCHORAGE OF LONGITUDINAL BEAM BARS AT EXTERIOR BEAM-COLUMN JOINT

F-5.2.6 *Splicing of Longitudinal Bars*

F-5.2.6.1 *Lap splices*

When adopted, closed links shall be provided over the entire length over which the longitudinal bars are spliced. Further,

a) the spacing of these links shall not exceed 150 mm (*see* Fig. 36).

b) the lap length shall not be less than the development length of the largest longitudinal reinforcement bar in tension.

c) lap splices shall not be provided,

1) within a joint ;

2) within a distance of 2*d* from face of the column; and

3) within a quarter length of the beam adjoining the location where flexural yielding may occur under earthquake effects.

d) not more than 50 percent of area of steel bars on either top or bottom face shall be spliced at any one section.

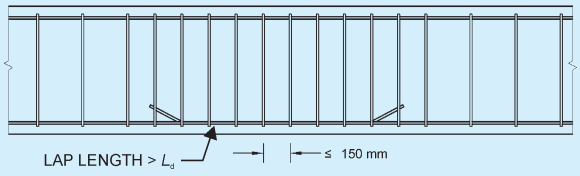


FIG. 36 LAP LENGTH AT LOCATION OF SPLICING OF LONGITUDINAL BARS IN BEAM

F-5.2.6.2 *Mechanical couplers*

Mechanical couplers {conforming to accepted standard [6-5A(38)]} shall be used when longitudinal steel bars have to be continued for beam spans larger than their manufacture lengths. Further,

a) only those mechanical splices conforming to the above code and capable of developing the specified tensile strength of spliced bar shall be permitted within a distance equal to two times the depth of the member from the member face or in any location where yielding of reinforcement is likely to take place; and

b) the spacing between adjacent longitudinal bars shall be based also on the outer size of the coupler to allow easy flow of concrete.

F-5.2.6.3 *Welded splices*

Welded splices shall not be used in beams for a distance equal to two times the depth of the member from the member face or in any location where yielding of reinforcement is likely to take place. At any location, not more than 50 percent of area of steel bars shall be spliced at any one section.

Welding of links, ties, inserts or other similar elements to vertical reinforcement bars required as per design is not permitted, in any seismic zone.

F-5.3 Transverse Reinforcement

F-5.3.1 Only vertical links shall be used in beams (*see* Fig. 37A); inclined links shall not be used; and,

a) in normal practice, a link is made of a single

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bent bar. But, it may be made of two bars also, namely a U-link with a 135° hook with an extension of 6 times diameter (but not less than 65 mm) at each end, embedded in the core concrete, and a cross-tie (*see* Fig. 37B).

b) the hooks of the links and cross-ties shall engage around peripheral longitudinal bars. Consecutive crossties engaging the same longitudinal bars shall have their 90° hooks at opposite sides of the beam. When the longitudinal reinforcement bars are secured by cross-ties in beams that have a slab on one side, the 90° hooks of the cross-ties shall be placed on that side.

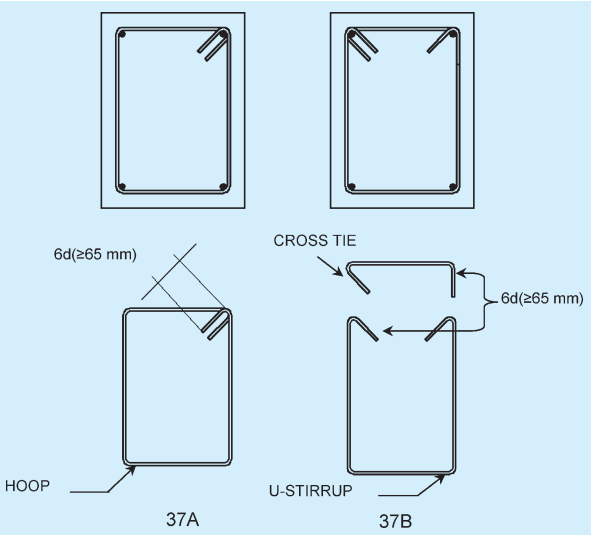


FIG. 37 DETAILS OF TRANSVERSE REINFORCEMENT IN BEAMS

F-5.3.2 The minimum diameter of a link shall be 8 mm.

F-5.3.3 Shear force capacity of a beam shall be more than larger of,

a) factored shear force as per linear structural analysis; and

b) factored gravity shear force, plus equilibrium shear force when plastic hinges are formed at both ends of the beam (*see* Fig. 38) given by :

1) For sway to right:

$$V_{u,a} = V_{u,a}^{D+L} - 1.4\,\frac{M_u^{As} + M_u^{Bh}}{L_{AB}} \text{ and}$$

$$V_{u,b} = V_{u,b}^{D+L} + 1.4\,\frac{M_u^{As} + M_u^{Bh}}{L_{AB}}.$$

2) For sway to left:

$$V_{u,a} = V_{u,a}^{D+L} - 1.4\,\frac{M_u^{Ah} + M_u^{Bs}}{L_{AB}} \text{ and}$$

$$V_{u,b} = V_{u,b}^{D+L} + 1.4\,\frac{M_u^{Ah} + M_u^{Bs}}{L_{AB}}$$

where M_u^{As}, M_u^{Ah}, M_u^{Bs} and M_u^{Bh} are sagging and hogging moments of resistance of the beam section at ends A and B, respectively. These shall be calculated as per this Subsection 5A. L_{AB} is clear span of the beam. $V_{u,a}^{D+L}$ and $V_{u,b}^{D+L}$ are the factored shear forces at ends A and B, respectively, due to vertical loads acting on the span; the partial safety factor for dead and live loads shall be 1.2, and the beam shall be considered to be simply supported for this estimation.

The design shear force demand at end A of the beam shall be the larger of the two values of $V_{u,a}$ computed above. Similarly, the design shear force demand at end B shall be the larger of the two values of $V_{u,b}$ computed above.

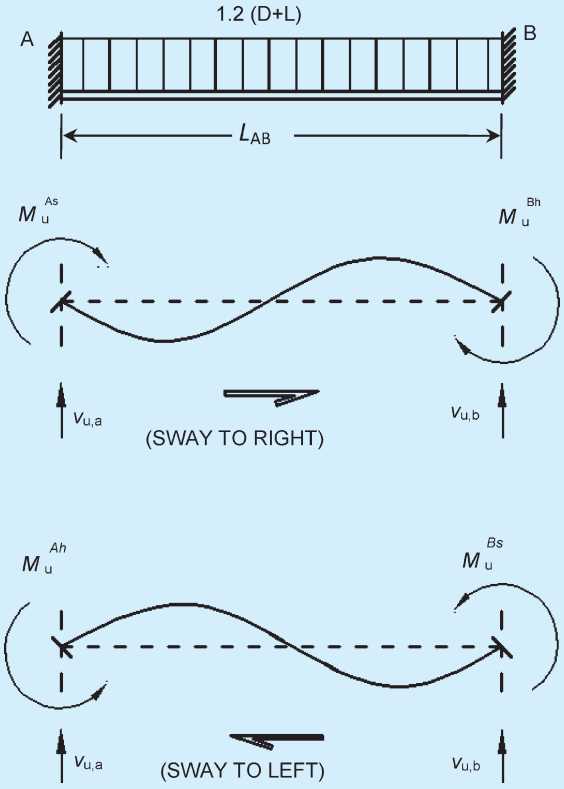


FIG. 38 CALCULATION OF DESIGN SHEAR FORCE DEMAND ON BEAMS UNDER PLASTIC HINGE ACTION AT THEIR ENDS

F-5.3.4 In the calculation of design shear force capacity of RC beams, contributions of the following shall not be considered:

a) Bent up bars,

b) Inclined links, and

c) Concrete in the RC section.

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F-5.3.5 *Close Spacing of Links*

Spacing of links over a length of 2*d* at either end of a beam shall not exceed,

a) *d*/4;
b) 8 times the diameter of the smallest longitudinal bar; and
c) 100 mm (*see* Fig. 39).

F-5.3.5.1 The first link shall be at a distance not exceeding 50 mm from the joint face.

F-5.3.5.2 Closely spaced links shall be provided over a length equal to 2*d* on either side of a section where flexural yielding may occur under earthquake effects. Over the remaining length of the beam, vertical links shall be provided at a spacing not exceeding *d*/2.

F-6 COLUMNS AND INCLINED MEMBERS

F-6.1 Geometry

Requirements of this section shall apply to columns and inclined members resisting earthquake-induced effects, in which the factored axial compressive stress due to gravity and earthquake effects exceeds $0.08 f_{ck}$. The factored axial compressive stress considering all load combinations relating to seismic loads shall be limited to $0.40 f_{ck}$ in all such members, except in those covered in **10**.

For various shapes of columns other than rectangular and circular like 'T' shaped, 'X' shaped, etc. Appropriate designs and detailing shall be carried out using specialist literature where such columns are part of lateral load resisting systems.

F-6.1.1 The minimum dimension of a column shall not be less than,

a) 20 d_b, where d_b is diameter of the largest diameter longitudinal reinforcement bar in the beam passing through or anchoring into the column at the joint, or
b) 300 mm (*see* Fig. 40).

F-6.1.2 The cross-section aspect ratio (that is, ratio of smaller dimension to larger dimension of the cross-section of a column or inclined member) shall not be less than 0.45. Vertical members of RC buildings whose cross-section aspect ratio is less than 0.4 shall be designed as per requirements of **F-8**.

F-6.2 Relative Strengths of Beams and Columns at a Joint

F-6.2.1 At each beam-column joint of a moment-resisting frame, the sum of nominal design strength of columns meeting at that joint (with nominal strength calculated for the factored axial load in the direction of the lateral force under consideration so as to give

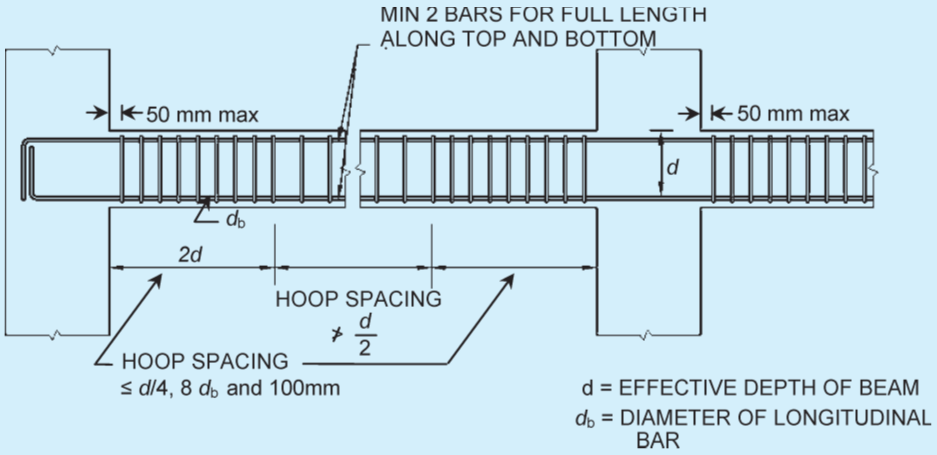


FIG. 39 DETAILS OF TRANSVERSE REINFORCEMENT IN BEAMS

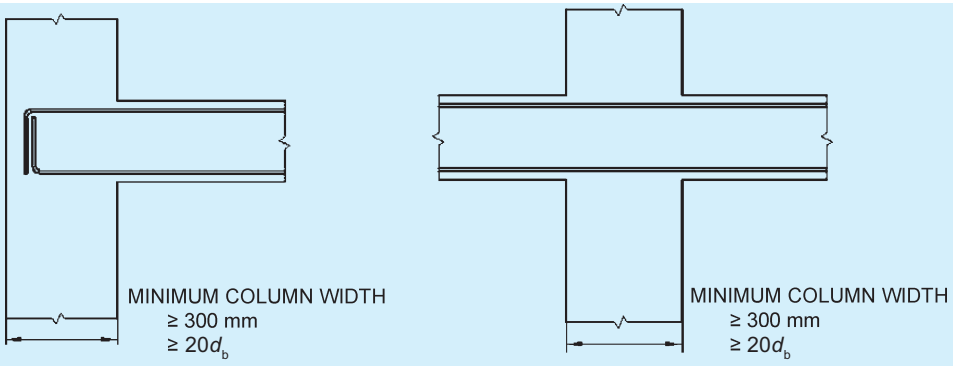


FIG. 40 MINIMUM SIZE OF RC COLUMNS BASED ON DIAMETER OF LARGEST LONGITUDINAL REINFORCEMENT BAR IN BEAMS FRAMING INTO IT

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least column nominal design strength) along each principal plane shall be at least 1.4 times the sum of nominal design strength of beams meeting at that joint in the same plane (*see* Fig. 41).

In the event of a beam-column joint not conforming to above, the columns at the joint shall be considered to be gravity columns only and shall not be considered as part of the lateral load resisting system.

F-6.2.1.1 The design moments of resistance of a beam shall be estimated based on the principles of mechanics and the limiting strain states of the limit state design method enunciated in this Subsection 5A. The design moment of resistance of a column shall be estimated as in case of beams corresponding to zero axial force on the design *P-M* interaction diagram.

F-6.2.1.2 This check shall be performed at each joint for both positive and negative directions of shaking in the plane under consideration. Further, in this check, design moments of resistance in beam(s) meeting at a joint shall be considered in the same direction, and similarly the design moments of resistance of column(s) at the same joint shall be considered to be in the direction opposite to that of the moments in the beams.

F-6.2.1.3 This check shall be waived at all joints at roof level only, in buildings more than 4 storeys tall.

The provisions of **F-6.2** are not applicable for flat slab structures.

F-6.3 Longitudinal Reinforcement

F-6.3.1 Circular columns shall have minimum of 6 bars.

F-6.3.2 *Splicing of Longitudinal Bars*

F-6.3.2.1 *Lap splices*

When adopted, closed links shall be provided over the entire length over which the longitudinal bars are spliced. Further,

a) the spacing of these links shall not exceed 100 mm.
b) the lap length shall not be less than the development length of the largest longitudinal reinforcement bar in tension.
c) lap splices shall be provided only in the central half of clear column height, and not
   1) within a joint, or
   2) within a distance of 2*d* from face of the beam.
d) not more than 50 percent of area of steel bars shall be spliced at any one section.
e) lap splices shall not be used for bars of diameter larger than 32 mm for which mechanical splicing shall be adopted,

F-6.3.2.2 *Mechanical couplers*

Mechanical couplers {*see* accepted standard [6-5A(38)]} shall be used. Further, only those mechanical splices conforming to the above standard and capable of developing the specified tensile strength of spliced bar shall be permitted within a distance equal to two times the depth of the member from the column face in any location where yielding of reinforcement is likely to take place.

F-6.3.2.3 *Welded splices*

Welded splices shall not be used in columns for a distance equal to two times the depth of the member from the member face or in any location where yielding of reinforcement is likely to take place. At any location, not more than 50 percent of area of steel bars shall be spliced at any one section. But, welding of links, ties, inserts or other similar elements to vertical reinforcement bars required as per design is not permitted, in any seismic zone.

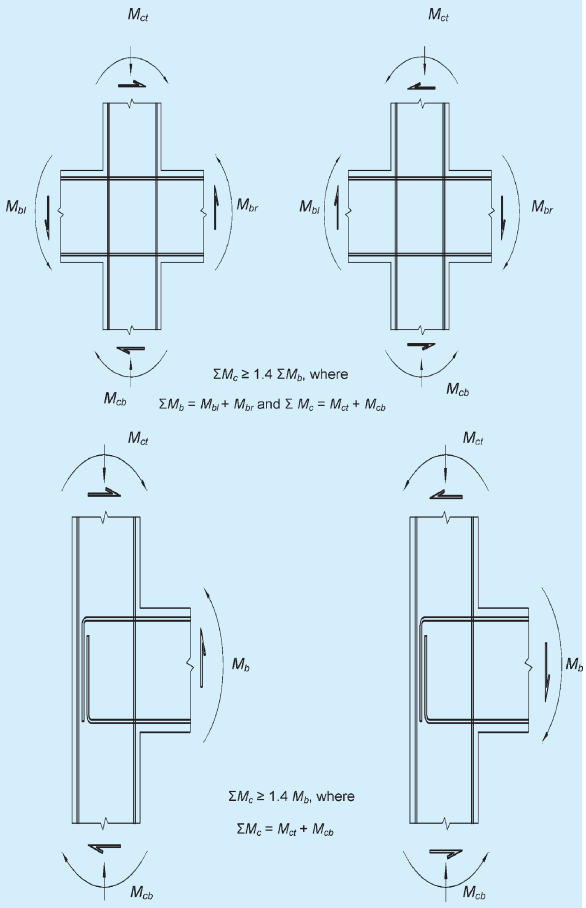


FIG. 41 STRONG COLUMN – WEAK BEAM

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F-6.3.3 A column that extends more than 100 mm beyond the confined core owing to architectural requirement (*see* Fig. 42) shall be detailed in the following manner:

a) When the contribution of this area is considered in the estimate of strength of columns, it shall have at least the minimum longitudinal and transverse reinforcement given in this Subsection 5A.

b) When the contribution of this area is not considered in the estimate of strength of columns, it shall have at least the minimum longitudinal and transverse reinforcement given in this Subsection 5A.

F-6.4 Transverse Reinforcement

F-6.4.1 Transverse reinforcement shall consist of closed loop,

a) spiral or circular links in circular columns, and

b) rectangular links in rectangular columns.

In either case, the closed link shall have 135° hook ends with an extension of 6 times its diameter (but not < 65 mm) at each end, which are embedded in the confined core of the column (*see* Fig. 43A).

F-6.4.2 When rectangular links are used,

a) the minimum diameter permitted of transverse reinforcement bars is 8 mm, when diameter of longitudinal bar is less than or equal to 32 mm, and 10 mm, when diameter of longitudinal bar is more than 32 mm;

b) the maximum spacing of parallel legs of links shall be 300 mm centre-to-centre;

c) a cross-tie shall be provided, if the length of any side of the link exceeds 300 mm (*see* Fig. 43B); the cross-tie shall be placed perpendicular to this link whose length exceeds 300 mm. Alternatively, a pair of overlapping links may be provided within the column (*see* Fig. 43C). In either case, the hook ends of the links and cross-ties shall engage around peripheral longitudinal bars. Consecutive cross-ties engaging the same longitudinal bars shall have their 90° hooks on opposite sides of the column. Crossties of the same or smaller bar size as the hoops shall be permitted; and,

d) the maximum spacing of links shall be half the least lateral dimension of the column, except where special confining reinforcement is provided as per **F-7**.

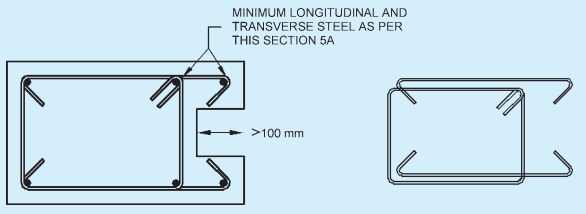


FIG. 42 REINFORCEMENT REQUIREMENT IN COLUMNS WITH PROJECTION MORE THAN 100 mm BEYOND CORE

F-6.5 Design Shear Force in Columns

The design shear force demand on columns is the larger of,

a) factored shear force demand as per linear structural analysis; and

b) factored equilibrium shear force demand when plastic hinges are formed at both ends of the beams given by:

1) For sway to right:

$$V_u = 1.4\frac{\left(M_u^{As} + M_u^{Bh}\right)}{h_{st}},$$

2) For sway to left:

$$V_u = 1.4\frac{\left(M_u^{Ah} + M_u^{Bs}\right)}{h_{st}},$$

where M_u^{As}, M_u^{Ah}, M_u^{Bs} and M_u^{Bh} are design sagging and hogging moments of resistance of beams framing into the column on opposite faces *A* and *B*, respectively, with one hogging moment and the other sagging (*see* Fig. 44); and h_{st} the storey height. The design moments of resistance of beam sections shall be calculated as per this Subsection 5A.

F-6.5.1 The calculation of design shear force capacity of RC columns shall be calculated as per this Subsection 5A.

F-7 SPECIAL CONFINING REINFORCEMENT

The requirements of this section shall be met with in beams and columns, unless a larger amount of transverse reinforcement is required from shear strength considerations given in **F-5.3.3** for beams and **F-6.5** for columns.

F-7.1 Flexural yielding is likely in beams during strong earthquake shaking and in columns when the shaking intensity exceeds the expected intensity of earthquake shaking (*see* Fig. 45). This special confining reinforcement shall,

a) be provided over a length l_o from the face of the joint towards mid-span of beams and mid heights of columns, on either side of the joint; where l_o is not less than,

1) larger lateral dimension of the member at the section where yielding occurs,

2) 1/6 of clear span of the member; or

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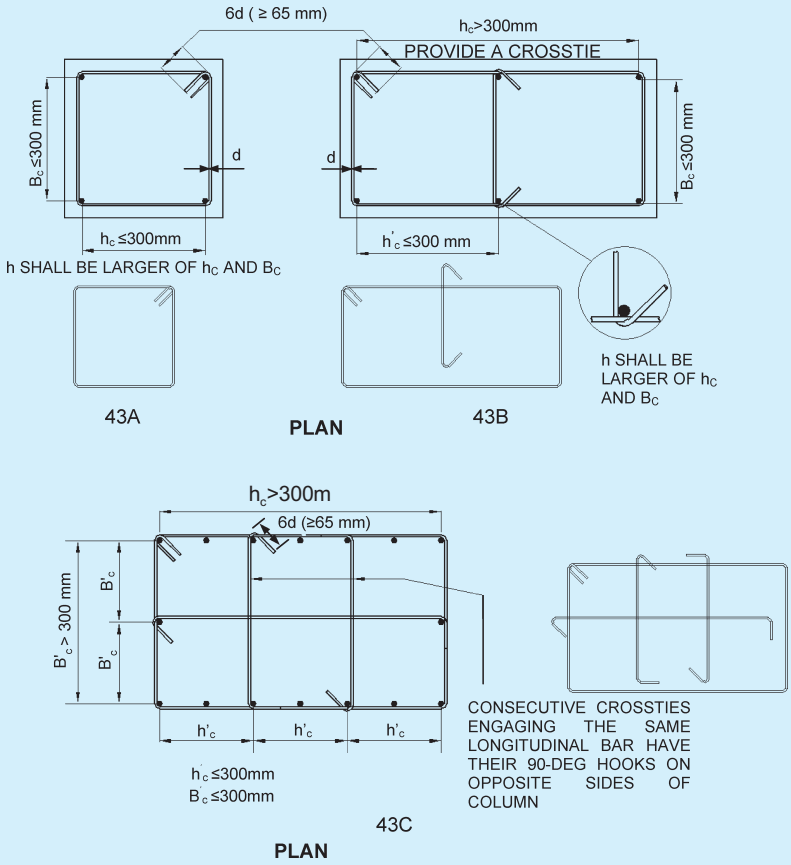


FIG. 43 DETAIL OF TRANSVERSE REINFORCEMENT IN COLUMNS

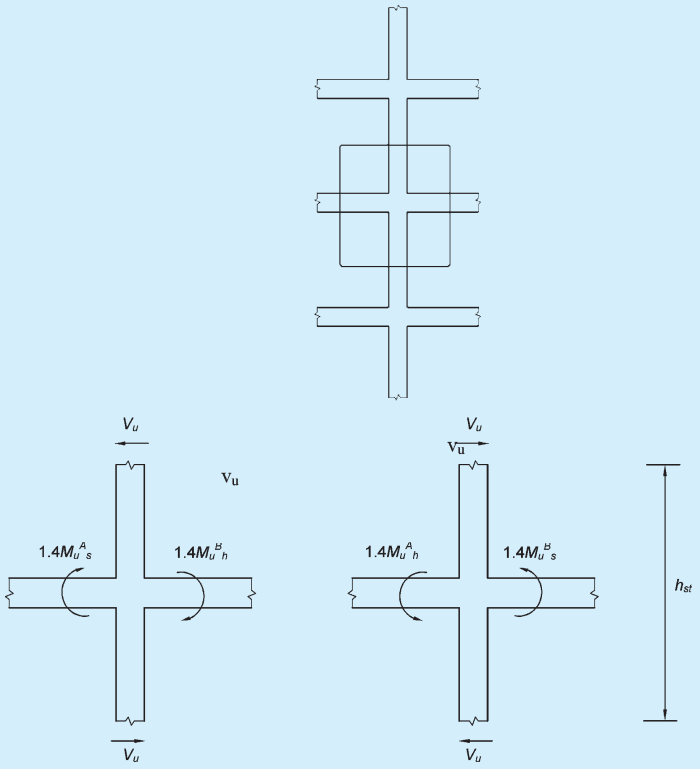


FIG. 44 EQUILIBRIUM DESIGN SHEAR FORCE DEMAND ON COLUMN WHEN PLASTIC HINGES ARE FORMED AT BEAM ENDS

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3) 450 mm.

b) have a spacing not more than,
   1) 1/4 of minimum member dimension of the beam or column;
   2) 6 times diameter of the smallest longitudinal reinforcement bars; and
   3) 100 mm link.

c) have area A_{sh} of cross-section of the bar forming links or spiral of at least:
   1) in circular links or spirals:

A_{sh} = Maximum of

$$\begin{bmatrix} 0.09\, s_v D_k \dfrac{f_{ck}}{f_y}\left(\dfrac{A_g}{A_k}-1\right) \text{ and} \\ 0.024\, s_v D_k \dfrac{f_{ck}}{f_y} \end{bmatrix}$$

where

s_v = pitch of spiral or spacing of links,
D_k = diameter of core of circular column measured to outside of spiral/link,
f_{ck} = characteristic compressive strength of concrete cube,
f_y = 0.2 percent proof strength of transverse steel reinforcement bars,
A_g = gross area of column cross-section, and
A_k = area of concrete core of column

$$= \frac{\pi}{4} D_k^2$$

   2) in rectangular links:

A_{sh} = Maximum of

$$\begin{bmatrix} 0.18\, s_v h \dfrac{f_{ck}}{f_y}\left(\dfrac{A_g}{A_k}-1\right) \\ 0.05\, s_v h \dfrac{f_{ck}}{f_y} \end{bmatrix}$$

where

h = longer dimension of rectangular link measured to its outer face, which does not exceed 300 mm (*see* Fig. 43B), and
A_k = area of confined concrete core in rectangular link measured to its outer dimensions.

h of the link could be reduced by introducing crossties (*see* Fig. 43C). In such cases, A_k shall be measured as overall core area, regardless of link arrangement. Hooks of cross-ties shall engage peripheral longitudinal bars.

F-7.2 When a column terminates into a footing or mat, special confining reinforcement shall extend at least 300 mm into the footing or mat (*see* Fig. 46).

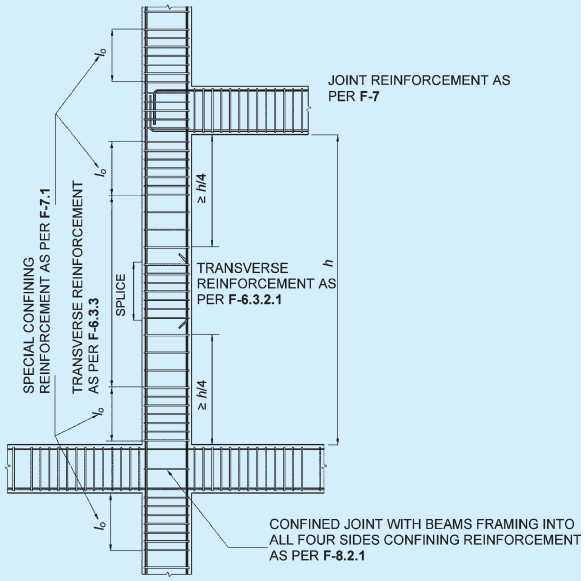


FIG. 45 COLUMN AND JOINT DETAILING

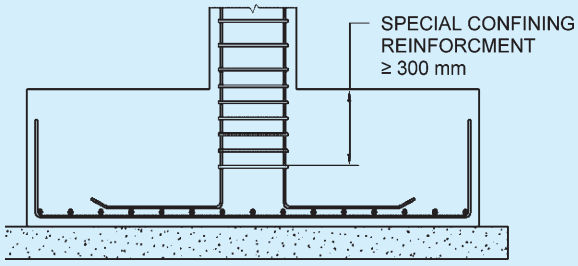


FIG. 46 PROVISION OF SPECIAL CONFINING REINFORCEMENT IN FOOTING

F-7.3 When the calculated point of contra-flexure, under the effect of gravity and earthquake effects, is not within the middle half of the member clear height, special confining reinforcement shall be provided over the full height of the column.

F-7.4 Special confining reinforcement shall be provided over the full height of a column which has significant variation in stiffness along its height. This variation in stiffness may result due to abrupt changes in cross-section size, or unintended restraint to the column provided by stair-slab, mezzanine floor, plinth or lintel beams framing into the columns, RC wall or masonry wall adjoining column and extending only for partial column height.

F-7.5 Columns supporting reactions from discontinued stiff members, such as walls, shall be provided with special confining reinforcement over their full height. (*see* Fig. 47). This reinforcement shall also be placed above the discontinuity for at least the development length of the largest longitudinal bar in the column.

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Where the column is supported on a wall, this reinforcement shall be provided over the full height of the column; it shall also be provided below the discontinuity for the same development length.

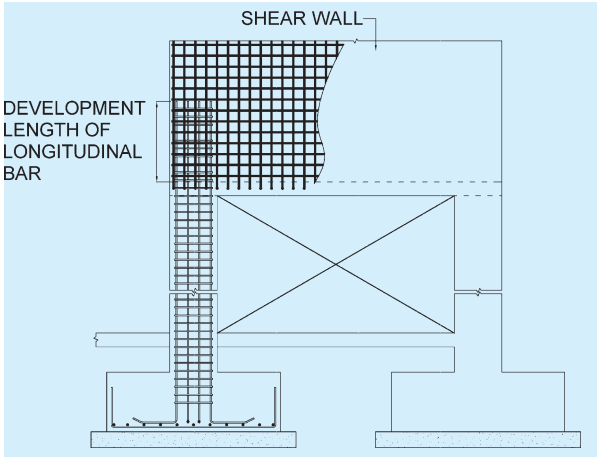


FIG. 47 COLUMNS WITH VARIABLE STIFFNESS

F-8 BEAM-COLUMN JOINTS OF MOMENT-RESISTING FRAMES

F-8.1 Design of Beam-Column Joint for Distortional Shear

F-8.1.1 *Shear Strength of Concrete in a Joint*

The nominal shear strength τ_{jc} of concrete in a beam-column joint shall be taken as:

$$\tau_{jc} = \begin{cases} 1.5 \; A_{ej}\sqrt{f_{ck}} & \text{for joints confined by beams on all four faces} \\ 1.2 \; A_{ej}\sqrt{f_{ck}} & \text{for joints confined by beams on three faces} \\ 1.0 \; A_{ej}\sqrt{f_{ck}} & \text{for other joints} \end{cases}$$

where A_{ej} is effective shear area of joint given by $b_j w_j$, in which b_j is the effective breadth of joint perpendicular to the direction of shear force and w_j the effective width of joint along the direction of shear force. The effective width of joint b_j (*see* Fig. 48) shall be obtained from following:

$$\min [b_b; b_c + 0.5h_c] \text{ if } b_c < b_b$$

where

b_b = width of beam. b_c = width of column.

h_c = Depth of column in considered direction.

F-8.1.2 *Design Shear Stress Demand on a Joint*

a) Design shear stress demand acting horizontally along each of the two principal plan directions of the joint shall be estimated from earthquake shaking considered along each of these directions, using,

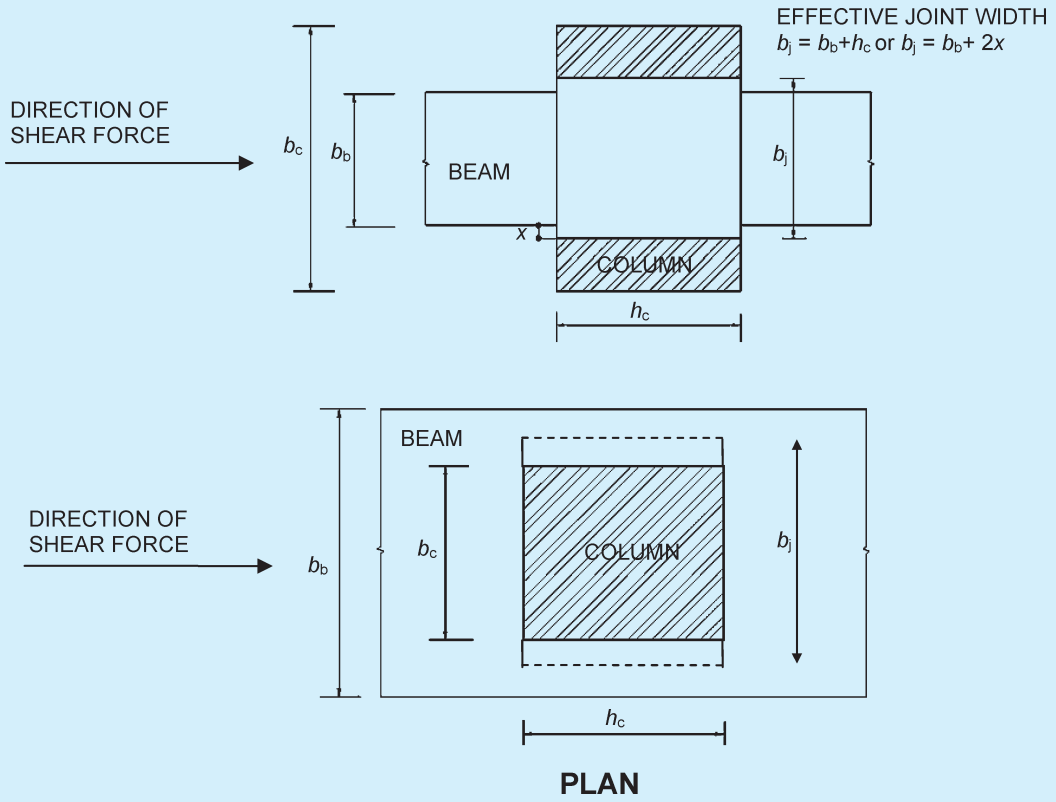


FIG. 48 PLAN VIEW OF A BEAM COLUMN JOINT SHOWING EFFECTIVE BREADTH AND WIDTH OF JOINT

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$\tau_{jdX} = \frac{V_{djX}}{b_j w_j}$ for shaking along plan direction X of earthquake shaking,

$\tau_{jdY} = \frac{V_{djY}}{b_j w_j}$ for shaking along plan direction Y of earthquake shaking

It shall be ensured that the joint shear capacity of joint concrete estimated using **F-8.1.1** exceeds both τ_{jdX} and τ_{jdY}.

b) Design shear force demands V_{jdX} and V_{jdY} acting horizontally on the joint in principal plan directions X and Y shall be estimated considering that the longitudinal beam bars in tension reach a stress of 1.25 f_y (when over strength plastic moment hinges are formed at beam ends).

F-8.1.3 *Width of Beam Column Joint*

When beam reinforcement extends through beam-column joint, the minimum width of the column parallel to beam shall be 20 times the diameter of the largest longitudinal beam bar.

F-8.2 Transverse Reinforcement

F-8.2.1 *Confining Reinforcement in Joints*

a) When all four vertical faces of the joint are having beams framing into them covering at least 75 percent of the width on each face,
   1) At least half the special confining reinforcement required as per **F-7** at the two ends of columns, shall be provided through the joint within the depth of the shallowest beam framing into it; and
   2) Spacing of these transverse links shall not exceed 150 mm.

b) When all four vertical faces of the joint are not having beams framing into them or when all four vertical faces have beams framing into them but do not cover at least 75 percent of the width on any face,
   1) special confining reinforcement required as per **F-7** at the two ends of columns shall be provided through the joint within the depth of the shallowest beam framing into it, and
   2) spacing of these transverse links shall not exceed 150 mm.

F-8.2.2 In the exterior and corner joints, all 135° hooks of cross-ties should be along the outer face of columns.

F-9 SPECIAL SHEAR WALLS

F-9.1 General Requirements

F-9.1.1 The requirements of this clause apply to special shear walls that are part of lateral force resisting system of earthquake-resistant RC buildings.

F-9.1.2 The minimum thickness of special shear walls shall not be less than,

a) 150 mm; and

b) 300 mm for buildings with coupled shear walls in any seismic zone.

The minimum thickness provided shall conform to the fire resistance requirements based on occupancy as laid down in this Subsection 5A.

F-9.1.3 The minimum ratio of length of wall to its thickness shall be 4.

F-9.1.4 Special shear walls shall be classified as squat, intermediate or slender depending on the overall height h_w to Length L_w ratio as:

a) Squat walls: $h_w/L_w < 1$,

b) Intermediate walls: $1 \leq h_w/L_w \leq 2$, and

d) Slender walls: $h_w/L_w > 2$.

F-9.1.5 In the design of flanged wall sections, only that part of the flange shall be considered which extends beyond the face of the web of the structural wall at least for a distance equal to smaller of,

a) actual width available ;

b) half the distance to the adjacent structural wall web; and

c) $1/10^{th}$ of the total wall height.

F-9.1.6 Special shear walls shall be provided with uniformly spaced reinforcement in its cross-section along vertical and horizontal directions. At least a minimum area of reinforcement bars as indicated in Table 33 shall be provided along vertical and horizontal directions.

F-9.1.7 Reinforcement bars shall be provided in two curtains within the cross-section of the wall, with each curtain having bars running along vertical and horizontal directions, when,

a) factored shear stress demand in the wall exceeds $0.25\sqrt{f_{ck}}$ MPa; or

b) wall thickness is 200 mm or higher.

When steel is provided in two layers, all vertical steel bars shall be contained within the horizontal steel bars; the horizontal bars shall form a closed core concrete area with closed loops and cross-ties.

F-9.1.8 The largest diameter of longitudinal steel bars used in any part of a wall shall not exceed $1/10^{th}$ of the thickness of that part.

F-9.1.9 The maximum spacing of vertical or horizontal reinforcement shall not exceed smaller of,

a) $1/5^{th}$ horizontal length L_w of wall;

b) 3 times thickness t_w of web of wall; and

c) 450 mm.

F-9.1.10 Special shear walls shall be founded on properly designed foundations and shall not be discontinued to rest on beams, columns or inclined members.

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Table 33 Minimum Reinforcement in RC Shear Walls

(*Clause* F-9.1.6)

Sl No.	Type of Wall	Reinforcement Details
(1)	(2)	(3)
i)	Squat walls	$(\rho_h)_{min} = 0.002\,5$ $(\rho_v)_{min} = 0.002\,5 + 0.5\left(1 - \frac{h_w}{L_w}\right)(\rho_h - 0.002\,5$ $(\rho_{v,net}) = (\rho_{v,web}) + \left(\frac{t_w}{L_w}\right).\left[0.02 - 2.5(\rho_{v,web})\right]$ $(\rho_v)_{provided} < (\rho_h)_{provided}$
ii)	Intermediate walls	$(\rho_h)_{min} = 0.002\,5$ $(\rho_{v,be})_{min} = 0.008\,0$ $(\rho_{v,web})_{min} = 0.002\,5$ $(\rho_{v,net})_{min} = 0.002\,5 + 0.001\,375\left(\frac{t_w}{L_w}\right)$
iii)	Slender walls	$(\rho_h)_{min} = 0.002\,5 + 0.5\left(\frac{h_w}{L_w} - 2\right)(\rho_h - 0.002\,5)$ $(\rho_{v,be})_{min} = 0.008\,0$ $(\rho_{v,web})_{min} = 0.002\,5$ $(\rho_{v,net})_{min} = 0.002\,5 + 0.001\,375\left(\frac{t_w}{L_w}\right)$

F-9.2 Design for Shear Force

F-9.2.1 Nominal shear stress demand τ_v on a wall shall be estimated as:

$$\tau_v = \frac{V_u}{t_w d_w},$$

where, V_u is factored shear force, t_w thickness of the web, and d_w effective depth of wall section (along the length of the wall), which may be taken as 0.8 L_w for rectangular sections.

F-9.2.2 Design shear strength τ_c of concrete shall be calculated as per Table 19.

F-9.2.3 When nominal shear stress demand τ_v on a wall is,

a) more than maximum design shear strength $\tau_{c,max}$ of concrete (given in Table 20), the wall section shall be re-designed;

b) less than maximum design shear strength $\tau_{c,max}$ of concrete and more than design shear strength τ_c of concrete, design horizontal shear reinforcement shall be provided of area A_h given by:

$$A_h = \frac{V_{us}}{0.87 f_y \left(\frac{d}{s_v}\right)_{Integral}} = \frac{V_u - \tau_c t_w d_w}{0.87 f_y \left(\frac{d}{s_v}\right)_{Integral}},$$

which shall not be less than the minimum area of horizontal steel as per **F-9.1.5**; and

c) less than design shear strength τ_c of concrete, horizontal shear reinforcement shall be the minimum area of horizontal steel as per **F-9.1.5**.

F-9.3 Design for Axial Force and Bending Moment

F-9.3.1 Design moment of resistance M_u of the wall section subjected to combined bending moment and compressive axial load shall be estimated in accordance with requirements of limit state design method given in this Subsection 5A, using the principles of mechanics involving equilibrium equations, strain compatibility conditions and constitutive laws.

The moment of resistance of slender rectangular structural wall section with uniformly distributed vertical reinforcement may be estimated using expressions given in **F-9.9**. Expressions given in **F-9.9** are not applicable for structural walls with boundary elements,

F-9.3.2 The cracked flexural strength of a wall section shall be greater than its uncracked flexural strength.

F-9.3.3 In structural walls that do not have boundary elements, at least a minimum of 4 bars of 12 mm diameter arranged in 2 layers, shall be concentrated as vertical reinforcement at the ends of the wall over a length not exceeding twice the thickness of RC wall.

F-9.4 Boundary Elements

Boundary elements are portions along the wall edges that are strengthened by longitudinal and transverse reinforcement even if they have the same thickness as that of the wall web. It is advantageous to provide boundary elements with dimension greater than thickness of the wall web.

F-9.4.1 Boundary elements shall be provided along the vertical boundaries of walls, when the extreme fibre compressive stress in the wall exceeds 0.2 f_{ck} due to factored gravity loads plus factored earthquake force. Boundary elements may be discontinued at elevations where extreme fibre compressive stress becomes less than 0.15 f_{ck}. Extreme fibre compressive stress shall be estimated using a linearly elastic model and gross section properties.

F-9.4.2 A boundary element shall have adequate axial load carrying capacity, assuming short column action, so as to enable it to carry axial compression arising from factored gravity load and lateral seismic shaking effects.

F-9.4.2.1 The load factor for gravity load shall be taken as 0.8, if gravity load gives higher axial compressive strength of the boundary element.

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F-9.4.3 The vertical reinforcement in the boundary elements shall not be less than 0.8 percent and not greater than 6 percent; the practical upper limit would be 4 percent to avoid congestion.

F-9.4.4 Boundary elements, where required as per **F-9.4.1**, shall be provided with special confining reinforcement throughout their height, given by:

$$A_{sh} = 0.05\ s_v\ h \frac{f_{ck}}{f_y}$$

and have a spacing not more than,

a) 1/3 of minimum member dimension of the boundary element;

b) 6 times diameter of the smallest longitudinal reinforcement bars; and

c) 100 mm but may be relaxed to 150 mm if maximum distance between cross-ties/parallel legs of links or ties is limited to 200 mm, but need not be less than 100 mm.

F-9.4.5 Boundary elements need not be provided, if the entire wall section is provided with special confining reinforcement, as per **F-7**.

F-9.5 Coupling Beams

F-9.5.1 Coplanar special structural walls may be connected by means of coupling beams.

F-9.5.2 If earthquake induced shear stress τ_{ve} in coupling beam exceeds,

$$\tau_{ve} > 0.1\sqrt{f_{ck}}\left(\frac{L_s}{D}\right),$$

where L_s is clear span of coupling beam and D overall depth, the entire earthquake-induced shear, bending moment and axial compression shall be resisted by diagonal reinforcement alone. Further,

a) area of this diagonal reinforcement along each diagonal shall be estimated as:

$$A_{sd} = \frac{V_u}{1.74\ \ f_y \sin\alpha},$$

where V_u is factored shear force on the coupling beam and α the angle made by diagonal reinforcement with the horizontal; and

b) at least 4 bars of 8 mm diameter shall be provided along each diagonal. All longitudinal bars along each diagonal shall be enclosed by special confining transverse reinforcement as per **F-7** at a spacing not exceeding 100 mm.

F-9.5.3 The diagonal of a coupling beam shall be anchored in the adjacent walls with an anchorage length of 1.5 times the development length in tension (*see* Fig. 49).

F-9.6 Openings in Walls

F-9.6.1 Shear strength of a wall with openings should be checked at critical horizontal planes passing through openings.

F-9.6.2 Additional steel reinforcement shall be provided along all four edges of openings in walls. Further,

a) the area of these vertical and horizontal steel should be equal to that of the respective interrupted bars, provided half on either side of the wall in each direction.

b) these vertical bars should extend for full height of the storey in which this opening is present.

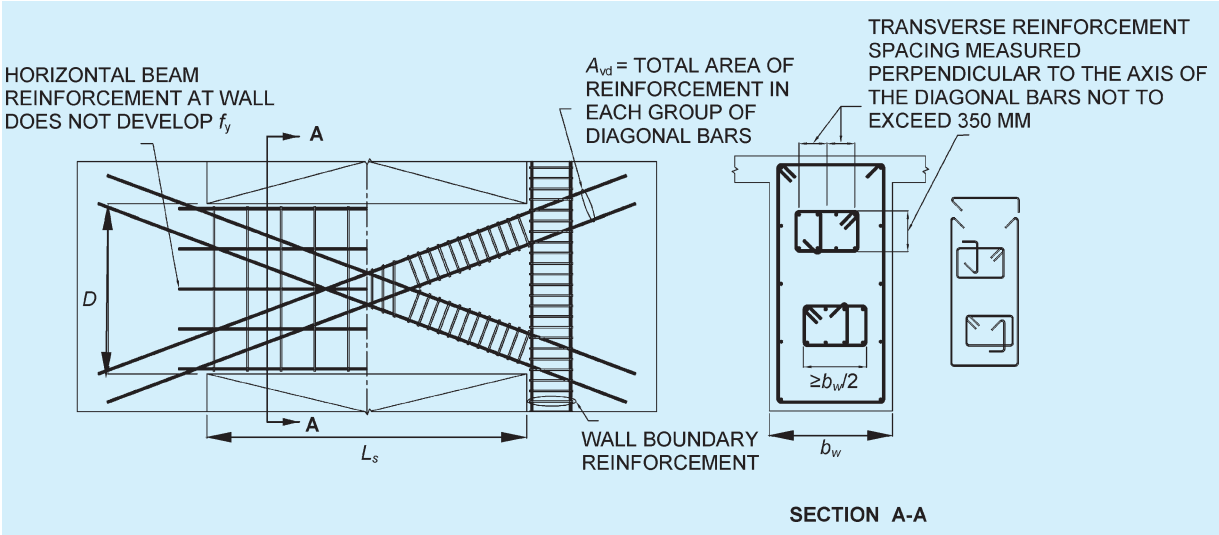


FIG. 49 COUPLING BEAMS WITH DIAGONAL REINFORCEMENT

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c) the horizontal bars should be provided with development length in tension beyond the edge of the opening.

F-9.7 Construction Joints

Vertical reinforcement across a horizontal construction joint shall have area, A_{st} is given by:

$$\frac{A_{st}}{A_g} \geq \frac{0.92}{f_y}\left(\tau_v - \frac{P_u}{A_g}\right)$$

where τ_v is factored shear stress at the joint, P_u factored axial force (positive for compression), and A_g gross cross-sectional area of joint.

F-9.8 Development, Splice and Anchorage Requirement

F-9.8.1 Horizontal reinforcement shall be anchored near the edges of wall or in confined core of boundary elements.

F-9.8.2 In slender walls ($H/L_w > 2$), splicing of vertical flexural reinforcement should be avoided, as far as possible, in regions where flexural yielding may take place, which extends for a distance larger of,

a) L_w above the base of the wall; and
b) $1/6^{th}$ of the wall height;

but not larger than $2L_w$.

F-9.8.3 *Splices*

F-9.8.3.1 *Lap splices*

When adopted, closed links shall be provided over the entire length over which the longitudinal bars are spliced. Further,

a) the spacing of these links shall not exceed 150 mm.
b) the lap length shall not be less than the development length of the largest longitudinal reinforcement bar in tension.
c) lap splices shall be provided only in the central half of clear wall height, and not,
   1) within a joint; or
   2) within a distance of $2d$ from a location where yielding of reinforcement is likely to take place.
d) not more than 50 percent of area of steel bars shall be spliced at any one section.

F-9.8.3.2 Mechanical couplers {conforming to accepted standard [6-5A(38)]} shall be used. Further, only those mechanical splices conforming to the above standard and capable of developing the specified tensile strength of spliced bar shall be permitted within a distance equal to two times the depth of the member from the beam-column joint or in any location where yielding of reinforcement is likely to take place

F-9.8.3.3 *Welded splices*

Welded splices shall be avoided as far as possible. In no case shall they be used for a distance equal to two times the depth of the member from the member face or in any location where yielding of reinforcement is likely to take place. At any location, not more than 50 percent of area of steel bars shall be spliced at any one section.

Welding of links, ties, inserts or other similar elements to vertical reinforcement bars required as per design is not permitted, in any seismic zone.

F-9.8.4 In buildings located in Seismic Zones II and III, closed loop transverse links shall be provided around lapped spliced bars larger than 16 mm in diameter. The minimum diameter of such links shall be $1/4^{th}$ of diameter of spliced bar but not less than 8 mm at spacing not exceeding 150 mm centres.

F-9.9 Moment of Resistance of Rectangular Shear Wall Section

The moment of resistance M_u of a slender rectangular structural wall section with uniformly distributed vertical reinforcement may be estimated as:

a) For $(x_u/L_w) < (x_u^*/L_w)$

$$\frac{M_u}{f_{ck}t_w L_w^2} = \varphi\left[\left(1+\frac{\lambda}{\varphi}\right)\left(\frac{1}{2}-0.416\frac{x_u}{L_w}\right) - \left(\frac{x_u}{L_w}\right)^2\left(0.168+\frac{\beta^2}{3}\right)\right]$$

where

$$\frac{x_u}{L_w} = \left(\frac{\varphi+\lambda}{2\varphi+0.36}\right);$$

$$\frac{x_u^*}{L_w} = \frac{0.003\,5}{0.003\,5+(0.002+0.87\,f_y/E_s)}$$

$$\varphi = \left(\frac{0.87 f_y \rho}{f_{ck}}\right);$$

$$\lambda = \frac{P_u}{f_{ck}t_w L_w}$$

ρ = vertical reinforcement ratio = $\left(\frac{A_{st}}{t_w L_w}\right)$,

A_{st} = area of uniformly distributed vertical reinforcement,

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$$\beta = \frac{(0.002 + 0.87 f_y / E_s)}{0.0035},$$

E_s = elastic modulus of steel, and

P_u = factored compressive axial force on wall.

b) For $(x_u^*/L_w) < (x_u/L_w) < 1.0$

$$\frac{M_u}{f_{ck} t_w L_w^2} = \alpha_1 \left(\frac{x_u}{L_w}\right) - \alpha_2 \left(\frac{x_u}{L_w}\right)^2 - \alpha_3 - \frac{\lambda}{2}$$

where

$$\alpha_1 = \left[0.36 + \varphi\left(1 - \frac{\beta}{2} - \frac{1}{2\beta}\right)\right]$$

$$\alpha_2 = \left[0.15 + \frac{\varphi}{2}\left(1 - \beta + \frac{\beta^2}{3} - \frac{1}{3\beta}\right)\right] \text{ and}$$

$$\alpha_3 = \frac{\varphi}{6\beta}\left(\frac{1}{x_u/L_w} - 3\right).$$

x_u/L_w to be used in this expression shall be obtained by solving the equation:

$$\alpha_1 \left(\frac{x_u}{L_w}\right)^2 + \alpha_4 \left(\frac{x_u}{L_w}\right) - \alpha_5 = 0$$

where

$$\alpha_4 = \left(\frac{\varphi}{\beta} - \lambda\right), \text{ and}$$

$$\alpha_5 = \left(\frac{\varphi}{2\beta}\right).$$

F-10 GRAVITY COLUMNS IN BUILDINGS

Gravity columns in buildings shall be detailed according to **F-10.1** and **F-10.2** for bending moments induced when subjected to 'R' times the design lateral displacement under the factored equivalent static design seismic loads given by **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

F-10.1 The provisions in **F-10.1.1** and **F-10.1.2** shall be satisfied, when induced bending moments and horizontal shear forces under the said lateral displacement combined with factored gravity bending moment and shear force do not exceed the design moment of resistance and design lateral shear capacity of the column.

F-10.1.1 Gravity columns shall satisfy **F-6.3.2**, **F-6.4.1** and **F-6.4.2.** But, spacing of links along the full column height shall not exceed 6 times diameter of smallest longitudinal bar or 150 mm.

F-10.1.2 Gravity columns with factored gravity axial stress exceeding $0.4 f_{ck}$ shall satisfy **F-10.1.1** and shall have transverse reinforcement at least one half of special confining reinforcement required by **F-7**.

F-10.2 When induced bending moments and shear forces under said lateral displacement combined with factored gravity bending moment and shear force exceed design moment and shear strength of the frame, **F-10.2.1** and **F-10.2.2** shall be satisfied.

F-10.2.1 Mechanical and welded splices shall satisfy **F-6.3.2.2** and **F-6.3.2.3.**

F-10.2.2 Gravity columns shall satisfy **F-6.4** and **F-7**.

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ANNEX G

(*Clauses* 34.3.2 and 42.1)

CALCULATION OF CRACK WIDTH

Provided that the strain in the tension reinforcement is limited to 0.8 F_y/E_s, the design surface crack width, which should not exceed the appropriate value given in **34.3.2** may be calculated from the following equation:

Design surface crack width:

$$W_{cr} = \frac{3a_{cr}\varepsilon_m}{1+\frac{2(2a_{cr}-C_{min})}{h-x}}$$

where

a_{cr} = distance from the point considered to the surface of the nearest longitudinal bar.

C_{min} = minimum cover to the longitudinal bar,

ε_m = average steel strain at the level considered,

h = overall depth of the member, and

x = depth of the neutral axis.

The average steel strain ε_m may be calculated on the basis of the following assumption:

The concrete and the steel are both considered to be fully elastic in tension and in compression. The elastic modulus of the steel may be taken as 200 kN/mm^2 and the elastic modulus of the concrete is as derived from the equation given in **5.2.3.1** both in compression and in tension.

Alternatively, as an approximation, it will normally be satisfactory to calculate the steel stress on the basis of a cracked section and then reduce this by an amount equal to the tensile force generated by the triangular distributions, having a value of zero at the neutral axis and a value at the centroid of the tension steel of 1 N/mm^2 instantaneously, reducing to 0.55 N/mm^2 in the long-term, acting over the tension zone divided by the steel area.

These assumptions are illustrated in Fig. 50,

For a rectangular tension zone, this gives:

$$\varepsilon_m = \varepsilon_1 - \frac{b(h-x)\ (a-x)}{3E_sA_s(d-x)}$$

where

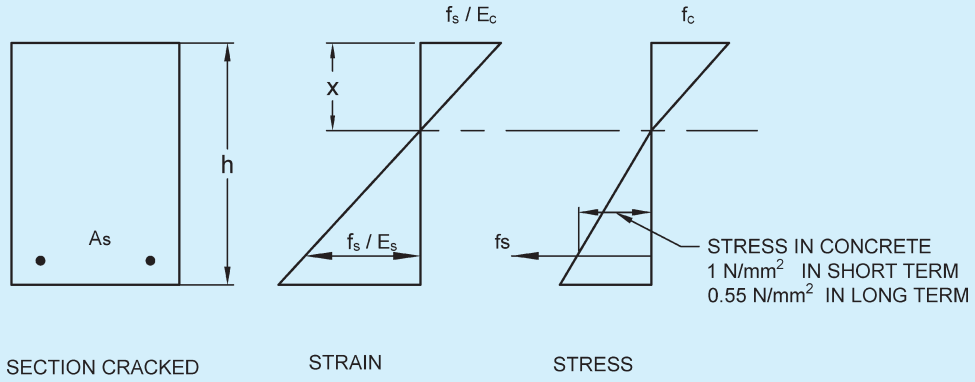
A_s = area of tension reinforcement,

b = width of the section at the centroid of the tension steel,

ε_1 = strain at the level considered, calculated ignoring the stiffening of the concrete in the tension zone,

a = distance from the compression face to the point at which the crack width is being calculated, and

d = effective depth.



where

h = overall depth of the section,

x = depth from the compression face to the neutral axis,

f_c = maximum compressive stress in the concrete,

f_s = tensile stress in the reinforcement, and

E_s = modulus of elasticify of the reinforcement.

FIG. 50

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ANNEX H

(*Clause* 37.1)

MOMENTS OF RESISTANCE FOR RECTANGULAR AND T-SECTIONS

H-0 The moments of resistance of rectangular and T-sections based on the assumption of **37.1** are given in this annex.

H-1 RECTANGULAR SECTIONS

H-1.1 Sections Without Compression Reinforcement

The moment of resistance of rectangular sections without compression reinforcement should be obtained as follows:

a) Determine the depth of neutral axis from the following equation:

$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b.d}$$

b) If the value of x_u/d is less than the limiting value (see Note below **37.1**), calculate the moment of resistance by the following expression:

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{A_{st} f_y}{b d f_{ck}}\right]$$

c) If the value of x_u/d is equal to the limiting value, the moment of resistance of the section is given by the following expression:

$$M_{u,\,lim} = 0.36 \frac{x_{u,max}}{d}\left[1 - 0.42 \frac{x_{u,max}}{d}\right] b d^2 f_{ck}$$

d) If x_u/d is greater than the limiting value, the section should be redesigned.

In the above equations,

x_u = depth of neutral axis,
d = effective depth,
f_y = characteristic strength of reinforcement,
A_{st} = area of tension reinforcement
f_{ck} = characteristic compressive strength of concrete,
b = width of the compression face,
$M_{u,lim}$ = limiting moment of resistance of a section without compression reinforcement, and
$x_{u,max}$ = limiting value of x_u from **37.1**.

H-1.2 Section with Compression Reinforcement

Where the ultimate moment of resistance of section exceeds the limiting value, $M_{u,lim}$ compression reinforcement may be obtained from the following equation:

$$M_u - M_{u,\,lim} = f_{sc} A_{sc} (d - d')$$

where

M_u, $M_{u,lim}$, d are same as in **H-1.1**

f_{sc} = design stress in compression reinforcement corresponding to a strain of

$$0.003\ 5\frac{(x_{u,max} - d')}{x_{u,max}}$$

$x_{u,max}$ = the limiting value of x_u from **37.1**.

A_{sc} = area of compression reinforcement, and

d' = depth of compression reinforcement from compression face.

The total area of tension reinforcement shall be obtained from the following equation:

$$A_{st} = A_{st1} + A_{st2}$$

where

A_{st} = area of the total tensile reinforcement,

A_{st1} = area of the tensile reinforcement for a singly reinforced section for $M_{u,lim}$, and

A_{st2} = $A_{sc} f_{sc} / 0.87 f_y$

H-2 FLANGED SECTION

H-2.1 For $x_u < D_f$, the moment of resistance may be calculated from the equation given in **H-1.1**.

H-2.2 The limiting value of the moment of resistance of the section may be obtained by the following equation when the ratio D_f/d does not exceed 0.2:

$$M_u = 0.36 \frac{x_{u,max}}{D}\left[1 - 0.42 \frac{x_{u,max}}{D}\right] f_{ck} b_w d^2 + 0.45 f_{ck} (b_f - b_w) D_f \left[d - \frac{D_f}{2}\right]$$

where

M_u, $x_{u,max}$, d and f_{ck} are same as in **H-1.1**,

b_f = breadth of the compression face/flange,

b_w = breadth of the web,

D_f = thickness of the flange.

H-2.2.1 When the ratio D_f/d exceeds 0.2, the moment of resistance of the section may be calculated by the following equation:

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$$M_u = 0.36\frac{x_{u,max}}{D}\left[1-0.42\frac{x_{u,max}}{D}\right]f_{ck}b_w d^2 + 0.45 f_{ck}\left(b_f - b_w\right)y_f\left[d-\frac{y_f}{2}\right]$$

where $y_f = (0.15\, x_u + 0.65\, D_f)$, but not greater than D_f and the other symbols are same as in **H-1.1** and **H-2.2**.

H-2.3 For $x_{u,max} > x_u > D_f$, the moment of resistance may be calculated by the equations given in **H-2.2** when D_f/x_u does not exceed 0.43 and **H-2.2.1** when D_f/x_u exceeds 0.43; in both cases substituting $x_{u,max}$ by x_u.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Subsection.

	IS No.	*Title*
(1)	3370	Concrete structures for the storage of liquids — Code of practice
	(Part 1) : 2009	General requirements (*first revision*)
	(Part 2) : 2009	Reinforced concrete structures (*first revision*)
	2210 : 1988	Criteria for design of reinforced concrete shell structures and folded plates (*first revision*)
	3201 : 1988	Criteria for design and construction of precast-trusses and purlins (*first revision*)
	4090 : 1967	Criteria for design of reinforced concrete arches
	4991 : 1968	Criteria for blast resistant design of structures for explosions above ground
	4995	Criteria for design of reinforced concrete bins for storage of granular and powdery materials
	(Part 1) : 1974	General requirements and bin loads
	(Part 2) : 1974	Design criteria
	4998 : 2015	Criteria for design of reinforced concrete chimneys (*third revision*)
	6922 : 1973	Criteria for safety and design of structures subject to underground blasts
(2)	4845 : 1968	Definitions and terminology relating to hydraulic cement
	6461	Glossary of terms relating to cement:
	(Part 1) : 1972	Concrete aggregates
	(Part 2) : 1972	Materials
	(Part 3) : 1972	Concrete reinforcement
	(Part 4) : 1972	Types of concrete
	(Part 5) : 1972	Formwork for concrete
	(Part 6) : 1972	Equipment, tool and plant
	(Part 7) : 1973	Mixing, laying, compaction, curing and other construction aspect
	(Part 8) : 1973	Properties of concrete
	(Part 9) : 1973	Structural aspects
	(Part 10) : 1973	Tests and testing apparatus
	(Part 11) : 1973	Prestressed concrete
	(Part 12) : 1973	Miscellaneous
(3)	269 : 2015	Ordinary Portland cement — Specification (*sixth revision*)
	8041 : 1990	Specification for rapid hardening Portland cement (*second revision*)
	455 : 2015	Specification for Portland slag cement (*fifth revision*)
	1489	Specification for Portland pozzolana cement:
	(Part 1) : 2015	Fly ash based (*fourth revision*)
	(Part 2) : 2015	Calcined clay based (*fourth revision*)
	8043 : 1991	Specification for hydrophobic Portland cement (*second revision*)
	12600 : 1989	Specification for low heat Portland cement
	12330 : 1988	Specification for sulphate resisting Portland cement
(4)	12600 : 1989	Specification for low heat Portland cement

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	IS No.	*Title*
(5)	6452 : 1989	Specification for high alumina cement for structural use (*first revision*)
(6)	6909 : 1990	Specification for supersulphated cement (*first revision*)
(7)	3812 (Part 1) : 2013	Pulverized fuel ash — Specification: Part 1 For use as pozzolana in cement, cement mortar and concrete (*third revision*)
(8)	15388 : 2013	Specification for silica fume
(9)	16353 : 2015	Specification for Metakaolin
(10)	12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
(11)	9103 : 1999	Specification for admixtures for concrete (*first revision*)
(12)	383 : 2016	Specification for coarse and fine aggregates for concrete (*third revision*)
(13)	3025	Methods of sampling and test (physical and chemical) for water and waste water:
	(Part 22) : 1986	Acidity (*first revision*)
	(Part 23) : 1986	Alkalinity (*first revision*)
	(Part 18) : 1984	Volatile and fixed residue (total filterable and non-filterable) (*first revision*)
	(Part 24) : 1986	Sulphates (*first revision*)
	(Part 32) : 1988	Chloride (*first revision*)
	(Part 17) : 1984	Non-filterable residue (total suspended solids) (*first revision*)
(14)	516 : 1959	Method of test for strength of concrete
(15)	4031 (Part 5) : 1988	Methods of physical tests for hydraulic cement: Part 5 Determination of initial and final setting times (*first revision*)
(16)	432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
	1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
	1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)
	2062 : 2011	Hot rolled medium and high tensile structural steel — Specification (*seventh revision*)
(17)	4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
(18)	516 : 1959	Method of test for strength of concrete
	5816 : 1999	Method of test for splitting tensile strength of concrete (*first revision*)
(19)	1343 : 2012	Prestressed concrete — Code of practice (*second revision*)
(20)	1199 (Part 6)	Methods of sampling and analysis of concrete : Part 6 Tests on fresh self compacting concrete (*under preparation*)
(21)	455 : 2015	Specification for Portland slag cement (*fifth revision*)
(22)	1489 (Part 1) : 2015	Specification for Portland pozzolana cement : Part 1 Fly ash based (*fourth revision*)
(23)	4925 : 2004	Specification for concrete batching and mixing plant (*first revision*)
(24)	4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
(25)	2386 (Part 3) : 1963	Methods of test for aggregates for concrete: Part 3 Specific gravity, density, voids, absorption and bulking
(26)	1791 : 1985	Specification for batch type concrete mixers (*second revision*)
	12119 : 1987	General requirements for pan mixers for concrete
(27)	4634 : 1991	Methods for testing performance of batch-type concrete mixers (*first revision*)
(28)	14687 : 1999	Guidelines for falsework for concrete structure
(29)	2502 : 1963	Code of practice for bending and fixing of bars for concrete reinforcement
(30)	2751 : 1979	Recommended practice for welding of mild steel plain and deformed bars for reinforced construction (*first revision*)
	9417 : 1989	Recommendations for welding cold worked bars for reinforced concrete construction (*first revision*)
(31)	2505 : 1992	Concrete vibrators – Immersion type – General requirements
	2506 : 1985	General requirements for screed board concrete vibrators (*first revision*)
	2514 : 1963	Specification for concrete vibrating tables

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IS No.	*Title*
(32) 7861	Code of practice for extreme weather concreting
(Part 1) : 1975	Recommended practice for hot weather concreting
(Part 2) : 1981	Recommended practice for cold weather concreting
(33) 9013 : 1978	Method of making, curing and determining compressive strength of accelerated cured concrete test specimens
(34) 13311	Methods of non-destructive testing of concrete
(Part 1) : 1992	Ultrasonic pulse velocity
(Part 2) : 1992	Rebound hammer
(35) 10262 : 2009	Guidelines for concrete mix design proportioning
(36) 1786 : 2008	High strength deformed steel bars and wires for concrete reinforcement — Specification (*fourth revision*)
(37) 13620 : 1993	Fusion bonded epoxy coated reinforcing bars — Specification
(38) 16172 : 2014	Reinforcement couplers for mechanical splices of bars for concrete reinforcement — Specification
(39) 3414 : 1968	Code of practice for design and installation of joints in buildings
(40) 3951 (Part 1) : 2009	Hollow clay tiles for floors and roofs —Specification: Part 1 Filler type (*second revision*)
(41) 6061 (Part 1) : 1971	Code of practice for construction of floor and roof with joists and filler blocks: Part 1 With hollow concrete filler blocks
6061 (Part 2) : 1981	Code of practice for construction of floor and roof with joists and filler blocks: Part 2 With hollow clay filler blocks (*first revision*)
(42) 432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
(43) 1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5B Prestressed Concrete

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 5B) covers the structural design aspects of prestressed concrete.

The Section 5 of Part 6 of the Code covers plain and reinforced concrete and also the prestressed concrete. The Section has been subdivided into the following subsections:

5A Plain and Reinforced Concrete
5B Prestressed Concrete

Provisions related to prestressed concrete are covered in the following format:

Section 5B (A)	General
Section 5B (B)	Materials, workmanship, inspection and testing
Section 5B (C)	General design requirements
Section 5B (D)	Structural design: Limit state method

In some clauses, the Code recommends reference to specialist literature, since the current knowledge on some aspects of design had not yet crystallized. This had also been done in order to avoid burdening the Code with a lot of details which may not be required for the design of great majority of structures.

While deciding on the symbols used in the Code, the recommendations on ISO 3898 : 2013 'Bases for design of structures — Names and symbols of physical quantities and generic quantities' had been taken into consideration. However, considering the convenience of the users of the Code, the familiar symbols of the old version were retained to the extent possible.

IS 456 was revised in the year 2000 as IS 456 : 2000 'Code of practice for plain and reinforced concrete (*fourth revision*)', to which 4 amendments were subsequently issued. In IS 456, major changes were incorporated in provisions relating to materials, workmanship, inspection and testing, and general design requirements. In view of the attempt at unification between provisions of reinforced concrete and prestressed concrete codes, these changes are relevant to prestressed concrete code also. Considering this aspect as also the need for a complete review of the provision of the Code in light of the latest international developments and the improved practices being followed now, a full scale revision of IS 1343 was done, bringing out IS 1343 : 2012 'Code of practice for prestress concrete (*second revision*)'.

In this second revision of this Subsection, the provisions have been brought in line with IS 1343 : 2012, along with the following further modifications incorporated with a view to keeping abreast with the rapid development in the field of prestressed concrete technology and also to bring in further clarifications and modifications in the light of experience gained, as follows:

a) It has been clarified that the Section/Code does not cover the specific requirements for bridges.
b) Clause on terminology has been reviewed and some new definitions such as anchorage device, cable, relaxation and sheathing have been added apart from modifications in other definitions such as on tendon.
c) Section on materials, workmanship, inspection and testing has been completely modified in line with IS 456 as applicable to prestressing and other changes have been incorporated as follows:
    1) All the references to materials for making prestressed concrete have been updated.
    2) Precautions to be made while using Portland slag cement and Portland pozzolana cement or mineral admixture to account for modified de-shuttering time, curing period and the time of prestressing have been included.
    3) Provisions relating to maximum water cement ratio, minimum grade of concrete and minimum cement concrete have been clarified *vis-à-vis* concrete exposed to sulphate attack.
    4) Uncoated stress relieved low relaxation seven ply strand has also been converted as prestressing steel.

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5) Provisions on modulus of elasticity have been modified.
6) Grades of concrete have been specified up to M 80 from the existing M 30 to M 60.
7) Provisions on creep and shrinkage of concrete have been revised.
8) Durability requirements have been covered exhaustively in line with IS 456 as applicable to prestressed concrete; the maximum cement content has been specified as 450 kg/m^3.
9) Assumed standard deviation has been specified as 5.0 N/mm^2 for concrete mix proportioning.
10) Provisions on assembly of prestressing and reinforcing steel and on prestressing have been thoroughly revised in line with the present improved practices, and details on protection of prestressing steel, sheathing and anchorages have been incorporated.
11) Sampling and strength test of designed concrete mix has been modified in line with IS 456.

d) The Sections on General Design Requirement and Structural Design (Limit State) have been modified as follows:
   1) Provisions are in line with IS 456 as applicable.
   2) Design provisions are updated in line with the latest practices.
e) Provisions related to bearing stress in the end zone in post-tensioned members have been updated.
f) Provisions related to ultimate shear resistance of a section uncracked in flexure have been updated.
g) Provisions related to ultimate shear resistance of a section cracked in flexure have been updated.
h) Test on wall thickness of the duct of corrugated HDPE sheathing duct has been updated.

In this Code, it has been assumed that the design of prestressed concrete structures is entrusted to a qualified engineer, and that the execution of the work is carried out under the direction of an experienced supervisor.

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 5 Concrete: 5B Prestressed Concrete

SECTION 5B (A) GENERAL

1 SCOPE

1.1 This Code (Part 6/Subsection 5B) deals with the general structural use of prestressed concrete. It covers both work carried out on site and the manufacture of precast prestressed concrete units.

1.2 Special requirements of structures such as pipes and poles covered in respective standards have not been covered in this Subsection; these standards shall be used in conjunction with this Subsection. This Subsection does not cover specific provisions regarding bridges.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply, and for other terms those given in the accepted standard [6-5B(1)] shall apply.

2.1 Anchorage Device — In post-tensioning, the hardware used for transferring the post-tensioning force from the tendon to the concrete in anchorage zone.

2.2 Bonded Member — A prestressed concrete member in which tendons are bonded to the concrete either directly or through grouting.

2.3 Bonded Post-Tensioning — Post-tensioned construction in which the annular spaces around the tendons are grouted after stressing, thereby bonding the tendon to the concrete section.

2.4 Cable — A group of wires or bars or strands or rods.

2.5 Characteristic Load — Load which has 95 percent probability of not being exceeded during the life of the structure (*see* **20.2**).

2.6 Characteristic Strength — Strength of material below which not more than 5 percent of the test results are expected to fall (*see* **20.1**).

2.7 Column or Strut — A compression member, the effective length of which exceeds three times the least lateral dimension.

2.8 Creep — Time dependent deformation due to sustained load.

2.9 Creep Coefficient — The ratio of creep strain to elastic strain in concrete.

2.10 Final Prestress — The stress which exists after substantially all losses have occurred.

2.11 Final Tension — The tension in the prestressing tendon corresponding to the state of the final prestress.

2.12 Initial Prestress — The prestressing force in the tendon at transfer.

2.13 Initial Tension — The maximum stress induced in the prestressing tendon at the time of the stressing operation.

2.14 Post-Tensioning — A method of prestressing concrete in which prestressing steel is tensioned against the hardened concrete.

2.15 Prestressed Concrete — Concrete in which permanent internal stresses are deliberately introduced, usually by tensioned steel, to counteract to the desired degree the stresses caused in the member during service.

2.16 Pre-Tensioning — A method of prestressing concrete in which the tendons are tensioned before concreting.

2.17 Relaxation — Time dependent decrease in steel stress at constant strain.

2.18 Sheathing — A material encasing a prestressing tendon to prevent bonding the tendon with the surrounding concrete during placement of concrete and to provide protection against corrosion.

2.19 Short Column — A column, the effective length of which does not exceed 12 times the least lateral dimension.

2.20 Slender Column — A column, the effective length of which exceeds 12 times the least lateral dimension.

2.21 Shrinkage Loss — The loss of stress in the prestressing steel resulting from the shrinkage of the concrete.

2.22 Stress at Transfer — The stress in both the prestressing tendon and the concrete when the prestressing tendon is released from the prestressing mechanism.

2.23 Tendon — A steel element, such as a wire, cable, bar, rod or strand, or a bundle of such elements used to impart prestress to concrete when the element is tensioned.

2.24 Transfer — The act of transferring the stress in prestressing tendons from the jacks or pre-tensioning bed to the concrete member.

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2.25 Transmission Length — The distance required at the end of a pre-tensioned tendon for developing the maximum tendon stress by bond.

3 SYMBOLS

For the purpose of this Subsection, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place:

A = Area
B = Breadth of beam
b_w = Breadth of web or rib
D = Overall depth of beam
DL = Dead load
d = Effective depth of beam
d_t = Effective depth of beam in shear
E_c = Short term modulus of elasticity of concrete
EL = Earthquake load
E_s = Modulus of elasticity of steel
e = Eccentricity
F = Characteristic load
F_{bst} = Bursting tensile force
F_d = Design load
f = Characteristic strength of material
f_{ci} = Cube strength of concrete at transfer
f_{ck} = Characteristic compressive strength of concrete
f_{cp} = Compressive stress at centroidal axis due to prestress or average intensity of effective prestress in concrete
f_{cr} = Modulus of rupture of concrete (flexural tensile strength)
f_d = Design strength
f_p = Characteristic strength of prestressing steel
f_{pe} = Maximum prestress after losses
f_{pi} = Maximum initial prestress
f_{pu} = Ultimate tensile stress in the tendons
f_t = Maximum principal tensile stress
f_y = Characteristic strength of reinforcement
IL = Imposed load
M = Bending moment
m = Modular ratio
P = Load due to prestressing effect
s = Spacing of stirrups
T = Torsional moment
V = Shear force
V_c = Ultimate shear resistance of concrete
V_{co} = Ultimate shear resistance of a section uncracked in flexure
V_{cr} = Ultimate shear resistance of a section cracked in flexure
WL = Wind load
x_u = Depth of neutral axis
γ_f = Partial safety factor for load
γ_m = Partial safety factor for material
δ_m = Percentage reduction in moment
τ_c = Shear stress in concrete
ϕ = Diameter of tendon or bar

SECTION 5B (B) MATERIALS, WORKMANSHIP, INSPECTION AND TESTING

4 MATERIALS

4.1 Cement

The cement used shall be any of the following conforming to accepted standards [6-5B(2)] and the type selected should be appropriate for the intended use:

a) Ordinary Portland cement,
b) Rapid-hardening Portland cement,
c) Portland slag cement,
d) Portland pozzolana cement (fly ash based),
e) Portland pozzolana cement (calcined clay based),
f) Hydrophobic cement,
g) Low heat Portland cement, and
h) Sulphate resisting Portland cement.

Other combinations of Portland cement with mineral admixtures (*see* **4.2**) of quality conforming to relevant Indian Standards laid down may also be used in the manufacture of concrete provided that there are satisfactory data on their suitability, such as performance test on concrete containing them. Rate of slow gain of strength with Portland slag cement and Portland pozzolana cement should be taken into account while deciding the de-shuttering time, curing period and the time of prestressing (*see also* **10** and **13**).

4.1.1 Low heat Portland cement conforming to the accepted standard [6-5B(3)] shall be used with adequate precautions with regard to removal of formwork, etc.

4.1.2 High alumina cement conforming to the accepted standard [6-5B(4)] or supersulphated cement conforming to the accepted standard [6-5B(5)] may be used only under special circumstances with the prior approval of the engineer-in-charge. Specialist literature may be consulted for guidance regarding the use of these types of cements.

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4.1.3 The attention of the engineer-in-charge and users of cement is drawn to the fact that quality of various cements mentioned in **4.1** is to be determined on the basis of its conformity to the performance characteristics given in the respective Indian Standard specification for that cement. Any trade-mark or any trade name indicating any special features not covered in the standard or any qualification or other special performance characteristics sometimes claimed/ indicated on the bags or containers or in advertisement alongside the 'Statutory Quality Marking' or otherwise have no relation whatsoever with the characteristic guaranteed by the 'Statutory Quality Marking' as relevant to that cement. Consumers are, therefore, advised to go by the characteristics as given in the corresponding Indian Standard specification or seek specialist advice to avoid any problem in concrete making and construction.

4.2 Mineral Admixtures

Mineral admixtures used shall conform to **4.2** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code. When mineral admixtures are used, rate of slow gain in strength should be taken into account while deciding the de-shuttering time, curing period and the time of prestressing (*see also* **10** and **13**).

4.3 Aggregates

All aggregate shall comply with the requirements of accepted standard [6-5B(6)].

4.3.1 Heavy weight aggregates may also be used provided the engineer-in-charge is satisfied with the data on the properties of concrete made with them.

NOTE — Some of the provisions of the standard would require modification when these aggregates are used. Specialist literature may be consulted for guidance.

4.3.2 *Size of Aggregates*

The nominal maximum size of coarse aggregate should be as large as possible within the limits specified but in no case greater than one-fourth of the minimum thickness of the member, provided that the concrete can be placed without difficulty so as to surround all prestressing tendons and reinforcements thoroughly and fill the corners of the form. For most work, 20 mm aggregate is suitable.

The nominal maximum size of the aggregate shall be 5 mm less than the spacing between the tendons, sheathings, ducts or untensioned steel, where provided.

4.4 Water

The requirements of water used for mixing and curing shall conform to the requirements given in **4.4** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code. However, use of sea water is prohibited.

4.5 Chemical Admixtures

Chemical admixtures shall be used according to **4.5** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

4.6 Prestressed and Untensioned Steel

4.6.1 *Prestressing Steel*

4.6.1.1 The prestressing steel shall be any one of the following conforming to accepted standards [6-5B(7)]:

a) Plain hard-drawn steel wire (cold-drawn stress relieved wire),
b) Indented wire,
c) High tensile steel bar,
d) Uncoated stress relieved strand, and
e) Uncoated stress relieved low relaxation seven ply strand.

4.6.1.1.1 All prestressing steel shall be free from welded joints and splits, harmful scratches, surface flaws; rough, jagged and imperfect edges and other defects likely to impair its use in prestressed concrete.

4.6.1.2 *Mechanical properties*

Data in respect of modulus of elasticity, relaxation loss at 1 000 h at mean temperature of 20°C, minimum ultimate tensile strength, stress-strain curve, etc, shall necessarily be obtained from manufacturer. Prestressing steel shall be subjected to acceptance tests prior to actual use on the works. The modulus of elasticity value, as per acceptance tests, shall conform to the values assumed in the design which shall be within a range not more than 2.5 percent between the maximum and the minimum.

4.6.1.2.1 For design purposes, the minimum requirements given in the relevant Indian Standards may be adopted.

4.6.2 *Untensioned Steel*

4.6.2.1 The reinforcement used as untensioned steel shall be any of the following conforming to accepted standards [6-5B(8)]:

a) Mild steel and medium tensile steel bars.
b) High strength deformed steel bars.
c) Hard-drawn steel wire fabric.

4.6.2.2 All reinforcement shall be free from loose mill scales, loose rust and coats of paints, oil mud or any other substances which may destroy or reduce bond. Sand blasting or other treatment is recommended to clean reinforcement.

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Special precautions like coating of reinforcement may be required for reinforced concrete elements in exceptional cases and for rehabilitation of structures. Specialist literature may be referred to in such cases. Reduction in design bond strength of coated bars shall be looked into.

4.6.2.3 The modulus of elasticity of steel shall be taken as 200 kN/mm^2. The characteristic yield strength of different steel shall be assumed as the minimum yield stress/0.2 percent proof stress specified in the relevant Indian Standard.

4.7 Storage of Materials

Storage of materials shall be as described in good practice [6-5B(9)].

5 CONCRETE

5.1 Grades

The concrete shall be in grades designated as per Table 1.

Table 1 Grade of Concrete

(*Clauses* 5.1, 8.2.2 *and* 20.1)

Sl No.	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Size Cube at 28 Days N/mm^2
(1)	(2)	(3)
i)	M 30	30
ii)	M 35	35
iii)	M 40	40
iv)	M 45	45
v)	M 50	50
vi)	M 55	55
vii)	M 60	60
viii)	M 65	65
ix)	M 70	70
x)	M 75	75
xi)	M 80	80
xii)	M 85	85
xiii)	M 90	90
xiv)	M 95	95
xv)	M 100	100

NOTES

1 In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2.

2 For pre-tensioned prestressed concrete, the grade of concrete shall be not less than M 40.

3 Except where specifically mentioned otherwise, for concrete grade greater than M 60, design parameters given in the Subsection may not be applicable and the values may be obtained from specialized literatures and experimental results.

5.1.1 The characteristic strength of concrete is defined as the strength of the concrete below which not more than 5 percent of the test results are expected to fall.

5.2 Properties of Concrete

5.2.1 *Increase in Strength with Age*

There is normally a gain of strength beyond 28 days. The quantum of increase depends upon the grade and type of cement, curing and environmental conditions, etc. The design should be based on 28 days characteristic strength of concrete unless there is an evidence to justify a higher strength for a particular structure due to age.

5.2.1.1 The rate of increase of compressive strength with age shall be based on actual investigations.

5.2.2 *Tensile Strength of Concrete*

The flexural and splitting tensile strength shall be obtained in accordance with accepted standards [6-5B(10)]. When the designer wishes to use an estimate of the flexural tensile strength from the compressive strength, the following formula may be used:

$$f_{cr} = 0.7\sqrt{f_{ck}}$$

where

f_{cr} = flexural tensile strength, in N/mm^2; and

f_{ck} = characteristic compressive strength of concrete, in N/mm^2.

5.2.3 *Elastic Deformation*

The modulus of elasticity is primarily influenced by the elastic properties of the aggregate and to a lesser extent by the conditions of curing and age of the concrete, the mix proportions and the type of cement. The modulus of elasticity is normally related to the compressive strength of concrete.

5.2.3.1 The modulus of elasticity for concrete may be assumed as follows:

$$E_c = 5\,000\sqrt{f_{ck}}$$

where

E_c = short term static modulus of elasticity, in N/mm^2 ; and

f_{ck} = characteristic compressive strength of concrete, in N/mm^2.

Actual measured values may differ by ±20 percent from the values obtained from the above expression.

5.2.4 *Shrinkage*

The total shrinkage of concrete depends upon the constituents of concrete, size of the member and environmental conditions. For a given humidity and temperature, the total shrinkage of concrete is most influenced by the total amount of water present in the concrete at the time of mixing and, to a lesser extent, by the cement content.

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5.2.4.1 The total shrinkage strain is composed of two components, the autogenous shrinkage strain and the drying shrinkage strain.

The value of the total shrinkage strain, ε_{cs} is given by:

$$\varepsilon_{cs} = \varepsilon_{cd} + \varepsilon_{ca}$$

where

ε_{cs} = total shinkage strain;

ε_{cd} = drying shrinkage strain; and

ε_{ca} = autogenous shrinkage strain.

5.2.4.2 The autogenous shrinkage strain develops during hardening of concrete; the major part develops in the early days after casting. Autogenous shrinkage is a linear function of concrete strength. It should be considered specifically when new concrete is cast against hardened concrete.

In the absence of accurate field/laboratory data, the following values may be considered in design:

Grade of Concrete	*Autogenous Shrinkage* ($\varepsilon_{ca} \times 10^6$)
M 30	35
M 35	45
M 45	65
M 50	75
M 60	95

5.2.4.3 The drying shrinkage strain develops slowly, as it is a function of migration of the water through the hardened concrete.

The final value of the drying shrinkage strain, $\varepsilon_{cd,\infty}$ may be taken as equal to $k_h.\varepsilon_{cd}$ Values of ε_{cd} may be taken from the table given below for guidance. These values are expected mean values, with a coefficient of variation of about 30 percent.

f_{ck} MPa	*Unrestrained Drying Shrinkage Values* ($\varepsilon_{cd} \times 10^6$) *for Concrete with Portland Cement for Relative Humidity*	
	50 percent	80 percent
(1)	(2)	(3)
25	535	300
50	420	240
75	330	190

NOTE — The values for the other designated grades may be obtained by interpolation.

k_h is a coefficient depending on the notional size h_0, as given below:

h_0 mm	k_h
100	1.0
200	0.85
300	0.75
≥ 500	0.70

5.2.4.4 The development of autogenous shrinkage with time may be taken as:

$$\varepsilon_{ca}(t) = \beta_{as}(t).\varepsilon_{ca}$$

where

$\beta_{as}(t) = 1\text{-}\exp\left(-0.2\sqrt{t}\right)$ where, t is in days.

5.2.4.5 The development of the drying shrinkage strain in time may be taken as:

$$\varepsilon_{cd}(t) = \beta_{ds}(t, t_s).k_h.\varepsilon_{cd}$$

$$\beta_{ds}(t, t_s) = \frac{(t - t_s)}{(t - t_s) + 0.04\sqrt{h_0^3}}$$

where

t = age of the concrete at the moment considered, in days;

t_s = age of the concrete at the beginning of drying shrinkage, in days; normally this is at the end of curing; and

h_0 = notional size of the cross-section, in mm

= $2A_c/u$, where A_c is the concrete cross-sectional area and u is the perimeter of that part of the cross-section which is exposed to drying.

5.2.5 *Creep*

Creep of concrete depends, in addition to the factors listed in **5.2.4** on the stress in the concrete, age at loading and the duration of loading. As long as the stress in concrete does not exceed one-third of characteristic compressive strength, creep may be assumed to be proportional to the stress.

5.2.5.1 The creep coefficient

$$\phi(t, t_0) = \frac{\varepsilon_{cc}(t)}{\varepsilon_{ci}(t_0)}$$

where

$\varepsilon_{cc}(t)$ = creep strain at time $t > t_0$,

$\varepsilon_{ci}(t_0)$ = initial strain at loading, and

t_0 = initial time of loading.

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The creep coefficient $\phi(t,t_0)$ is given by:

$$\phi(t,t_0)=\phi_0.\beta(t,t_0),$$

where

ϕ_0 = notional creep coefficient to which the creep co-efficient reaches asymptotically with time (this can be taken as value reached in 70 years), and

$\beta(t, t_0)$ = coefficient describing development of creep with time (*see* **5.2.5.2**).

The notional creep coefficient ϕ_0 is given by:

$$\phi_0=\phi_{RH}.\beta(f_{cm}).\beta(t_0)$$

where

ϕ_{RH} = factor to allow for the effect of relative humidity on the notional creep coefficient

$$= 1+\frac{1-RH/100}{0.1\sqrt[3]{h_0}} \text{ for } f_{ck}\le 45 \text{ MPa}$$

$$= \left[1+\frac{1-RH/100}{0.1\sqrt[3]{h_0}}.\alpha_1\right].\alpha_2 \text{ for } f_{ck}>45 \text{ MPa}$$

RH = relative humidity of the ambient environment in percent;

h_0 = notional size of the member, in mm;

$= 2A_c/u$;

A_c = cross-sectional area, and

u = perimeter of the member in contact with the atmosphere;

$\beta(f_{cm})$= factor to allow for the effect of concrete strength on the notional creep coefficient

$$=\frac{16.8}{\sqrt{f_{ck}+8}}$$

$\beta(t_0)$ = factor to allow for the effect of concrete age at loading on the notional creep coefficient

$$=\frac{1}{\left(0.1+t_0^{0.20}\right)}$$

Where end results are not sensitive to precise values calculated as given above, the values given in the table below can be considered as final creep coefficient for design for normal weight concrete of grades between M 30 and M 60, subject to condition that the compressive stress does not exceed $0.36 f_{ck}$ at the age of loading, and mean temperature of concrete is between 10°C and 20°C with seasonal variation between -20°C and 40°C. For temperature greater than 40°C the coefficient given may be increased by 10 percent in absence of accurate data.

Age at Loading t_0 (days)	*Creep Coefficient* ϕ_o *(70 yr,* t_0*) of an Ordinary Structural Concrete after 70 Years of Loading*					
	Under Dry Atmospheric Conditions (RH 50 Percent) Notional Size ($2A_c/u$)			Under Humid Atmospheric Conditions (Outdoor) (RH 80 Percent) Notional Size ($2A_c/u$)		
	50 mm	150 mm	600 mm	50 mm	150 mm	600 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	5.8	4.8	3.9	3.8	3.4	3.0
7	4.1	3.3	2.7	2.7	2.4	2.1
28	3.1	2.6	2.1	2.0	1.8	1.6
90	2.5	2.1	1.7	1.6	1.5	1.3
365	1.9	1.6	1.3	1.2	1.1	1.0

5.2.5.2 The development of creep with time may be taken as $\phi(t,t_0)=\beta(t,t_0)\phi_0$

$$\beta(t,t_0)=\left[\frac{t-t_0}{\beta_H+(t-t_0)}\right]^{0.3}$$

where

t = age of concrete in days at the moment considered;

t_0 = age of concrete at loading, in days;

$(t - t_0)$ = duration of loading, in days; and

β_H = a coefficient depending on the relative humidity (RH in percent) and the notional member size (h_0 in mm).

$$= 1.5\left[1+\left(1.2\frac{RH}{RH_0}\right)^{18}\right]h_0+250\le 1\ 500$$

for $f_{ck}\le 45$ MPa

$$= 1.5\left[1+\left(1.2\frac{RH}{RH_0}\right)^{18}\right]h_0+250\alpha_3\le 1500\alpha_3$$

for $f_{ck} > 45$ MPa

where

RH = relative humidity expressed as percent.

RH_0 = 100 (that is, 100 percent relative humidity).

$\alpha_1, \alpha_2, \alpha_3$= coefficients to consider the influence of the concrete strength,

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$$\alpha_1 = \left[\frac{45}{f_{ck}+8}\right]^{0.7}, \alpha_2 = \left[\frac{45}{f_{ck}+8}\right]^{0.2}, \alpha_3 = \left[\frac{45}{f_{ck}+8}\right]^{0.5}$$

5.2.6 *Thermal Expansion*

The coefficient of thermal expansion depends on nature of cement, the aggregate, the cement content, the relative humidity and the size of sections. The values of coefficient of thermal expansion for concrete with different aggregates may be taken as given below:

Type of Aggregate	*Coefficient of Thermal Expansion for Concrete / °C*
Quartzite	1.2 to 1.3 × 10^{-5}
Sandstone	0.9 to 1.2 × 10^{-5}
Granite	0.7 to 0.95 × 10^{-5}
Basalt	0.8 to 0.95 × 10^{-5}
Limestone	0.6 to 0.9 × 10^{-5}

6 WORKABILITY OF CONCRETE

The concrete mix proportions chosen should be such that the concrete is of adequate workability for the placing conditions of the concrete and can properly be compacted with the means available. Suggested ranges of values of workability of concrete are given in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

7 DURABILITY OF CONCRETE

7.1 General

A durable concrete is one that meets predetermined expectations under the working environment (exposure) conditions during its service life. The materials and mix proportions specified and used should be such as to maintain its integrity and, if applicable, to protect embedded metal from corrosion.

7.1.1 One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances. Impermeability is governed by the constituents and workmanship used in making the concrete. With normal-weight aggregates a suitably low permeability is achieved by having an adequate cement content, sufficiently low free water/cement ratio, by ensuring complete compaction of the concrete, and by adequate curing.

The factors influencing durability include,

a) the environment;
b) the cover to embedded steel;
c) the type and quality of constituent materials;
d) the cement content and water-cement ratio of the concrete;
e) workmanship, to obtain full compaction and efficient curing; and
f) the shape and size of the member.

The degree of exposure anticipated for the concrete during its service life together with other relevant factors relating to mix composition, workmanship, design and detailing should be considered. The concrete mix to provide adequate durability under these conditions should be chosen taking account of the accuracy of current testing regimes for control and compliance as described in this Subsection.

7.2 Requirements for Durability

7.2.1 *Shape and Size* of *Member*

The shape or design details of exposed structures should be such as to promote good drainage of water and to avoid standing pools and rundown of water. Care should also be taken to minimize any cracks that may collect or transmit water. Adequate curing is essential to avoid the harmful effects of early loss of moisture. Member profiles and their intersections with other members shall be designed and detailed in a way to ensure easy flow of concrete and proper compaction during concreting.

Concrete is more vulnerable to deterioration due to chemical or climatic attack when it is in thin sections, in sections under hydrostatic pressure from one side only, in partially immersed sections and at corners and edges of elements. The life of the structure can be lengthened by providing extra cover to steel, by chamfering the corners or by using circular cross-sections or by using surface coatings which prevent or reduce the ingress of water, carbon dioxide or aggressive chemicals.

7.2.2 *Exposure Conditions*

7.2.2.1 *General environment*

The general environment to which the concrete will be exposed during its working life is classified into five levels of severity, that is, mild, moderate, severe, very severe and extreme as described in Table 2.

7.2.2.2 *Abrasion*

Abrasion of concrete surfaces results from friction, which may cause a grinding action; or by repetitive impact and overloading, which causes local crushing.

Abrasion resistant surfaces primarily involve consideration of surface finishing technique curing regime, aggregate characteristics and cement content. Compressive strength of concrete may also provide a relative indication of resistance.

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Table 2 Environmental Exposure Conditions

(*Clause* 7.2.2.1)

Sl No.	Environment	Exposure Conditions
(1)	(2)	(3)
i)	Mild	Concrete surfaces protected against weather or aggressive conditions, except those situated in coastal areas
ii)	Moderate	Concrete surfaces sheltered from severe rain or freezing whilst wet Concrete exposed to condensation and rain Concrete continuously under water Concrete in contact or buried under non-aggressive soil/ground water Concrete surfaces sheltered from saturated salt air in coastal area
iii)	Severe	Concrete surfaces exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation Concrete completely immersed in sea water Concrete exposed to coastal environment
iv)	Very severe	Concrete surfaces exposed to sea water spray, corrosive fumes or severe freezing conditions whilst wet Concrete in contact with or buried under aggressive sub-soil/ground water
v)	Extreme	Surface of members in tidal zone and splash zone Members in direct contact with liquid/solid aggressive chemicals

Specialist literatures may be referred to for durability requirements of concrete surfaces exposed to abrasive action, for example in case of machinery and metal tyres.

7.2.2.3 *Freezing and thawing*

Where freezing and thawing actions under wet conditions exist, enhanced durability can be obtained by the use of suitable air entraining admixtures. When concrete lower than grade M 50 is used under these conditions, the mean total air content by volume of the fresh concrete at the time of delivery into the construction should be as follows:

Nominal Maximum Aggregate Size mm	*Entrained Air Percentage*
10	7 ± 1
20	5 ± 1
40	4 ± 1

Since air entrainment reduces the strength, suitable adjustments may be made in the mix design for achieving required strength.

7.2.2.4 *Exposure to sulphate attack*

Table 3 gives recommendations for the type of cement, maximum free water/cement ratio and minimum cement content, which are required at different sulphate concentrations in near actual ground water having *p*H of 6 to 9.

For the very high sulphate concentrations in Class 5 conditions, some form of lining such as polyethylene or polychloroprene sheet; or surface coating based on asphalt, chlorinated rubber, epoxy, or polyurethane materials should also be used to prevent access by the sulphate solution.

7.2.3 *Requirement of Concrete Cover*

7.2.3.1 The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality concrete.

7.2.3.2 The nominal cover to the reinforcement shall be provided as per **25.4** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

7.2.4 *Concrete Mix Proportions*

7.2.4.1 *General*

The free water cement ratio is an important factor in governing the durability of concrete and should always be the lowest value. Appropriate value for minimum cement content and the maximum free water-cement ratio are given in Table 4 for different exposure conditions. The minimum cement content and maximum water-cement ratio apply to 20 mm nominal maximum size aggregate. For other sizes of aggregate they should be changed as given in Table 5.

7.2.4.2 *Maximum cement content*

Cement content in excess of 450 kg/m^3 should not be used unless special consideration has been given in design to the increased risk of cracking due to drying shrinkage in thin sections, or to thermal stresses in thicker sections.

7.2.5 *Mix Constituents*

7.2.5.1 *General*

For concrete to be durable, careful selection of the mix and materials is necessary, so that deleterious constituents do not exceed the limits.

7.2.5.2 *Chlorides in concrete*

Whenever there is chloride in concrete there is an increased risk of corrosion of embedded steel. The higher the chloride content, or if subsequently exposed to warm moist conditions, the greater the risk of corrosion. All constituents may contain chlorides and concrete may be contaminated by chlorides from the external environment. To minimize the chances of deterioration of concrete from harmful chemical salts, the levels of such harmful salts in concrete coming from concrete materials, that is, cement, aggregates, water and admixtures, as well as by diffusion from the environment should be limited. The total amount of

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Table 3 Requirements for Prestressed Concrete Exposed to Sulphate Attack

(*Clauses* 7.2.2.4 *and* 8.1.2)

Sl No.	Class	Concentration of Sulphates, Expressed as SO_3			Type of Cement	Dense, Fully Compacted Concrete, made with 20 mm Nominal Maximum Size Aggregates Complying with the Accepted Standard [6-5B(6)]	
		In Soil		In Ground Water			
		Total SO_3	SO_3 in 2:1 Water: Soil Extract				
		Percent	g/ℓ	g/ℓ		Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1	Traces (<0.2)	Less than 1.0	Less than 0.3	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	280	0.55
ii)	2	0.2 - 0.5	1.0 - 1.9	0.3 - 1.2	Ordinary Portland cement or Portland slag cement or Portland pozzolana cement	330	0.50
					Supersulphated cement or sulphate resisting Portland cement	310	0.50
iii)	3	0.5 - 1.0	1.9 - 3.1	1.2 - 2.5	Supersulphated cement or sulphate resisting Portland cement	330	0.50
					Portland pozzolana cement or Portland slag cement	350	0.45
iv)	4	1.0 - 2.0	3.1 - 5.0	2.5 - 5.0	Supersulphated or sulphate resisting Portland cement	370	0.45
v)	5	More than 2.0	More than 5.0	More than 5.0	Sulphate resisting Portland cement or supersulphated cement with protective coatings	400	0.40

NOTES

1 Cement content given in this table is irrespective of grades of cement. Suitable adjustment may be made in the minimum cement content specified in case of use of aggregate other than 20 mm nominal maximum size.

2 Use of supersulphated cement is generally restricted where the prevailing temperature is above 40 °C.

3 Supersulphated cement gives an acceptable life provided that the concrete is dense and prepared with a water-cement ratio of 0.4 or less, in mineral acids, down to *p*H 3.5.

4 The cement contents given in col 7 of this table are the minimum recommended. For SO_3 contents near the upper limit of any class, cement contents above these minimum are advised.

5 For severe conditions, such as thin sections under hydrostatic pressure on one side only and sections partly immersed, considerations should be given to a further reduction of water-cement ratio.

6 Portland slag cement with slag content more than 50 percent exhibits better sulphate resisting properties.

7 Where chloride is encountered along with sulphates in soil or ground water, ordinary Portland cement with C_3A content from 5 to 8 percent shall be desirable to be used in concrete, instead of sulphate resisting cement.

acid soluble chloride content (as Cl) in the concrete at the time of placing shall be not more than 0.4 kg/m^3 of concrete.

The total acid soluble chloride content should be calculated from the mix proportions and the measured chloride contents of each of the constituents. Wherever possible, the total chloride content of the concrete should be determined.

7.2.5.3 *Sulphates in concrete*

Sulphates are present in most cements and in some aggregates; excessive amounts of water-soluble sulphate from these or other mix constituents can cause expansion and disruption of concrete. To prevent this, the total water-soluble sulphate content of the concrete mix, expressed as SO_3 (where $SO_3 = 0.833\ SO_4$) should not exceed 4 percent by mass of the cement in the mix. The sulphate content should be calculated as the total from the various constituents of the mix.

7.2.5.4 *Alkali-aggregate reaction*

Some aggregates containing particular varieties of silica may be susceptible to attack by alkalis (Na_2O and K_2O) originating from cement or other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally occur only when all the following are present together:

a) A high moisture level, within the concrete;
b) A cement with high alkali content, or another source of alkali; and
c) Aggregate containing an alkali reactive constituent.

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Table 4 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(*Clauses* 7.2.4.1 *and* 8.1.2)

Sl No.	Exposure	Prestressed Concrete		
		Minimum Cement Content	Maximum Free Water Cement Ratio	Minimum Grade of Concrete
		kg/m^3		
(1)	(2)	(3)	(4)	(5)
i)	Mild	300	0.55	M 30
ii)	Moderate	300	0.50	M 30
iii)	Severe	320	0.45	M 30
iv)	Very severe	340	0.45	M 35
v)	Extreme	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades and types of cement and it is inclusive of additions mentioned in **4.2**. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolana as specified in the accepted standard [6-5B(11)] and that of slag as specified in the accepted standard [6-5B(12)] beyond which these additions, though permitted, shall not be considered for these purposes.

2 The minimum cement content, maximum free water-cement ratio and minimum grade of concrete are individually related to exposure.

Table 5 Adjustments to Minimum Cement Contents for Aggregates Other than 20 mm Nominal Maximum Size

(*Clause* 7.2.4.1)

Sl No.	Nominal Maximum Aggregate Size	Adjustments to Minimum Cement Contents in Table 4
	mm	kg/m^3
(1)	(2)	(3)
i)	10	+ 40
ii)	20	0
iii)	40	– 30

Where the service records of particular cement/ aggregate combination are well established, and do not include any instances of cracking due to alkali-aggregate reaction, no further precautions should be necessary. When the materials are unfamiliar, precautions should take one or more of the following forms:

a) Use of non-reactive aggregate from alternate sources.

b) Use of low alkali ordinary Portland cement having total alkali content not more than 0.6 percent [as Na_2O equivalent (expressed as $Na_2O + 0.678\ K_2O$)]. Further advantage can be obtained by use of fly ash conforming to the accepted standard [6-5B(13)] or granulated blast furnace slag conforming to the accepted standard [6-5B(14)] as part replacement of ordinary Portland cement (having total alkali content as Na_2O equivalent not more than 0.6 percent), provided fly ash content is at least 20 percent or slag content is at least 50 percent.

c) Measures to reduce the degree of saturation of the concrete during service such as use of impermeable membranes.

d) Limiting the cement content in the concrete mix and thereby limiting total alkali content in the concrete mix. For more guidance specialist literatures may be referred.

7.2.6 *Concrete in Aggressive Soils and Water*

7.2.6.1 *General*

The destructive action of aggressive waters on concrete is progressive. The rate of deterioration decreases as the concrete is made stronger and more impermeable, and increases as the salt content of the water increases. Where structures are only partially immersed or are in contact with aggressive soils or waters on one side only, evaporation may cause serious concentrations of salts with subsequent deterioration, even where the original salt content of the soil or water is not high.

NOTE — Guidance regarding requirements for concrete exposed to sulphate attack is given in **7.2.2.4**.

7.2.6.2 *Drainage*

At sites where alkali concentrations are high or may become very high, the ground water should be lowered by drainage so that it will not come into direct contact with the concrete.

Additional protection may be obtained by the use of impermeable barriers.

7.2.7 *Compaction, Finishing and Curing*

Adequate compaction without segregation should be ensured by providing suitable workability and by employing appropriate placing and compacting equipment and procedures. Full compaction is particularly important in the vicinity of construction and movement joints and of embedded water bars and reinforcement.

Good finishing practices are essential for durable concrete.

Overworking the surface and the addition of water-cement to aid in finishing should be avoided; the resulting laitance will have impaired strength and durability and will be particularly vulnerable to freezing and thawing under wet conditions.

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It is essential to use proper and adequate curing techniques to reduce the permeability of the concrete and enhance its durability by extending the hydration of the cement, particularly in its surface zone (*see also* provisions on curing under **13**).

8 CONCRETE MIX PROPORTIONING

8.1 Mix Proportion

The mix proportions shall be selected to ensure the workability of the fresh concrete and when concrete is hardened, it shall have the required strength, durability and surface finish.

8.1.1 The determination of the proportions of cement, aggregates and water to attain the required strengths shall be made by designing the concrete mix; such concrete shall be called 'Design mix concrete'.

8.1.2 *Information Required*

In specifying a particular grade of concrete, the following information shall be included:

a) Grade designation,
b) Type of cement,
c) Maximum nominal size of aggregates,
d) Minimum cement content (for design mix concrete),
e) Maximum water-cement ratio,
f) Workability,
g) Exposure conditions as per Tables 3 and 4,
h) Maximum temperature of concrete at the time of placing,
j) Method of placing, and
k) Degree of supervision.

8.1.2.1 In appropriate circumstances, the following additional information may be specified:

a) Type of aggregate,
b) Maximum cement content, and
c) Whether an admixture shall or shall not be used and the type of admixture and the conditions of use.

8.2 Design Mix Concrete

8.2.1 As the guarantor of quality of concrete used in the construction, the constructor shall carry out the mix design and the mix so designed (not the method of design) shall be approved by the employer within the limitations of parameters and other stipulations laid down by this section.

8.2.2 The mix shall be designed to produce the grade of concrete having the required workability and a characteristic strength not less than the appropriate values given in Table 1. The target mean strength of concrete mix should be equal to the characteristic strength plus 1.65 times the standard deviation.

8.2.3 Mix design done earlier not prior to one year may be considered adequate for later work provided there is no change in source and the quality of the materials.

8.2.4 *Standard Deviation*

The standard deviation for each grade of concrete shall be calculated separately.

8.2.4.1 *Standard deviation based on test strength of sample*

a) *Number of test results of samples* — The total number of test strength of samples required to constitute an acceptable record for calculation of standard deviation shall be not less than 30. Attempts should be made to obtain the 30 samples, as early as possible, when a mix is used for the first time.
b) *In case of significant changes in concrete* — When significant changes are made in the production of concrete batches (for example, changes in the materials used, mix design, equipment or technical control), the standard deviation value shall be separately calculated for such batches of concrete.
c) *Standard deviation to be brought up to date* — The calculation of the standard deviation shall be brought up to date after every change of mix design.

8.2.4.2 *Assumed standard deviation*

Where sufficient test results for a particular grade of concrete are not available, the value of standard deviation shall be assumed to be 5.0 N/mm^2 for design of mix in the first instance. As soon as the results of samples are available, actual calculated standard deviation shall be used and the mix designed properly.

9 PRODUCTION OF CONCRETE

9.1 Quality Assurance Measures

9.1.1 In order that the properties of the completed structure be consistent with the requirements and the assumptions made during the planning and the design, adequate quality assurance measures shall be taken. The construction should result in satisfactory strength, serviceability and long term durability so as to lower the overall life-cycle cost. Quality assurance in construction activity relates to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately proper care

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during the use of structure including timely maintenance and repair by the owner.

9.1.2 Quality assurance measures are both technical and organizational. Some common cases should be specified in a general Quality Assurance Plan which shall identify the key elements necessary to provide fitness of the structure and the means by which they are to be provided and measured with the overall purpose to provide confidence that the realized project will work satisfactorily in service fulfilling intended needs. The job of quality control and quality assurance would involve quality audit of both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation, placing, compaction and curing; and the related plant, machinery and equipment; resulting in the output in the form of concrete in place. To ensure proper performance, it is necessary that each step in concreting which will be covered by the next step is inspected as the work proceeds (*see also* **17**).

9.1.3 Each party involved in the realization of a project should establish and implement a Quality Assurance Plan, for its participation in the project. Supplier's and subcontractor's activities shall be covered in the plan. The individual Quality Assurance Plans shall fit into the general Quality Assurance Plan. A Quality Assurance Plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures, and the organization and maintaining adequate documentation of the building process and its results. Such documentation should generally include,

a) test reports and manufacturer's certificate for materials, concrete mix design details;
b) pour cards for site organization and clearance for concrete placement;
c) record of site inspection of workmanship, field tests;
d) non-conformance reports, change orders;
e) quality control charts; and
f) statistical analysis.

NOTE — Quality control charts are recommended wherever the concrete is in continuous production over considerable period.

9.2 Batching

To avoid confusion and error in batching, consideration should be given to using the smallest practical number of different concrete mixes on any site or in any one plant. In batching concrete, the quantity of both cement and aggregate shall be determined by mass; admixture, if solid, by mass; liquid admixture may however be measured in volume or mass; water shall be weighed or measured by volume in a calibrated tank {*see also* accepted standard [6-5B(15)]}.

For large and medium project sites the concrete shall be sourced from ready-mixed concrete plants or from on site or off site batching and mixing plants {*see* good practice [6-5B(16)]}.

9.2.1 The grading of aggregate should be controlled by obtaining the coarse aggregate in different sizes and blending them in the right proportions, the different sizes being stocked in separate stock-piles. The material should be stock-piled for several hours preferably a day before use. The grading of coarse and fine aggregate should be checked as frequently as possible, the frequency for a given job being determined by the engineer-in-charge to ensure that the specified grading is maintained.

9.2.2 The accuracy of the measuring equipment shall be within ±2 percent of the quantity of cement being measured and within ±3 percent of the quantity of aggregate, admixtures and water being measured.

9.2.3 Proportion/type and grading of aggregates shall be made by trial in such a way so as to obtain densest possible concrete.

9.2.4 It is important to maintain the water-cement ratio constant at its correct value. To this end, determination of moisture content in both fine and coarse aggregates shall be made as frequently as possible, the frequency for a given job being determined by the engineer-in-charge according to weather conditions. The amount of the added water shall be adjusted to compensate for any observed variations in the moisture contents. For the determination of moisture content in the aggregates, accepted standard [6-5B(17)] may be referred to. To allow for the variation in mass of aggregate due to variation in their moisture content, suitable adjustments in the masses of aggregates shall also be made.

9.2.5 No substitutions in materials used on the work or alterations in the established proportions, except as permitted in **9.2.4** shall be made without additional tests to show that the quality and strength of concrete are satisfactory.

9.3 Mixing

Concrete shall be mixed in a mechanical mixer {*see also* accepted standards [6-5B(18)]}. The mixers shall be fitted with water measuring (metering) devices. The mixing shall be continued until there is a uniform distribution of the materials and the mass is uniform in colour and consistency. If there is segregation after unloading from the mixer, the concrete should be remixed.

9.3.1 As a guidance, the mixing time shall be at least 2 min for conventional free fall mixers. For other types of more efficient mixers, manufacturers' recommendations shall be followed.

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9.3.2 Workability should be checked at frequent intervals {*see* accepted standard [6-5B(19)]}.

9.3.3 Dosages of retarders, plasticizers and superplasticizers shall be restricted to 0.5, 1.0 and 2.0 percent respectively by mass of cementitious materials and unless a higher value is agreed upon between the manufacturer and the constructor based on performance test.

10 FORMWORK

10.1 The provisions of **10** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall generally apply. In addition, **10.1.1** shall also apply.

10.1.1 Moulds for pre-tension work shall be sufficiently strong and rigid to withstand, without distortion, the effects of placing and compacting concrete as well as those of prestressing in the case of manufacture by the individual mould process where the prestressing tendon is supported by the mould before transfer.

11 ASSEMBLY OF PRESTRESSING AND REINFORCING STEEL

11.1 Prestressing Steel

11.1.1 *Straightness*

11.1.1.1 The wire or strand, as supplied, shall be self-straightening when uncoiled.

11.1.1.2 In the case of high tensile alloy steel bars, any straightening shall be carried out by mechanical means. Bars shall not be bent when their temperature is less than 10°C.

11.1.1.3 In no case heat shall be applied to facilitate straightening or bending of prestressing steel.

11.1.2 *Arrangement and Positioning*

11.1.2.1 All prestressing steel shall be carefully and accurately located in the exact positions shown in the design drawings. The permissible tolerance in the location of the prestressing tendon shall be ±5 mm. Curves or bends in prestressing tendon required by the designer shall be gradual and the prestressing tendon shall not be forced around sharp bends exceeding 1 in 6 both in plan and elevation or be formed in any manner which is likely to set up undesirable secondary stresses. The minimum radius of curvature for curved cables shall be specified to ensure that bursting of side cover both perpendicular to the plane of curvature and in the plane of the ducts do not take place.

11.1.2.2 The relative position of prestressing steel in a cable shall be maintained by suitable means such as sufficiently rigid and adequately distributed spacers.

11.1.2.3 The internal cross-sectional area of duct shall generally be 2.5 to 3 times the nominal area of prestressing tendons to ensure free flow of grout.

11.1.2.4 The method of fixing and supporting the steel in the mould or the formwork shall be such that it is not displaced during the placing or compaction of the concrete or during tensioning of the steel.

11.1.2.5 The type of fixtures used for positioning the steel shall be such that it does not give rise to friction greater than that assumed in the design.

11.1.3 *Jointing*

11.1.3.1 Coupling units and other similar fixtures used in conjunction with the prestressing steel shall have an ultimate tensile strength of not less than the individual strengths of the wires or bars being joined.

11.1.3.2 High tensile wire other than hard-drawn wire may be joined together by suitable means provided the strength of such joints is not less than the individual strengths of the wires being joined. Hard-drawn wire used in prestressed concrete work shall be continuous over the entire length of the tendon.

11.1.3.3 High tensile steel bars may be joined together by means of couplings, provided the strength of the coupling is such that in a test of destruction, the bar shall fail before the coupling.

11.1.3.4 Welding shall not be permitted in prestressing steel.

11.1.4 *Cutting*

11.1.4.1 All cutting to length and trimming of the ends of wires or strands shall be done by suitable mechanical cutters. Under factory conditions flame cutting may be permitted.

11.1.4.2 Bars shall preferably be ordered to the exact length required. Any trimming required shall be done only after the bar has been tensioned and the grout has set; it shall then be carried out in accordance with **11.1.4.1.**

11.1.5 *Protection of Prestressing Steel, Sheathing and Anchorages*

In all constructions of the post-tensioned type whether prestressing is subsequently bonded or not bonded with concrete, the prestressing steel, sheathing material forming ducts in concrete and anchorages shall be given adequate protection against corrosion at all stages of construction and during service life.

11.1.5.1 *Construction with unbonded steel embedded in concrete*

For protection of sheathing material forming ducts, the durability requirements shall be followed. Furthermore,

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the internal surface of duct, prestressing steel and anchorage shall be protected by following methods in suitable combination depending upon severity of environment and extent of layers of protection considered desirable:

a) Coating of steel and duct by reactive metals like zinc (Zn) or zinc plus aluminium (Zn + Al) preferably applied by hot dipping method.
b) Use of non-corroding sheath material like high density polyethylene and fibre reinforced plastic.
c) Coating of steel by non-reactive materials like epoxy (factory applied).
d) Covering individual uncoated steel or coated steel strands/wires in sheaths formed by extrusion process in factory using non-corroding material like HDPE or similar. The space between sheathing and duct can be filled with corrosion inhibiting materials like grease and wax.
e) In case of large size prestressing units use of protective and replaceable corrosion inhibition material for grouting the ducts such as grease, wax polyurethane foam, wherein any corrosive trace elements are controlled to remain within acceptable limits. Systems for checking the efficacy of the method during service life and provisions for replacing/ making up loss of filler material shall be incorporated.
f) External parts of anchorages and projecting cables should be covered by suitable casing and protected by suitable material and method.

For selection of appropriate method, material specifications and installation process, etc, specialist literature should be referred to.

11.1.5.2 *Construction with unbonded steel and anchorages not embedded in concrete (external prestressing elements)*

The methods given in **11.1.5.1** shall be applicable for this type of construction also. In addition, the material, strength and environmental resistance of the ducts forming external enclosure shall provide adequate mechanical strength and stability against environmental attack, including solar radiation. The ducts should be strong enough to resist pressure from the grouting operations.

11.1.5.3 *Construction with post-tensioned bonded prestressing steel*

Internal prestressing sheathing material as well as prestressing steel is protected by dense alkaline concrete cover, which shall be of quality and thickness as specified. The steel inside ducts is best protected in long terms by cement grouts which are properly executed following recommendations given in **12**.

The protection by grouting can be further augmented by use of methods given below:

a) Use of coated steel using Zn, Zn + Al or epoxy.
b) Use of non-corroding impervious sheathing material like HDPE is beneficial. However, bond between sheathing and concrete and sheathing and grout shall be adequate as needed by design. This method is particularly suitable in presence of migrating water or variable drying/wetting condition of concrete of severe external penetration of corrosive agents.

External parts of anchorages and projecting cables should be covered by suitable casing and protected by suitable material and method.

11.1.5.4 *Protection during construction period*

a) The prestressing steel, sheathing and anchorages shall be manufactured, transported and stored at site in such a way as to provide them with adequate corrosion protection. Use of proper packaging and provision of externally applied passivating agents, oil films, etc, which is carried over in factory itself is recommended.
b) If prestressing steel/metallic sheathing material is left unprotected at site or embedded in concrete during construction period longer than two weeks, it shall be protected by flushing with oil/water mixture (for example cutting oil) with periodic re-flushing at not more than three months interval.
c) After stressing, the sheaths/steel shall be provided with permanent protection as soon as possible, preferably within one week. While providing protection by pressure grouting of cement care should be taken that the neighbouring cables are not penetrated by grout. In case of doubt such cables shall be grouted in immediate sequence before the earlier grout could have set. If the earlier stressed cables are not grouted to avoid this problem, they should be protected by periodic flushing by oil/water mixture as given in (b).

11.1.6 *Nominal Cover to Prestressing Steel*

11.1.6.1 *Nominal cover*

Nominal cover is the design depth of concrete cover. It is the dimension used in design and indicated in drawings.

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11.1.6.2 *Nominal cover to meet the durability requirements*

11.1.6.2.1 Minimum values of the nominal cover which should be provided in post-tensioned work, where cables and large-sized bars are used, the minimum clear cover from sheathing/duct shall be at least 75 mm.

11.1.6.2.2 In pre-tensioned work, the cover of concrete measured from the outside of the prestressing tendon shall be as per Table 16 of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

11.1.6.3 *Nominal cover to meet specified period of fire resistance*

Minimum values of nominal cover of normal-weight aggregate concrete to be provided to all reinforcement including links to meet specified period of fire resistance shall be as given in Table 16A of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

11.1.7 *Spacing*

11.1.7.1 In the case of single wires used in pre-tension system, the minimum clear spacing shall not be less than the greater of the following:

a) 3 times diameter of wire, and
b) Nominal maximum size of aggregate plus 5 mm.

11.1.7.2 In the case of cables or large bars, the minimum clear spacing (measured between sheathings/ ducts, wherever used) shall not be less than the largest of the following:

a) 40 mm,
b) Maximum size of duct or bar, and
c) Nominal maximum size of aggregate plus 5 mm.

11.1.8 *Grouped Cables*

11.1.8.1 Cables or ducts may be grouped together vertically in groups of not more than two.

11.1.8.2 The minimum clear horizontal spacing between groups of cables or ducts of grouped cables shall be greater of the following:

a) 40 mm, and
b) Nominal maximum size of aggregate plus 5 mm

The vertical distance between groups shall not be less than 50 mm. In case there is possibility of obstruction of flow of concrete or in case of severe exposure condition, horizontal grouping should be avoided.

11.2 Sheathing Ducts

The sheathing ducts shall be either of mild steel as per **A-1** or HDPE as per **A-2**. They shall be in as long lengths as practical from handling and transportation considerations without getting damaged. They shall conform to the requirements specified in **A-3** and **A-4** and a test certificate shall be furnished by the manufacturer. The tests specified in **A-4** are to be performed as part of additional acceptance tests for prestressing systems employing corrugated HDPE sheathing ducts and are not meant for routine site testing purposes.

11.3 Untensioned Steel

11.3.1 Provisions for assembly of reinforcement given in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply.

11.3.2 The requirements of cover and spacing between bars shall conform to Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

12 PRESTRESSING

12.1 Prestressing Equipment

12.1.1 *Tensioning Equipment*

12.1.1.1 The requirements of **12.1.1** shall apply to both the pre-tensioned and the post-tensioned methods of prestressing concrete except where specifically mentioned otherwise.

12.1.1.2 Prestressing steel may be tensioned by means of hydraulic or mechanical jacks.

The tension equipment shall be such that it facilitates measurement and control of application of force.

The tensioning equipment should be independently supported so that it does not induce any undesirable secondary stresses.

12.1.1.3 The anchorage provided for the temporary gripping of tendons on the tensioning equipment shall be secure and such as not to damage the tendon.

12.1.1.4 Devices attached to the tensioning equipment for measuring the applied force shall be such that they do not introduce errors exceeding 5 percent.

12.1.2 *Temporary Gripping Device*

Prestressing tendons may be gripped by wedges, yokes, double cones or any other approved type of gripping devices. The prestressing wires may be gripped singly or in groups. Gripping devices shall be such that in a tensile test, the wire or wires fixed by them would break before failure of the grip itself.

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12.1.3 *Releasing Device*

The releasing device shall be so designed that during the period between the tensioning and release, the tension in the prestressing elements is fully maintained by positive means, such as external anchorages. The device shall enable the transfer of prestress to be carried out gradually so as to avoid large difference of tension between wires in a tendon, severe eccentricities of prestress or the sudden application of stress to the concrete.

12.1.4 *Anchorage Device*

12.1.4.1 The anchorage device may be patented or otherwise, which complies with the requirements laid down under **12.1.4.2** to **12.1.4.5**.

12.1.4.2 The anchoring device shall be strong enough to resist in all respects a force equal to at least the breaking strength of the prestressing tendon it anchors.

12.1.4.3 The anchorage shall transfer effectively and distribute, as evenly as possible, the entire force from the prestressing tendon to the concrete without inducing undesirable secondary or local stresses.

12.1.4.4 The anchorage shall be safe and secure against both dynamic and static loads as well as against impact (*see* Annex B).

12.1.4.5 The anchorage shall have provision for the introduction of a suitable protective medium, such as cement grout, for the protection of the prestressing steel unless alternative arrangements are made.

12.2 Procedure for Tensioning and Transfer

12.2.1 *Stressing*

12.2.1.1 The tensioning of prestressing tendons shall be carried out in a manner that will induce a smooth and even rate of increase of stress in the tendons. The prestressing shall be controlled by measuring both the force applied to the tendon and the elongation of the tendon.

Stressing schedule shall be incorporated in the design, which may include the following:

a) Details of equipment and procedure for applying prestress, specification of one end or simultaneous stressing from both ends of tendons, stressing in single stage or multiple stages, re-stressing for adjustment of force or for monitoring of force, if required, etc.

b) Calculated amount of tensile force and corresponding expected elongation of each tendon when methods described in (a) are followed.

c) Minimum requirements of strength of concrete at transfer (*see also* **15.2**), stressing sequence with respect to age of concrete or stage of construction, requirements with respect to grouting operations of neighbouring tendons.

d) Method(s) of measuring force and elongation.

e) Tolerances/limits of variation from design requirements stated in (a) and (b) beyond which reference should be made to the designer. In the absence of any specified provision provided by the designer method described in **12.2.1.3** may be adopted for acceptance.

f) Assumptions made in calculation of force-elongation relationship should be given. These include effective '*E*' value of tendon, cross sectional area of tendon, coefficient of friction and wobble factor between tendon and duct, assumed slip in anchoring devices if any, efficiency of prestressing jacks where force is measured indirectly by pressure gauges on jacks, corrections to elongation due to changes in gripping length beyond anchorages during stressing and any other relevant information.

12.2.1.2 Any slack in the prestressing tendon shall first be taken up by applying a small initial tension. The initial tension required to remove slackness shall be taken as the starting point for measuring elongation. Further increase of tension shall be carried out in suitable steps and corresponding elongations noted. The 'force-elongation' relationship shall be recorded in tabular and/or graphical form. The magnitude of initial effective elongation corresponding to initial tension applied to remove slackness shall be obtained from the recorded and linearized portion of measured tension-elongation relationship and added to the measured elongation to give the total elongation. Alternatively, the same correction can be carried out graphically as shown in Fig. 1.

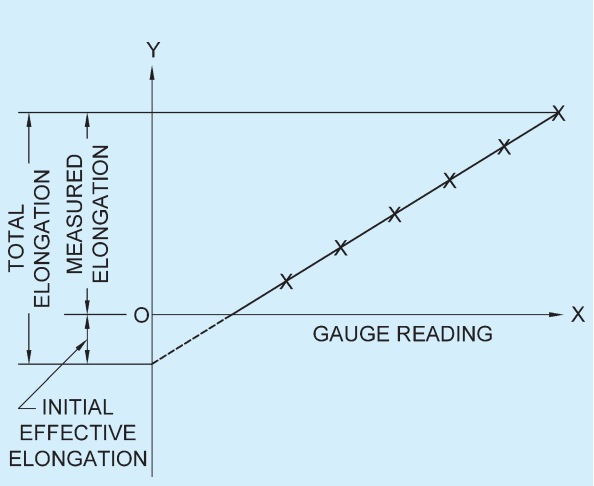


FIG. 1 DETERMINATION OF ACTUAL ELONGATION

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12.2.1.3 In practice, the force and elongation of tendon may not exactly match with the expected values given in stressing schedule. In such cases either the force (or the elongation) will be achieved first and the other value lag behind. In such cases the force (or elongation) shall be further increased, but not exceeding 5 percent of the design value till the elongation (or force), which had lagged behind reaches the design value. If, even after reaching 5 percent extra value of the force (or elongation), the other lagged quantity does not reach the design value, reference should be made to the designer for review and corrective action.

12.2.1.4 When two or more prestressing wires or strands are to be tensioned simultaneously by the same tensioning apparatus, care shall be taken to ensure that all such tendons are of the same length from grip to grip.

12.2.1.5 The placement of tendons and the order of stressing and grouting shall be so arranged that the prestressing steel, when tensioned and grouted, does not adversely affect the adjoining ducts.

12.2.2 *Measurement of Prestressing Force*

12.2.2.1 The force induced in the prestressing tendon shall be determined by means of gauges attached to the tensioning apparatus as well as by measuring the extension of the steel. It is essential that both methods are used jointly so that the inaccuracies to which each is singly susceptible are minimized. Due allowance shall be made for the frictional losses in the tensioning apparatus.

12.2.2.2 All dynamometers and pressure gauges including master gauge shall be calibrated by an approved laboratory immediately prior to use and then at intervals not exceeding 3 months and true force determined from the calibration curve. Further, whenever there is a breakage of tendons, the calibration shall be carried out before reuse of the gauges. The pressure gauges shall be accurate within 2 percent of their full capacity.

12.2.2.3 In measuring the extension of prestressing steel, any slip which may occur in the gripping device shall be taken into consideration.

12.2.3 *Breakage of Wires*

The breakage of wires in anyone prestressed concrete member shall not exceed 2.5 percent during tensioning. If the breakages are more than 2.5 percent, it shall be examined and corrective actions taken. Wire breakages after anchorage, irrespective of percentage, shall not be condoned without special investigations.

12.2.4 *Transfer of Prestressing Force*

12.2.4.1 The transfer of the prestress shall be carried out gradually so as to avoid large differences of tension between wires in a tendon, severe eccentricities of prestressing force and the sudden application of stress to the concrete.

12.2.4.2 Where the total prestressing force in a member is built up by successive transfers to the force of a number of individual tendons on to the concrete, account shall be taken of the effect of the successive prestressing.

12.2.4.3 In the long line and similar methods of prestressing, when the transfer is made on several moulds at a time, care shall be taken to ensure that the prestressing force is evenly applied on all the moulds, and that the transfer of prestress to the concrete is uniform along the entire length of the tension line.

12.3 Grouting

The purpose of grouting is to provide permanent protection to the post-tensioned steel against corrosion and to develop bond between the prestressing steel and the surrounding structural concrete. The grout ensures encasement of steel in an alkaline environment for corrosion protection and by filling the duct space, it prevents water collection and freezing.

12.3.1 *Materials*

12.3.1.1 *Water*

Only clean potable water free from impurities conforming to **4.4** shall be permitted. No sea or creek water is to be permitted.

12.3.1.2 *Cement*

Cement used for preparation of grout shall be in accordance with **4.1**.

12.3.1.3 *Sand*

It is not recommended to use sand for grouting of prestressing tendons. In case the internal diameter of the ducts exceeds 150 mm, use of sand may be considered. Sand, if used, shall conform to the accepted standard [6-5B(6)] and shall pass through IS Sieve No. 150. The mass of sand in the grout shall not be more than 10 percent of the mass of cement, unless proper workability can be ensured by addition of suitable plasticizers.

12.3.1.4 *Chemical admixtures*

Chemical admixtures conforming to the accepted standard [6-5B(20)] may be used if tests have shown that their use improves the properties of grout, that is, increasing fluidity, reducing bleeding, entraining air or expanding the grout. Admixtures shall not contain chlorides, nitrates, sulphides, sulphites or any other products which are likely to damage the steel or grout.

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When an expanding agent is used, the total unrestrained expansion shall not exceed 10 percent. Aluminium powder as an expanding agent is not recommended for grouting because its long term effects are not free from doubt.

12.3.1.5 *Sheathing*

For requirements of sheathing, **11.2** shall be referred.

12.3.1.6 *Grout openings or vents*

a) All ducts should have grout opening at both ends. For this purpose special openings should be provided where such openings are not available at end anchorages. For draped (curved) cables crown points should have a grout vent. For draped cables longer than 50 m grout vents or drain holes may be provided at or near the lowest points. It is a good practice to provide additional air vents at suitable intervals. All grout openings or vents should include provisions for preventing grout leakage.
b) Standard details of fixing couplers, inlets, outlets and air vents to the duct/anchorage shall be followed as recommended by the supplier of the system of prestressing.

Ducts should be securely fastened at close intervals. All unintended holes or openings in the duct shall be repaired prior to concrete placing. The joints of the couplers and the sheathing should be made water proof by use of tape or similar suitable system capable of giving leak proof joints. Grout openings and vents shall be securely anchored to the duct and to either the forms or to reinforcing steel to prevent displacement during concreting operations due to weight, buoyancy and vibrations.

Ducts require very careful handling as, being of thin metal, they are susceptible to leakage due to corrosion in transit or storage, by tearing ripping in handling particularly when placed adjoining to reinforcing steel, by pulling apart of joints while inserting tendons prior to concreting, or by accidental puncturing while drilling for form ties/inserts or by sparks from welding being done close by. Care shall be taken to avoid any damage by rough use of internal vibrator. Such local damage shall be repaired using tape to make it water tight to prevent ingress of slurry from the fresh concrete.

12.3.2 *Equipment*

12.3.2.1 *Grout colloidal mixer*

It is essential that the grout is maintained in a homogenous state and of uniform consistency by use of suitable agitator so that there is no separation of cement during entire grouting process. It is, therefore necessary that the grout be continuously mixed in a colloidal mixer with a minimum speed of 1 000 rpm and travel of discharge not exceeding 15 m/s.

12.3.2.2 *Grout pump*

The pump should be positive displacement type and should be capable of injecting the grout in a continuous operation and not by way of pulses. The grout pump shall be fitted with a pressure gauge to enable pressure of injection to be controlled. The minimum pressure at which grout should be pumped shall be 0.3 MPa and the grout pump shall have a relief arrangement for bypass of the grout in case of built up of pressure beyond 1 MPa. The capacity of the grout pump should be such as to achieve a forward speed of grout of around 5 to 10 m/min. The slower rates are preferable as they reduce the possibility of occurrence of voids. If the capacity of the pump is large, it is usual to grout two or more cables simultaneously through a common manifold.

Use of hand pumps for grouting is not recommended. Use of compressed air operated equipment for injection is prohibited as it is likely that there will be some air entrapped in grout.

12.3.2.3 *Water pump*

Before commencement of grouting, a stand by direct feed high pressure water pump should be available at site for an emergency.

In case of any problem in grouting the ducts, such pump shall immediately be connected to the duct and all grout flushed by use of high pressure water flushing. It is, therefore, necessary to have adequate storage of clean potable water for operation of the water pump for such emergencies.

12.3.2.4 *Grout screen*

The grouting equipment should contain a screen having a mesh size of IS Sieve No. 106 (IS Sieve No. 150, if sand is used). Prior to introduction into the grout pump, the grout should be passed through such screen. This screen should be easily accessible for inspection and cleaning.

12.3.2.5 *Connections and air vents*

Standard details of fixing inlets, outlets, and air vents to the sheathing and/or anchorage should be followed as recommended by specialist supplier of the system of prestressing. In general, all connections are to be of the 'Quick couple' type and at change of diameters suitable reducers are to be provided.

12.3.3 *Properties of the Grout*

Water-cement ratio should be as low as possible, consistent with workability. This ratio should not normally exceed 0.45.

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The temperature of the grout after accounting for the ambient temperature of the structure shall not exceed 25°C.

Before grouting, the properties of the grout mix should be tested in a laboratory depending on the facilities available. Tests should be conducted for each job periodically. The recommended test is described below.

The compressive strength of 100 mm cubes of the grout shall be not less than 27 MPa at 28 days. Cubes shall be cured in a moist atmosphere for the first 24 h and subsequently in water. These tests shall be conducted in advance to ascertain the suitability of the grout mix.

Chlorides from all sources, that is, cement, water, sand, fillers and admixture should not exceed 0.1 percent by mass of the cement.

12.3.4 *Mixing of Grout*

Proportions of materials should be based on field trials made on the grout before commencement of grouting, but subject to the limits specified above. The materials should be measured by weight.

Water should be added to the mixer first, following by Portland cement and sand, if used. Admixture, if any, may be added as recommended by the manufacturer.

Mixing time depends upon the type of the mixer but will normally be between 2 and 3 min. However, mixing should be for such a duration as to obtain uniform and thoroughly blended grout, without excessive temperature increase or loss of expansive properties of the admixtures. The grout should be continuously agitated until it is injected.

Once mixed, no water shall be added to the grout to increase its fluidity.

Hand mixing is not permitted.

12.4 Grouting Operations

12.4.1 *General*

a) Grouting shall be carried out as early as possible but not later than 2 weeks of stressing a tendon. Whenever this stipulation cannot be complied with for unavoidable reasons, adequate temporary protection of the steel against corrosion by methods or products which will not impair the ultimate adherence of the injected grout should be ensured till grouting. The sealing of the anchorage ends after concreting is considered to be a good practice to prevent ingress of water. For structures in aggressive environment, sealing of the anchorage ends is mandatory.

b) Any traces of oil if applied to steel for preventing corrosion should be removed before grouting operation.

c) Ducts shall be flushed with water for cleaning as well as for wetting the surfaces of the duct walls. Water used for flushing should be of same quality as used for grouting. It may, however, contain about 1 percent of slaked lime or quick lime. All water should be drained through the lowest drain pipe or by blowing compressed air through the duct.

d) The water in the duct should be blown out with oil free compressed air.

Blowing out water from duct for cables longer than 50 m draped up at both ends by compressed air is not effective, outlet/vent provided at or near the lowest point shall be used to drain out water from duct.

e) The connection between the nozzle of the injection pipe and duct should be such that air cannot be sucked in.

f) All outlet points including vent openings should be kept open prior to commencement of injection grout.

g) Before grouting, all air in the pump and hose should be expelled. The suction circuit of the pump should be air-tight.

12.4.2 *Injection of Grout*

a) After mixing, the grout shall be kept in continuous movement.

b) Injection of grout be continuous and should not be interrupted.

c) For vertical cable or cables inclined more than 60° to the horizontal injection shall be effected from the lowest anchorage or vent of the duct.

d) The method of injection shall ensure complete filling of the ducts. To verify this, it is advisable to compare the volume of the space to be filled by the injected grout with the quantity or grout actually injected.

e) Grouting should be commenced initially with a low pressure of injection of up to 0.3 MPa increasing it until the grout comes out at the other end. The grout may be allowed to flow freely from the other end until the consistency of the grout at this end is the same as that of the grout at the injection end. When the grout flows at the other end, it should be closed off and buildup of pressure commenced. Full injection pressure of about 0.5 MPa shall be maintained for at least 1 min before closing the injection pipe. It is a recommended practice to provide a stand pipe at the highest point of the tendon profile to hold all water displaced by sedimentation or bleeding. If

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there is a buildup of pressure much in excess of 1 MPa without flow of grout coming at the other end, the grouting operation shall be discontinued and the entire duct flushed with high pressure water. Also, the bypass system indicated in **12.3.2.2** is essential for further safety.

f) In the case of cables draped downwards for example, in cantilever construction simultaneous injection from both ends may be adopted (*see* Fig. 2).

g) Grout not used within 30 min of mixing should be rejected.

h) Disconnection is facilitated if a short length of flexible tube connects the duct and injection pipe. This may be squeezed and cut off after the grout has hardened.

12.4.3 *Precautions and Recommendations for Effective Grouting*

a) In cold and frosty weather, injection should be postponed unless special precautions are taken. If frost is likely to occur within 48 h after injection, heat shall be applied to the member and maintained for at least 48 h after injection so that the temperature of the grout does not fall below 5°C. Prior to commencement of grout, care shall be taken to ensure that the duct is completely free of frost/ice by flushing with warm water but not with steam.

b) When the ambient temperature during the day is likely to exceed 40°C, grouting should be done in the early morning or late evening hours.

c) When the cables are threaded after concreting, the duct shall be temporarily protected during concreting by inserting a stiff rod or a rigid PVC pipe or any other suitable method.

d) During concreting, care shall be taken to ensure that the sheathing is not damaged.

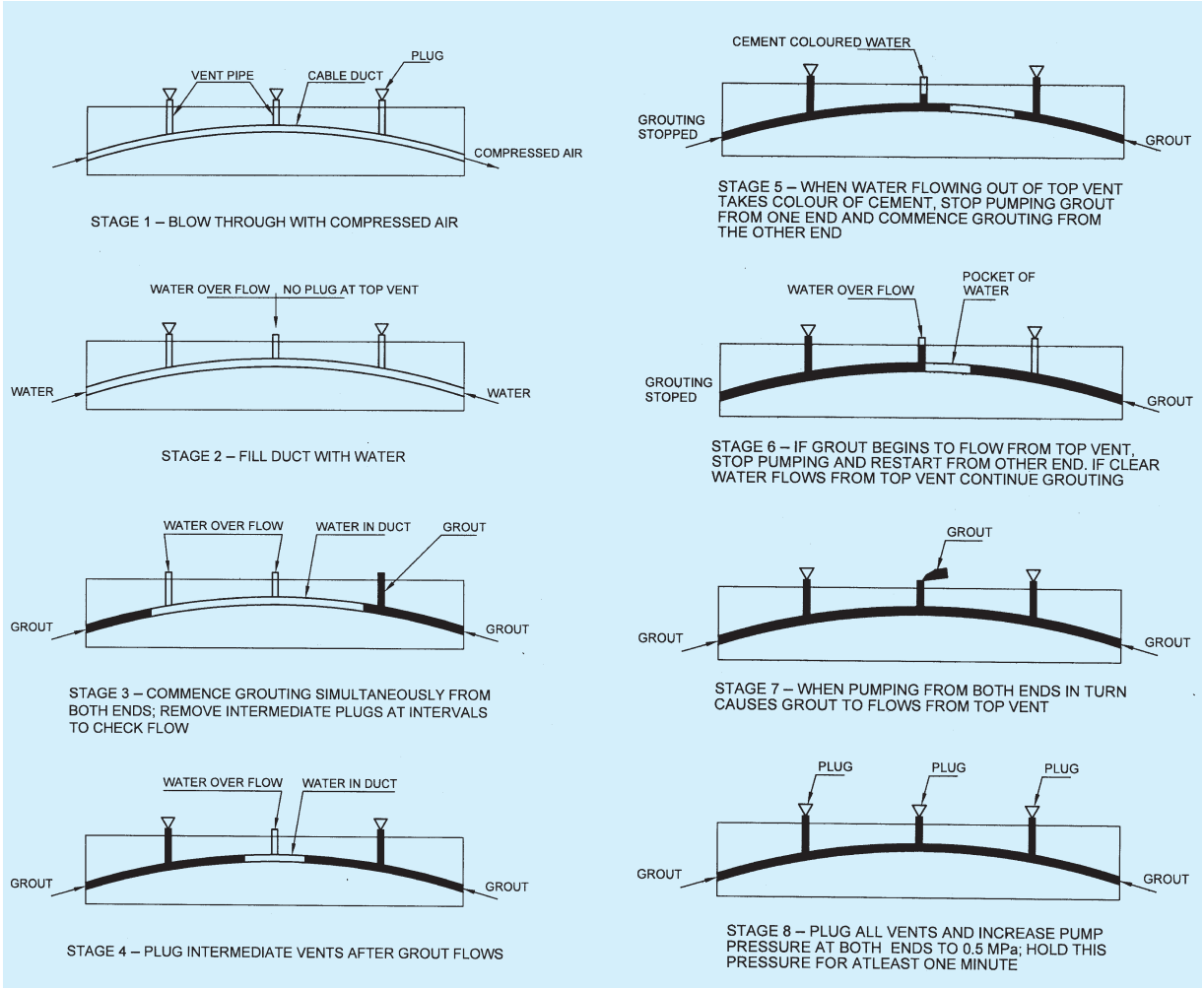


FIG. 2 PROCEDURE FOR GROUTING OF CABLES DRAPED DOWNWARDS

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Needle vibrators shall be used with extreme care by well experienced staff only, to ensure the above requirements.

e) It is a good practice to move the cables in both directions during the concreting operations. This can easily be done by light hammering the ends of the wires/strands during concreting. It is also advisable that 3 h to 4 h after concreting the cable should be moved both ways through a distance of about 200 mm. With such movement, any leakage of mortar which has taken place in spite of all precautions loses bond with the cables, thus reducing the chance of blockages. This operation can also be done by fixing prestressing jacks at one end pulling the entire cable and then repeating the operation by fixing the jack at the other end.

f) The cables to be grouted should be separated by as much distance as possible.

g) In case of stage prestressing, cables tensioned in the first stage should not remain ungrouted till all cables are stressed. It is a good practice, while grouting any duct in stage prestressing, to keep all the remaining ducts filled up with water containing 1 percent lime or by running water through such ducts till the grout has set. After grouting the particular cable, the water in the other cables should be drained and removed with compressed air to prevent corrosion.

h) Care should be taken to avoid leaks from one duct to another at joints of precast members.

j) End faces where anchorages are located are vulnerable points of entry of water. They have to be necessarily protected with an effective barrier. Recesses should be packed with mortar concrete and should preferably be painted with water proof paint.

k) After grouting is completed, the projecting portion of the vents should be cut off and the face protected to prevent corrosion.

13 TRANSPORTING, PLACING, COMPACTING AND CURING

13.1 Provisions given Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply. In addition, the provisions given in **13.1.1** and **13.1.2** shall also apply.

13.1.1 *Jointing of Butted Assemblies*

13.1.2 The joints of butted assemblies shall be made of either cement grout or cement mortar or concrete. Cement grouting shall be used for joints up to 12 mm thick. For joints thicker than 12 mm and up to 75 mm, cement mortar shall be used. The mortar which may be made of one part cement and one-and-a-half parts sand shall be of a dry consistency and shall be packed hard in layers so that it rings true. Where joints exceeding 75 mm are encountered, the joint shall be made up of concrete. Use of epoxy may be permitted with the approval of engineer-in-charge.

13.1.2.1 The stressing operations may be carried out in case of mortar joints immediately after placing the mortar but the stress in the mortar shall not exceed 7.0 N/mm^2. In the case of grouted joints and concrete joints the allowable stress in the first 24 h after placing of the grout or concrete in the joint shall approximate as closely as possible to the strength of the grout or concrete used.

13.1.3 The holes for the prestressing tendons shall be accurately located and shall be in true alignment when the units are put together.

13.1.4 Full tensioning shall not be carried out until the strength of the concrete or mortar in the joint has reached twice the stress at transfer.

14 CONCRETING UNDER SPECIAL CONDITIONS

14.1 Work in Extreme Weather Conditions

During hot or cold weather, the concreting should be done as per the procedure set out in good practices [6-5B(21)].

15 SAMPLING AND STRENGTH TEST OF DESIGN CONCRETE MIX

15.1 The provisions given in **14.1** to **14.4** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply.

Samples from fresh concrete shall be taken as per accepted standard [6-5B(19)] and cubes shall be made, cured and tested at 28 days in accordance with the accepted standard [6-5B(22)].

15.2 In addition to the tests required as per Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code, additional cube tests should be conducted at appropriate intervals to ensure that the concrete strength in the member at transfer conforms to the design requirements.

16 ACCEPTANCE CRITERIA

The provisions of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply.

17 INSPECTION AND TESTING OF STRUCTURES

The provision of Part 6 'Structural Design, Section 5

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Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply, except for the following:

a) The test load specified in **16.6.2** of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall be limited to full dead load of the structure plus design imposed load.

b) For Type 1 and Type 2 structures (*see* **19.3.2**), if within 24 h of removal of the imposed load, the structure does not recover at least 85 percent of the deflection under imposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 90 percent, the structure shall be deemed to be unacceptable.

c) For Type 3 structures (*see* **19.3.2**), if within 24 h of the imposed load, the structure does not recover at least 75 percent of the deflection under imposed load, the test may be repeated after a lapse of 72 h. If the recovery is less than 80 percent, the structure shall be deemed to be unacceptable.

SECTION 5B (C) GENERAL DESIGN REQUIREMENTS

18 GENERAL DESIGN REQUIREMENTS

18.1 General

The general design requirements for design of prestressed concrete structures shall be as per **17** to **23** of Subsection 5A(C) of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code except as modified and supplemented in **18.2** to **18.6.5.**

18.2 Effects of Prestress

The effects of prestress shall also be taken into account in assessing loads and forces.

18.3 Deductions for Prestressing Tendons

The deductions for prestressing tendons as in **18.3.1** shall be considered for the determination of area, centroid and moment of inertia of the cross-section.

18.3.1 In calculating area, centroid and moment of inertia of a cross-section, deduction (or addition in case of transformed area of tendons) for prestressing tendons shall be made as follows:

a) In the case of pre-tensioned members, where the prestressing tendons are single wires distributed on the cross-section or strands of wires of relatively small cross-sectional area, allowance for the prestressing tendons need not be made. Where allowance is made, it shall be on the basis of (m-1) times the area of the prestressing tendons, m being the modular ratio.

b) In the case of post-tensioned members, deductions shall invariably be made for prestressing tendons, cable ducts or sheaths and such other openings whether they are formed longitudinally or transversally. These deductions need not, however, be made for determining the effect of loads applied after the ducts, sheaths or openings have been grouted or filled with concrete. Where such deductions are not made, a transformed area equivalent to (m–1) times the area of the prestressing tendon shall be taken in calculation, m being the modular ratio.

NOTE — m shall be calculated as E_s/E_c; for values of E_s and E_c, *see* **4.6.1.2.1** and **5.2.3.1**, respectively. Wherever necessary, creep effects shall also be taken into consideration.

c) In case of multi-directional prestressing, loss of area due to presence of ungrouted ducts/ sheaths placed at an angle to the prestressing tendons under consideration may be made at full area (100 percent) of such ducts. In case, such ducts placed at an angle have been grouted prior to stressing of tendons 50 percent of area of such ducts can be considered as effectively available.

18.4 Instability During Erection

In evaluating the slenderness effects during lifting of slender members following factors require consideration:

a) Member geometry,
b) Location of lifting points,
c) Method of lifting, and
d) Tolerances in construction.

All beams, which are lifted on vertical or inclined slings, shall be checked for lateral stability and lateral moment on account of tilting of beam due to inaccuracies in location of lifting points, and due to the lateral bow.

For calculating the factor of safety against lateral instability (γ_i) references may be made to specialist literature; the factor shall not be less than two.

For determining the lateral moment due to tilting, realistic values which are not likely to be exceeded in practice shall be assumed for the eccentricity of lifting points and the lateral bow. The maximum tensile stress for $\gamma_i/(\gamma_i - 1)$ times the lateral moment due to tilting shall not exceed 1.5 N/mm^2.

18.5 Prestressing Requirements

18.5.1 *Maximum Initial Prestress*

At the time of initial tensioning, the maximum tensile

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stress, f_{pi} immediately behind the anchorages shall not exceed 76 percent of the ultimate tensile strength, f_{pu} of the wire or bar or strand.

18.5.2 *Losses in Prestress*

While assessing the stresses in concrete and steel during tensioning operations and later in service, due regard shall be paid to all losses and variations in stress from creep of concrete, shrinkage of concrete, relaxation of steel, the shortening (elastic deformation) of concrete at transfer, and friction and slip of anchorage. Unless otherwise determined by actual tests, allowance for these losses shall be made in accordance with the values specified under **18.5.2.1** to **18.5.2.6**.

18.5.2.1 *Loss of prestress due to creep of concrete*

The loss of prestress due to creep of concrete under load shall be determined for all the permanently applied loads including the prestress.

The creep loss due to live load stresses, erection stresses and other stresses of short duration may be ignored. The loss of prestress due to creep of concrete is obtained as the product of the modulus of elasticity of the prestressing steel and the ultimate creep strain of the concrete fibre integrated along the line of centre of gravity of the prestressing tendon at the section at which creep loss is being calculated for bonded tendons. In case of unbonded tendons, the creep loss is a product of modulus of elasticity of prestressing steel and creep strain calculated by integrating and averaging creep stress along the line of centre of gravity between the anchorage points.

The total creep strain during any specific period shall be assumed for all practical purposes, to be the creep strain due to sustained stress equal to the average of the stresses at the beginning and end of the period.

18.5.2.2 *Loss of prestress due to shrinkage of concrete*

The loss of prestress due to shrinkage of concrete shall be the product of the modulus of elasticity of prestressing steel and the shrinkage strain of concrete calculated as per **5.2.4**.

18.5.2.3 *Loss* of *prestress due to relaxation* of *steel*

The relaxation losses in prestressing steels vary with type of steel, initial prestress, age, and temperature and, therefore, shall be determined from experiments. When experimental values are not available, the relaxation losses may be assumed as given in Table 6.

For long term relaxation losses, the values of relaxation losses given in Table 6 may be multiplied by 3.

For periods less than 1 000 h the value of relaxation loss (expressed as percent of 1 000 h value) shall be as shown below:

Time, h		1	5	20	100	200	500	1 000
Percent of Relaxation Loss at 1 000 h	for Normal Relaxation Steel	34	44	55	70	78	90	100
	for Low Relaxation Steel	37	47	57	72	79	90	100

For tendons at higher temperatures or subjected to large lateral loads, greater relaxation losses as specified by the engineer-in-charge shall be allowed for. No reduction in the value of the relaxation losses should be made for a tendon with a load equal to or greater than the relevant jacking force that has been applied for a short time prior to the anchoring of the tendon.

Table 6 Relaxation Losses for Prestressing Steel at 1 000 h at 20 ± 2 °C

(*Clause* 18.5.2.3)

Sl No.	Initial Stress	Relaxation Loss Percent	
		Normal Relaxation	Low Relaxation
(1)	(2)	(3)	(4)
i)	$0.5 f_p$	0	0
ii)	$0.6 f_p$	3.0	1.0
iii)	$0.7 f_p$	5.0	2.5
iv)	$0.8 f_p$	8.0	4.5

NOTE — f_p is the characteristic strength of prestressing steel.

18.5.2.4 *Loss of prestress due to elastic shortening of concrete*

This type of loss occurs when the prestressing tendons upon release from tensioning devices cause the concrete to be compressed. This loss is proportional to the modular ratio and initial stress in the concrete and shall be calculated as below, assuming that the tendons are located at their centroid:

a) For pretensioning, the loss of prestress in the tendons at transfer shall be calculated on a modular ratio basis using the stress in the adjacent concrete.

b) For members with post-tensioned tendons which are not stressed simultaneously, there is a progressive loss of prestress during transfer due to the gradual application of the prestressing forces. This loss of prestress should be calculated on the basis of half the product of the stress in the concrete adjacent to the tendons averaged along their lengths and the modular ratio. Alternatively, the loss of prestress may be exactly computed based on the sequence of tensioning.

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18.5.2.5 *Loss of prestress due to slip in anchorage*

Any loss of prestress which may occur due to slip of wires during anchoring or due to the strain of anchorage shall be allowed for in the design.

18.5.2.6 *Loss of prestress due to friction*

The design shall take into consideration all losses in prestress that may occur during tensioning due to friction between the prestressing tendons and the surrounding concrete or any fixture attached to the steel or concrete.

For straight or moderately curved structures, with curved or straight cables, the value of prestressing force P_x at a distance x metre from tensioning end and acting in the direction of the tangent to the curve of the cable, shall be calculated as below:

$$P_x = P_0 e^{-(\mu\alpha + kx)}$$

where

P_0 = prestressing force in the prestressed steel at the tensioning end acting in the direction of the tangent to the force of the cable;

α = cumulative angle through which the tangent to the cable profile has turned between any two points under consideration, in radians;

μ = coefficient of friction in curve; and

k = coefficient for wobble effect.

The value of μ and k given below may be adopted for calculating the friction losses:

Type of High Tensile Steel	*Type of Duct or Sheath*	*Values Recommended to be Used in Design*	
		k per metre	μ
(1)	(2)	(3)	(4)
Wire cables	Bright metals	0.009 1	0.25
	Galvanized	0.004 6	0.20
	Lead coated	0.004 6	0.18
Uncoated stress relieved strand	Bright metals	0.004 6	0.25
	Galvanized	0.003 0	0.20
	Lead coated	0.003 0	0.18
	Corrugated HDPE	0.002 0	0.17

18.6 Considerations Affecting Design Details

18.6.1 *Transmission Zone in Pre-Tensioned Members*

18.6.1.1 *Transmission length*

The considerations affecting the transmission length shall be as follows:

a) The transmission length depends on a number of variables, the most important being the strength of concrete at transfer, the size and type of tendon, the surface deformations of the tendon. The transmission length of the tendon towards the top of a unit is usually greater than that at the bottom.

b) The following values may be used, provided the concrete is well-compacted and detailing is as per the relevant provisions of this Section, and its strength at transfer is not less than 35 N/mm^2 and the tendon is released gradually:

1) For plain and indented wire : 100ϕ
2) For crimped wires : 65ϕ
3) Strands : 30ϕ

c) The development of stress in the tendon may be assumed to vary linearly along the length of the member.

NOTES

1 ϕ is the diameter of the tendon.

2 The transmission length may vary depending on the site conditions and therefore should be determined from tests carried out under the most unfavourable conditions.

18.6.2 *End Zone in Post-Tensioned Members*

18.6.2.1 *Bearing stress*

a) On the areas immediately behind external anchorages, the permissible unit bearing stress on the concrete, after accounting for losses due to elastic shortening and seating of anchorages, shall not exceed,

$$0.48 f_{ci} \sqrt{\frac{A_{br}}{A_{pun}}}$$

or $0.8 f_{ck}$, whichever is smaller, where f_{ci} is the cube strength at transfer, A_{br} is the bearing area and A_{pun} is the punching area.

b) During tensioning, the allowable bearing stress specified in (a) may be increased by 25 percent, provided that this temporary value does not exceed f_{ci}.

c) The effective punching area shall generally be the contact area of the anchorage devices which, if circular in shape, shall be replaced by a square of equivalent area. The bearing area shall be the maximum area of that portion of the member which is geometrically similar and concentric to the effective punching area.

d) Where a number of anchorages are used, the bearing area A_{br} shall not overlap. Where there is already a compressive stress prevailing over the bearing area, as in the case of anchorage placed in the body of a structure, the total stress shall not exceed the limiting values specified in (a), (b) and (e). For stage stressing of cables, the adjacent unstressed anchorages shall be neglected when determining the bearing area.

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e) The bearing stress specified in (a) and (b) for permanent and temporary bearing stress may be increased suitably if adequate hoop reinforcement complying with manufacturer's recommendations is provided at the anchorages.

f) When the anchorages are embedded in concrete, the bearing stress shall be investigated after accounting for the surface friction between the anchorage and the concrete. The reinforcement details, concrete strength, cover and other dimensions shall conform to manufacturer's specification/ specialist literature.

18.6.2.2 *Bursting tensile forces*

a) The bursting tensile forces in the end blocks, or regions of bonded post-tensioned members, should be assessed on the basis of the tendon jacking load. For unbonded members, the bursting tensile forces should be assessed on the basis of the tendon jacking load or the load in the tendon at the limit state of collapse, whichever is greater (*see* Annex C).

The bursting tensile force, F_{bst} existing in an individual square end block loaded by a symmetrically placed square anchorage or bearing plate, may be derived from the equation below:

$$\frac{F_{bst}}{P_0} = 0.32 - 0.3\frac{y_{p0}}{y_0}$$

where

F_{bst} = bursting tensile force,

P_0 = load in the tendon assessed as above,

y_{p0} = side of loaded area, and

y_0 = side of end block.

b) The force F_{bst} will be distributed in a region extending from 0.1 y_0 to y_0 from the loaded face of the end block. Reinforcement provided to sustain the bursting tensile force may be assumed to be acting at its design strength (0.87 times characteristic strength of reinforcement) except that the stress should be limited to a value corresponding to a strain of 0.001 when the concrete cover to the reinforcement is less than 50 mm.

c) In rectangular end blocks, the bursting tensile forces in the two principal directions should be assessed on the basis of **18.6.2.2**. When circular anchorage or bearing plates are used, the side of the equivalent square area should be used. Where groups of anchorages or bearing plates occur, the end blocks should be divided into a series of symmetrically loaded prisms and each prism treated in the above manner. For designing end blocks having a cross section different in shape from that of the general cross section of the beam, reference should be made to specialist literature.

d) Compliance with the requirements of (a), (b) and (c) will generally ensure that bursting tensile forces along the load axis are provided for. Alternative methods of design which make allowance for the tensile strength of the concrete may be used, in which case reference should be made to specialist literature.

e) Consideration should also be given to the spalling tensile stresses that occur in end blocks where the anchorage or bearing plates are highly eccentric; these reach a maximum at the loaded face.

18.6.3 *Detailing* of *Reinforcement (Untensioned) in Prestressed Concrete*

18.6.3.1 The detailing of reinforcement in prestressed concrete shall generally conform to the requirements given in relevant clauses of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code. In addition, the requirements of **18.6.3.2** and **18.6.3.3** shall be satisfied.

18.6.3.2 *Transverse reinforcement*

a) The amount and spacing of transverse reinforcement shall be governed by shear and torsion considerations. It is, however, desirable to provide transverse reinforcement in the web when the web is thin and cables are located in the web.

b) In the case of all members subjected to dynamic loading, webs shall be provided with transverse reinforcement, not less than 0.3 percent of the sectional area of the web in plan. This percentage of reinforcement may be reduced to 0.2 percent in members where the depth of the web is not more than four times the thickness of the web. These values may be reduced to 0.2 and 0.15 percent, respectively when high strength reinforcement is used.

c) In case of members not subjected to dynamic loading, reinforcement shall be provided when the depth of the web is more than 4 times the thickness. Such reinforcement shall not be less than 0.1 percent of the sectional area of the web in plan. The reinforcement shall be spaced

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at a distance not greater than the clear depth of the web and the size of such reinforcement shall be as small as possible.

d) Reinforcement in the form of links or helix shall be provided perpendicular to the line of heavy compression or shock loading to resist the induced tensile stresses.

18.6.3.3 *Longitudinal reinforcement*

a) A minimum longitudinal reinforcement of 0.2 percent of the total concrete area shall be provided in all cases except in the case of pretensioned units of small sections. This reinforcement may be reduced to 0.15 percent in the case of high yield strength deformed reinforcement. The percentage of steel provided, both tensioned and untensioned taken together, should be sufficient so that when the concrete in the precompressed tensile zone cracks, the steel is in a position to take up the additional tensile stress transferred on to it by the cracking of the adjacent fibres of concrete and a sudden failure is avoided.

b) When the depth of the web exceeds 500 mm, longitudinal distribution reinforcement not less than 0.05 percent of the area of the web shall be provided on each face. The spacing of the individual bars of such reinforcement shall not exceed 200 mm.

c) All untensioned longitudinal reinforcement shall be restrained in the lateral direction.

18.6.4 *Continuity*

In the design of continuous prestressed concrete structures, due consideration shall be given to the effects of the support restraints on both the external moment and the moment due to prestressing.

18.6.5 *Butted Assembly*

Where a butted assembly is used, or where like conditions of abuttal are employed, proper provision shall be made to transfer all shear stresses. Wherever the shear stresses exceed the limits specified under **22.4,** this provision shall include keying of all abutting faces.

SECTION 5B (D) STRUCTURAL DESIGN: LIMIT STATE METHOD

19 SAFETY AND SERVICEABILITY REQUIREMENTS

19.1 Limit State Design

The structural design shall be based on limit state concepts. In this method of design, the structure shall be designed to withstand safely all loads liable to act on it throughout its life; it shall also satisfy the serviceability requirements, such as limitations on deflection, cracking and maximum compression. The acceptable limit for the safety and serviceability requirements before failure occurs is called a 'Limit State'. The aim of design is to achieve acceptable probabilities that the structure will not become unfit for the use for which it is intended, that is, it will not reach a limit state.

19.1.1 All relevant limit states shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

19.1.2 For ensuring the specified objective, the design should be based on characteristic values for material strengths and applied loads, which take into account the variations in the material strengths and in the loads to be supported. The characteristic values should be based on statistical data if available; where such data are not available, they should be based on experience. The 'design values' are derived from the characteristic value through the use of partial safety factors, one for material strengths and the other for loads. In the absence of special considerations, these factors should have the values given in **20.4** according to the material, the type of loading and the limit state being considered.

19.2 Limit State of Collapse

The limit state of collapse of the structure or part of the structure could be assessed from rupture of one or more critical sections and from buckling due to elastic or plastic instability (including the effects of sway where appropriate) or overturning. The resistance to bending, shear, torsion and axial loads at every section shall not be less than appropriate value at that section produced by the probable most unfavourable combination of loads on the structure using the appropriate partial safety factors.

19.3 Limit States of Serviceability

19.3.1 *Limit State* of *Serviceability* : *Deflection*

The deflection of a structure or part thereof shall not adversely affect the appearance or functional requirements of the structure or finishes or partitions. The deflection shall generally be limited to the following:

a) The final deflection, due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the supports of floors, roofs and all other horizontal members, should not normally exceed span/250.

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b) The deflection including the effects of temperature, creep and shrinkage occurring after erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm, whichever is less.

c) If finishes are to be applied to prestressed concrete members, the total upward deflection should not exceed span/300, unless uniformity of camber between adjacent units can be ensured.

19.3.2 *Limit State of Serviceability* : *Cracking*

Cracking of concrete shall not affect the appearance or durability of the structure. The criteria of limit state of cracking for the three types of prestressed concrete members shall be as follows:

a) For *Type* 1, no tensile stress.

b) For *Type* 2, tensile stresses are allowed but no visible cracking.

c) For *Type* 3, cracking is allowed, but should not affect the appearance or durability of the structure; the acceptable limits of cracking would vary with the type of structure and environment and will vary between wide limits and the prediction of absolute maximum width is not possible.

NOTE — For design of Type 3 members, as a guide, the following may be regarded as reasonable limits. The surface width of cracks should not, in general, exceed 0.1 mm for members exposed to a particularly aggressive environment such as the 'severe category' and not exceeding 0.2 mm for all other members.

19.3.3 The flexural tensile stress at any section of the structure, both at transfer and under the most unfavourable combination of design loads, shall satisfy the criteria for the corresponding type of structure.

19.3.4 *Limit State* of *Serviceability* : *Maximum Compression*

The compressive stresses both at transfer and under design loads shall be limited to the values given in **23.3** for all types of structures.

19.3.5 *Other Limit States*

Additional limit states such as limiting vibrations for human comforts shall be complied with to meet the functional requirements of such structures as may be applicable.

20 CHARACTERISTIC AND DESIGN VALUES AND PARTIAL SAFETY FACTORS

20.1 Characteristic Strength of Materials

The term 'characteristic strength' means that value of the strength of the material below which not more than 5 percent of the test results are expected to fall. The characteristic strength for concrete shall be in accordance with Table 1. The characteristic strength shall be assumed for prestressing steel and the characteristic strength for reinforcing steel shall be assumed as minimum yield/0.2 percent proof stress.

20.2 Characteristic Loads

The term 'characteristic load' means that value of load which has a 95 percent probability of not being exceeded during the life of the structure. Since data are not available to express loads in statistical terms, for the purpose of this Section, the dead load, imposed load, wind load, seismic forces and snow load as given in **2**, **3**, **4**, **5** and **6** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code shall be assumed as the characteristic loads.

20.3 Design Values

20.3.1 *Materials*

The design strength of the materials, f_d is given by:

$$f_d = \frac{f_m}{\gamma_m}$$

where

f_m = characteristic strength of the material (*see* **20.1**), and

γ_m = partial safety factor appropriate to the material and the limit state being considered (*see* **20.4**).

20.3.2 *Loads*

The design load, F_d is given by:

$$F_d = F\gamma_f$$

where

F = characteristic load (*see* **20.2**), and

γ_f = partial safety factor appropriate to the nature of loading and the limit state being considered (*see* **20.4**).

20.3.3 *Consequences* of *Attaining Limit State*

Where the consequences of a structure attaining a limit state are of a serious nature such as huge loss of life and disruption of the economy, higher values for γ_m and γ_f than those given under **20.4.1** and **20.4.2** may be applied.

20.4 Partial Safety Factors

20.4.1 *Partial Safety Factor* γ_m *for Material Strength*

20.4.1.1 When assessing the strength of a structure or structural member for the limit state of collapse, the values of partial safety factor γ_m should be taken as 1.5 for concrete and 1.15 for steel.

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NOTE — γ_m values are already incorporated in the equations and tables given in this Section.

20.4.1.2 When assessing the deflection, the material properties such as modulus of elasticity of concrete should be taken as those associated with the characteristic strength of the material and safety factor shall not be applied.

20.4.2 *Partial Safety Factor γ_f for Loads*

The value of γ_f given in Table 7 shall normally be used.

21 ANALYSIS

21.1 Analysis of Structure

Methods of analysis as in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall be used. The material strength to be assumed shall be characteristic values in the determination of elastic properties of members, irrespective of the limit state being considered. Redistribution of the calculated moments may be made as given in **21.1.1**.

21.1.1 *Redistribution* of *Moments in Continuous Beams and Frames*

The redistribution of moments may be carried out satisfying the following conditions:

a) Equilibrium between the internal forces and the external loads is maintained.

b) The ultimate moment of resistance provided at any section of a member is not less than 80 percent of the moment at that section obtained from an elastic maximum moment diagram covering all appropriate combinations of loads.

c) The elastic moment at any section in a member due to a particular combination of loads shall not be reduced by more than 20 percent of numerically largest moment given anywhere by the elastic maximum moment diagram for the particular member, covering all appropriate combination of loads.

d) At sections where the moment capacity after redistribution is less than that from the elastic maximum moment diagram, the following relationship shall be satisfied:

$$\frac{x_u}{d} + \frac{\delta_M}{100} \leq 0.6$$

where

x_u = depth of neutral axis,

d = effective depth, and

δ_M = percentage reduction in moment.

e) In structures in which the structural frame provides the lateral stability, the reduction in moment allowed by condition given in **21.1.1** (c) shall be restricted to 10 percent for structures over 4 storeys in height.

21.1.2 *Analysis of Slabs Spanning in Two Directions at Right Angles*

In general, the provisions of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall apply.

22 LIMIT STATE OF COLLAPSE

22.1 Limit State of Collapse: Flexure

22.1.1 *Assumptions*

Design for the limit state of collapse in flexure shall be

Table 7 Values of Partial Safety Factor (γ_f) For Loads

(*Clause* 20.4.2)

Sl No.	Load Combination	Limit State of Collapse				Limit States of Serviceability			
		DL	IL	WL	P	DL	IL	WL	P
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	DL + IL + P	1.5	1.5	—	1.0	1.0	1.0	—	1.1 or 0.9 [2]
ii)	DL + WL + P	1.5 or 0.9 [1]	—	1.5	1.0	1.0	—	1.0	1.1 or 0.9 [2]
iii)	DL + IL + WL + P	1.2	1.2	1.2	1.0	1.0	0.8	0.8	1.1 or 0.9 [2]

[1] This value is to be considered when stability against overturning or stress reversal is critical.

[2] The structure shall be checked both for upper characteristics values and lower characteristics value shown. The values are for post tensioning with bonded tendons. In case of pretensioning or unbonded tendons, it shall be taken as 1.05 or 0.95 instead of the above value.

NOTES

1 While considering earthquake effects, substitute EL for WL.

2 While assessing the long-term effects due to creep, the dead load and that part of the imposed load likely to be permanent may only be considered.

3 While verifying the limit state for stability, with external prestress where an increase of the value of prestress can be unfavourable, partial safety factor of 1.3 shall be used.

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based on the assumptions given below:

a) Plane sections normal to the axis remain plane after bending.

b) The strain in the bonded reinforcement or bonded prestressing steel whether in tension or in compression is the same as that in the surrounding concrete.

c) The maximum strain in concrete at the outermost compression fibre is taken as 0.003 5 in bending.

d) The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangle, trapezoid, parabola or any other shape which results in prediction of strength in substantial agreement with the results of tests. An acceptable stress-strain curve is given in Fig. 3. For design purposes, the compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor $\gamma_m = 1.5$ shall be applied in addition to this.

NOTE — For the stress-strain curve in Fig. 3, the design stress block parameters for rectangular section are as follows (*see* Fig. 4):

Area of stress block	=	$0.36 f_{ck} x_u$
Depth of centre of compressive force from the extreme fibre in compression	=	$0.42 x_u$

where

f_{ck} = characteristic compressive strength of concrete, and

x_u = depth of neutral axis.

e) The tensile strength of the concrete is ignored.

f) The stresses in bonded prestressing tendons, whether initially tensioned or untensioned, and in additional reinforcement are derived from the representative stress-strain curve for the type of steel used given by the manufacturer or typical curves given in Fig. 5 for prestressing tendons and in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code for reinforcement. For design purposes, the partial safety factor γ_m equal to 1.15 shall be applied. In addition, the tendon will have an initial prestrain due to prestress after all losses.

For members with permanently unbonded internal or externally prestressed tendons, the deformation of the whole member shall be taken into account for calculating strain and stress in the tendon at ultimate condition. In the absence of rigorous analysis, the strain in unbonded tendon shall be assumed not to increase above the initial value due to prestress after all losses.

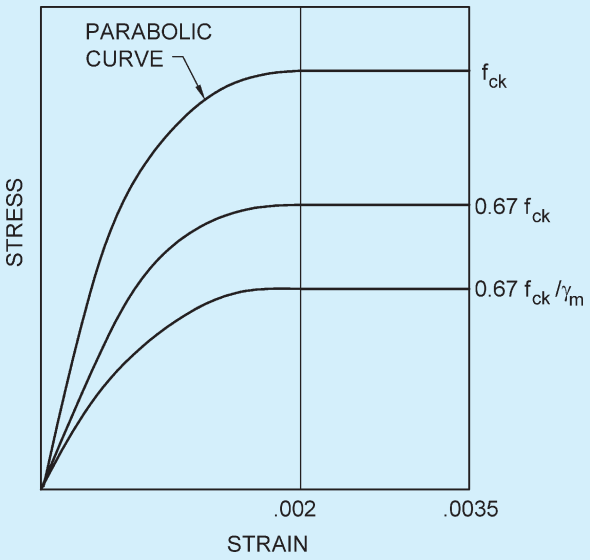


FIG. 3 STRESS STRAIN CURVE FOR CONCRETE

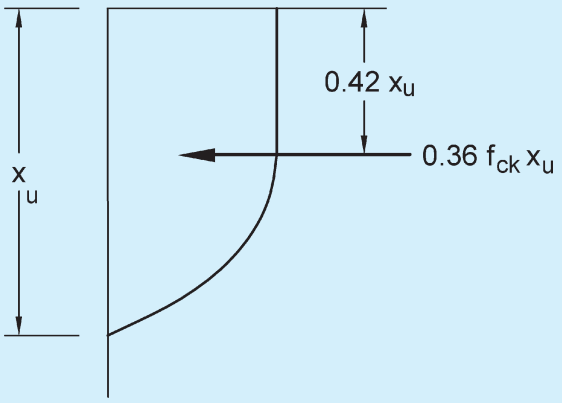


FIG. 4 STRESS BLOCK PARAMETERS

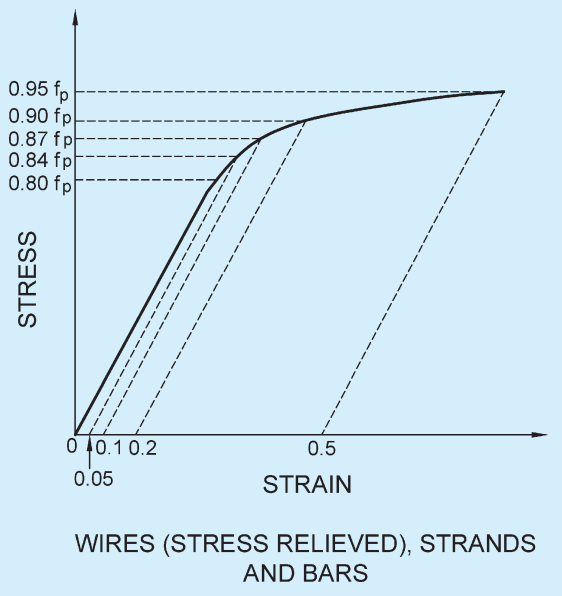


FIG. 5 REPRESENTATIVE STRESS STRAIN CURVES FOR PRESTRESSING STEEL

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22.1.2 *Design Formulae*

In the absence of an analysis based on the assumptions given in **22.1.1,** the moment of resistance of rectangular sections and flanged sections in which the neutral axis lies within the flange may be obtained by the procedure given in Annex C.

For flanged sections in which the neutral axis lies outside the flange, the moment of resistance shall be determined using assumptions given in **22.1.1.**

22.2 Limit State of Collapse: Compression

Prestressed concrete compression members in framed structures, where the mean stress in the concrete section imposed by tendons is less than 2.5 N/mm^2, may be analysed as reinforced concrete compression members in accordance with Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code, in other cases specialist literature may be referred to.

22.3 Limit State of Collapse: Tension

Tensile strength of the tension members shall be used on the design strength (0.87 times characteristic strength of prestressing tendons) and the strength developed by any additional reinforcement. The additional reinforcement may usually be assumed to be acting at its design stress (0.87 times characteristic strength of reinforcement); in special cases it may be necessary to check the stress in the reinforcement using strain compatibility.

22.4 Limit State of Collapse: Shear

The ultimate shear resistance of the concrete along, V_c, should be considered at both conditions uncracked and cracked in flexure, the lesser value taken and, if necessary, shear reinforcement provided.

22.4.1 *Section Uncracked in Flexure*

The ultimate shear resistance of a section uncracked in flexure, $V_c = V_{co}$, is given by:

$$V_{co} = 0.67\, bD\, \sqrt{\left(f_t^2 + 0.5 f_{cp} f_t\right)}$$

where

b = breadth of the member which for T, I and L beams should be replaced by breadth of the rib b_w,

D = overall depth of the member,

f_t = maximum principal tensile given by $0.24\sqrt{f_{ck}}$ taken as positive where f_{ck} is the characteristic compressive strength of concrete, and

f_{cp} = compressive stress at centroidal axis due to prestress taken as positive.

Where the position of a duct coincides with the position of maximum principal tensile stress, for example, at or near the junction of flange and the web near a support, the value of b should be reduced by the 1.2 times the diameter of duct if ungrouted metallic ducts or, grouted or ungrouted plastic ducts are used or in case of unbonded tendons and by half the diameter of the duct if grouted metallic ducts are used.

In flanged members where the centroidal axis occurs in the flange, the principal tensile stress should be limited to $0.24\sqrt{f_{ck}}$ at the intersection of the flanged web; in this calculation, 0.8 of the stress due to prestress at this intersection may be used, in calculating V_{co}.

For a section uncracked in flexure and with inclined tendons or vertical prestress, the component of prestressing force normal to the longitudinal axis of the member may be added to V_{co}.

22.4.2 *Sections Cracked in Flexure*

The ultimate shear resistance of a section cracked in flexure, $V_c = V_{cr}$ is given by:

$$V_{cr} = \left(1 - 0.55\frac{f_{pe}}{f_p}\right)\zeta_c bd + M_0\frac{V}{M}$$

where

f_{pe} = effective prestress after all losses have occurred, which shall not be taken as greater than $0.6 f_p$,

f_p = characteristic strength of prestressing steel,

ζ_c = ultimate shear stress capacity of concrete obtained from Table 8,

b = breadth of the member, which, for flanged sections, shall be taken as the breadth of the web (b_w),

d = distance from the extreme compression-fibre to the centroid of the tendons at the section considered,

M_0 = moment necessary to produce zero stress in the concrete at the depth, given by:

$$M_0 = 0.8 f_{pt}\frac{I}{y}$$

where f_{pt} is the stress due to prestress only at depth of d and distance y from the centroid of the concrete section which has second moment of area I, and

V and M = shear force and bending moment respectively, at the section considered due to ultimate loads.

V_{cr} should be taken as not less than $0.1bd\sqrt{f_{ck}}$.

The value of V_{cr} calculated at a particular section may be assumed to be constant for a distance equal to $d/2$,

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measured in the direction of increasing moment, from that particular section.

For a section cracked in flexure and with inclined tendons, the component of prestressing forces normal to the longitudinal axis of the member should be ignored.

Table 8 Design Shear Strength of Concrete, ζ_c, N/mm²

(*Clause* 22.4.2)

Sl No.	$100\frac{A_p}{bd}$	Concrete Grade		
		M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)
i)	≤ 0.15	0.29	0.29	0.30
ii)	0.25	0.37	0.37	0.38
iii)	0.50	0.50	0.50	0.51
iv)	0.75	0.59	0.59	0.60
v)	1.00	0.66	0.67	0.68
vi)	1.25	0.71	0.73	0.74
vii)	1.50	0.76	0.78	0.79
viii)	1.75	0.80	0.82	0.84
ix)	2.00	0.84	0.86	0.88
x)	2.25	0.88	0.90	0.92
xi)	2.50	0.91	0.93	0.95
xii)	2.75	0.94	0.96	0.98
xiii)	3.00	0.96	0.99	1.01

NOTE — A_p is the area of prestressing tendon.

22.4.3 *Shear Reinforcement*

22.4.3.1 When V, the shear force due to the ultimate loads, is less than V_c, the shear force which can be carried by the concrete, minimum shear reinforcement should be provided in the form of stirrups such that:

$$\frac{A_{sv}}{bs_v} = \frac{0.4}{0.87 f_y}$$

where

A_{sv} = total cross-sectional area of stirrup legs effective in shear,

b = breadth of the member which for T, I and L beams should be taken as the breadth of the rib, b_w,

s_v = stirrup spacing along the length of the member, and

f_y = characteristic strength of the stirrup reinforcement which shall not be taken greater than 415 N/mm².

However, shear reinforcement need not be provided in the following cases:

a) Where V is less than 0.5 V_c, and

b) In members of minor importance.

22.4.3.2 When V exceeds V_c, shear reinforcement shall be provided such that:

$$\frac{A_{sv}}{s_v} = \frac{V - V_c}{0.87 f_y d_t}$$

In rectangular beams, at both corners in the tensile zone, a stirrup should pass around a longitudinal bar, a tendon or a group of tendons having a diameter not less than the diameter of the stirrup. The depth d_t is then taken as the depth from the extreme compression fibre either to the longitudinal bars or to the centroid of the tendons, whichever is greater.

The spacing of stirrups along a member should not exceed 0.75 d_t nor 4 times the web thickness for flanged members. When V exceeds 1.8 V_c, the maximum spacing should be reduced to 0.5 d_t. The lateral spacing of the individual legs of the stirrups provided at a cross-section should not exceed 0.75 d_t.

22.4.4 *Maximum Shear Forces*

In no circumstances should the shear force V, due to ultimate loads, exceed the appropriate values given in Table 9 multiplied by bd.

Table 9 Maximum Shear Stress

(*Clause* 22.4.4)

Concrete Grade	M 30	M 35	M 40	M 45	M 50	M 55 and Over
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Maximum shear stress, N/mm²	3.5	3.7	4.0	4.3	4.6	4.8

22.5 Limit State of Collapse: Torsion

22.5.1 *General*

In general, where the torsional resistance or stiffness of members has not been taken into account in the analysis of the structure, no specific calculations for torsion will be necessary, adequate control in torsional cracking being provided by the required nominal shear reinforcement. Where the torsional resistance or stiffness of members is taken into account in the analysis, the members shall be designed for torsion.

22.5.2 *Application of Design Rules for Torsion*

The design rules laid down in **22.5.3** to **22.5.5** apply to,

a) beams of solid rectangular cross-section ($D > b$),

b) hollow rectangular beams with $D > b$ and with a wall thickness $t \geq b/4$, and

c) T-beams and I-beams.

In all these cases the average intensity of prestress in the concrete shall be less than 0.3 f_{ck}.

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22.5.3 *Longitudinal Reinforcement*

22.5.3.1 The longitudinal reinforcement shall be designed to resist an equivalent ultimate bending moment M_{e1} given by:

$$M_{e1} = M + M_t$$

where

M = applied ultimate bending moment at the cross-section acting in combination with T;

M_t = $T\sqrt{1+\frac{2D}{b}}$, the sign of M_t being the same as that of M;

D = overall depth of the beam; and

b = breadth of the member which for T and I beams shall be taken as the breadth of the web, b_w.

22.5.3.2 Where the numerical value of M is less than that of M_t, the member shall also be designed to withstand a moment M_{e2} given by:

$$M_{e2} = M_t - M$$

the moment M_{e2} being taken as acting in the opposite sense to the moment M.

22.5.3.3 Where the numerical value of M is less than or equal to that of M_t, the beam shall be designed to withstand an equivalent transverse bending moment M_{e3} (not acting simultaneously with M_{e1}), given by:

$$M_{e3} = M_t\left(1+\frac{x_1}{2e}\right)^2\left(\frac{1+\frac{2b}{D}}{1+\frac{2D}{b}}\right)$$

and acting about an axis at right angles to the axis of M, where x_1 is the smaller dimension of a closed hoop used as torsional shear reinforcement and e is as defined in **22.5.4.1.**

22.5.4 *Transverse Reinforcement*

22.5.4.1 *Torsional moment and shear carried by concrete*

The reduced torsional moment carried by the concrete T_{c1} is given by:

$$T_{c1} = T_c\left(\frac{e}{e+e_c}\right)$$

where

$$T_c = \sum 0.15b^2D\left(1-\frac{b}{3D}\right)\lambda_v\sqrt{f_{ck}}$$

$$e = \frac{T}{V}$$

$$e_c = \frac{T_c}{V_c}$$

$$\lambda_v = \sqrt{\left(1+12\frac{f_{cp}}{f_{ck}}\right)}$$

In the above expressions,

T_c = torsional moment carried by concrete;

b = breadth of the member, which for T and I beams shall be taken as the breadth of the web, b_w;

D = overall depth of beam;

f_{ck} = characteristic compressive strength of concrete;

T = torsional moment applied to a cross-section under ultimate load conditions;

V = shearing force at a cross-section calculated for the specified ultimate loads;

V_c = theoretical shear strength at a cross-section, assuming the most unfavourable conditions for inclined cracking, that is, smaller of V_{co} and V_{cr} (*see* **22.4.1** and **22.4.2**); and

f_{cp} = average intensity of effective prestress in concrete at this section.

22.5.4.2 The shear force carried by the concrete V_{c1} is given by:

$$V_{c1} = V_c\frac{e}{e+e_c}$$

where

V_c = smaller of V_{co} and V_{cr} obtained as in **22.4.1** and **22.4.2**.

22.5.4.3 *Design of transverse reinforcement*

The area of cross-section, A_{sv} of the closed stirrup enclosing the corner longitudinal bars shall be taken as the larger of the following two values:

$$A_{sv} = \frac{M_t s_v}{1.5b_1d_1f_y}, \text{ and}$$

$$A_{sv} = A_v + 2A_t$$

where

$$A_v = \frac{(V-V_{c1})s_v}{0.87f_yd_1}$$

$$A_t = \frac{(T-T_{c1})s_v}{0.87b_1d_1f_y}$$

In the above expressions,

M_t = as defined in **22.5.3.1**,

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s_v = spacing of the stirrup reinforcement,

b_1 = centre-to-centre distance between corner bars in the direction of the width,

d_1 = centre-to-centre distance between corner bars in the direction of the depth,

f_y = characteristic strength of shear reinforcement,

V = as defined in **22.5.4.1**,

V_{c1} = as defined in **22.5.4.2**, and

T and T_{c1} = as defined in **22.5.4.1**.

22.5.4.4 *Minimum reinforcement*

The value of A_{sv} shall not be taken lesser than that given by:

$$\frac{A_{sv}}{bs_v} = \frac{0.4}{0.87 f_y}$$

There shall be at least one longitudinal bar not less than 12 mm in diameter in each corner of the stirrups.

22.5.5 *Distribution of Torsion Reinforcement*

When a member is designed for torsion, torsion reinforcement shall be provided as below:

a) All transverse reinforcement provided for torsion shall be in the form of closed stirrups perpendicular to the axis of the members;

b) The spacing, s_v, of the stirrups shall not exceed $(x_1 + y_1)/4$ or 200 mm, whichever is smaller, where x_1 and y_1 are respectively short and long dimensions of the stirrup;

c) Each end of the bar forming the stirrup shall be anchored in accordance with Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code; and

d) Torsional reinforcement shall be continued to a distance not less than $(D + b_w)$ beyond the point at which it is no longer than theoretically required, where D is the overall depth and b_w is the effective width of the web of a flanged member.

23 LIMIT STATE OF SERVICEABILITY

23.1 Limit State of Serviceability: Deflection

23.1.1 *Type 1 and Type 2 Members*

23.1.1.1 *Short-term deflection*

The instantaneous deflection due to design loads may be calculated using elastic analysis based on the uncracked section and the modulus of elasticity of concrete as given in **5.2.3**.

23.1.1.2 *Long-term deflection*

The total long-term deflection due to the prestressing force, dead load and any sustained imposed load may be calculated using elastic analysis, taking into account the effects of cracking and of creep and shrinkage (*see* **5.2.4** and **5.2.5**) Due allowance shall be made for the loss of prestress (*see* **18.5.2**) after the period considered. The deflections should comply with the limits given in **19.3.1**.

23.1.2 *Type* 3 *Members*

Where the permanent load is less than or equal to 25 percent of the design imposed load, the deflection may be calculated as in **23.1.1.1**. When the permanent load is more than 25 percent of the design imposed load, the vertical deflection limits for beams and slabs may generally be assumed to be satisfied provided that the span to effective depth ratios are not greater than the values obtained as below:

a) Basic values of span to effective depth ratios for spans up to 10 m:

Cantilever	:	7
Simply supported	:	20
Continuous	:	26

b) For spans above 10 m, the values in (a) may be multiplied by 10/(span in metres), except for cantilever in which case deflection calculations should be made.

23.2 Limit State of Serviceability: Cracking

In members made up of precast units, no tension shall be allowed at any stage at mortar or concrete joints. For a member which is free of joints, the tensile stress shall not exceed the values specified below for the 3 types of members:

a) *Type 1* — No tensile stress.

b) *Type 2* — The tensile stress shall not exceed 3 N/mm^2. However, where part of the service loads is temporary in nature, this value may be exceeded by 1.5 N/mm^2, provided under the permanent component of the service load the stress remains compressive.

c) *Type 3* — For Type 3 members in which cracking is permitted, it may be assumed that the concrete section is uncracked, and that hypothetical tensile stresses exist at the maximum size of cracks. The hypothetical tensile stresses for use in these calculations for members with either pre-tensioned or post-tensioned tendons are given in Table 10, modified by coefficients given in Fig. 6.

23.3 Limit State of Serviceability: Maximum Compression

23.3.1 *Maximum Stress Under Service Conditions*

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Table 10 Hypothetical Flexural Tensile Stresses for Type 3 Members

[(*Clause* 23.2(c)]

Sl No.	Type of Tendons	Limiting Crack Width mm	Stress of Concrete for Grade				
			M 30	M 35	M 40	M 45	M 50 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Pre-tensioned tendons	0.1	—	—	4.1	4.4	4.8
		0.2	—	—	5.0	5.4	5.8
ii)	Grouted post-tensioned tendons	0.1	3.2	3.6	4.1	4.4	4.8
		0.2	3.8	4.4	5.0	5.4	5.8
iii)	Pre-tensioned tendons distributed in the tensile zone and positioned close to the tension faces of concrete.	0.1	—	—	5.3	5.8	6.3
		0.2	—	—	6.3	6.8	7.3

NOTE — When additional reinforcement is distributed within the tension zone and positioned close to the tension face of concrete, the hypothetical tensile stresses may be increased by an amount which is proportional to the cross sectional areas of the additional reinforcement expressed as a percentage of the cross sectional area of the concrete. For 1 percent of additional reinforcement, the stress may be increased by 4 N/mm^2 for members with pre-tensioned and grouted post-tensioned tendons and by 3 N/mm^2 for other members. For other percentages of additional reinforcement the stresses may be increased in proportion excepting that the total hypothetical tensile stress shall not exceed 0.25 times the characteristic compressive strength of concrete.

23.3.1.1 *Compressive stress in flexure*

The maximum permissible compressive stress, prestress and service loads after deduction of the full losses in the specified prestress shall be determined by a straight line relation as in Fig. 7; but different stress limits shall apply to the concrete of the structure depending on whether it falls in a part of the section where the compressive stresses are not likely to increase in service (Zone I) or in part of the section where the compressive stresses are likely to increase in service (Zone II) (*see* Fig. 7).

For Zone I, the straight line relation of permissible stress shall be determined by the straight line joining a point given by a permissible stress of 0.41 f_{ck} for concrete of Grade M 30 to another point given by a permissible stress of 0.35 f_{ck} for concrete of Grade M 60.

For Zone II, the determining points of the graph shall be reduced to 0.34 f_{ck} and 0.27 f_{ck}, respectively.

23.3.1.2 *Stress in direct compression*

Except in the parts immediately behind the anchorage, the maximum stress in direct compression shall be limited to 0.8 times the permissible stress obtained from **23.3.1.1**.

23.3.2 *Maximum Stress at Transfer*

23.3.2.1 *Compressive stress in flexure*

The maximum permissible compressive stress due to bending and direct force at the time of transfer of prestress shall be determined from a graph in which a straight line joins a point given by 0.54 f_{ci} for a concrete of Grade M 30 to a second point giving a permissible stress of 0.37 f_{ci} for concrete of Grade M 60 (*see* Fig. 8A); f_{ci} being cube strength of concrete at transfer which in no case shall be less than half the corresponding characteristic compressive strength of concrete. These values apply to post-tensioned work; for pre-tensioned work the variation represented by Fig. 8B will apply.

NOTE — The strength of concrete at the time of transfer f_{ci} shall be established by tests carried out on cubes at the age of the concrete at transfer for such other major structures and in other cases, if more convenient, from the straight line graph, joining the characteristic compressive strength of concrete and cube strength at 7 days. The transfer of prestress shall be made only after the concrete has attained a strength of at least half the characteristic compressive strength of concrete.

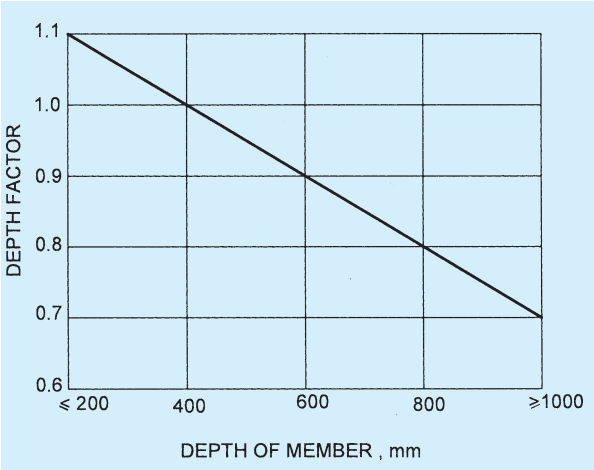


FIG. 6 DEPTH FACTORS FOR TENSILE STRESSES FOR TYPE 3 MEMBERS

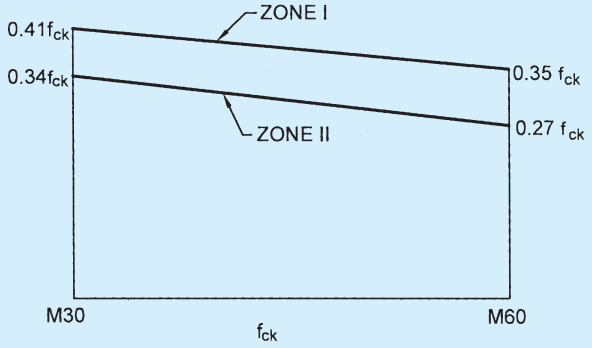


FIG. 7 COMPUTATION OF MAXIMUM PERMISSIBLE COMPRESSIVE STRESS IN FLEXURE DUE TO FINAL PRESTRESS

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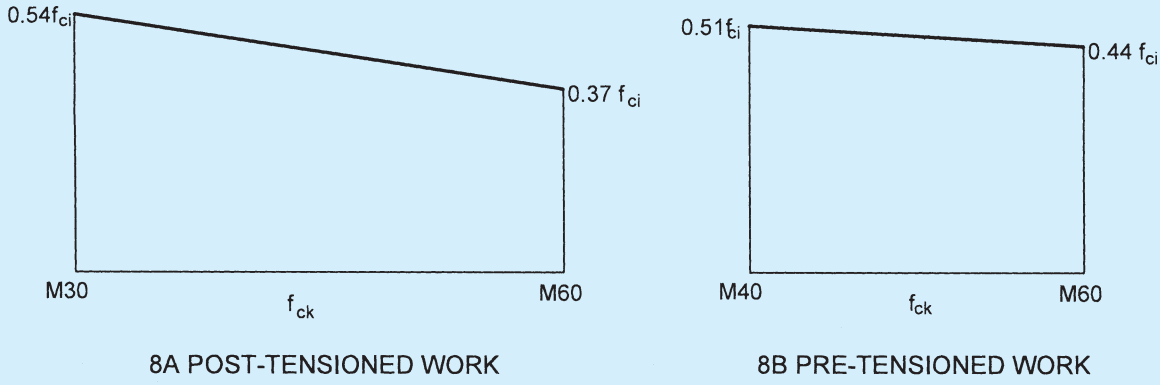


FIG. 8 COMPUTATION OF MAXIMUM PERMISSIBLE COMPRESSIVE STRESS IN FLEXURE AT TRANSFER

23.3.2.2 *Stress in direct compression*

Except in the parts immediately behind the anchorages, the maximum stress in direct compression shall be limited to 0.8 times the permissible stress obtained from **23.3.2.1**.

ANNEX A

(*Clause* 11.2)

SHEATHING DUCTS FOR PRESTRESSING

A-1 MILD STEEL SHEATHING DUCTS

Unless otherwise specified, the material shall be cold rolled cold annealed (CRCA) mild steel intended for mechanical treatment and surface refining but not for quench hardening or tempering.

The material shall be clean and free from rust and normally of bright metal finish. However, in case of use in aggressive environment galvanized or lead coated mild steel strips shall be adopted.

The thickness of metal sheathing shall not be less than 0.3 mm, 0.4 mm and 0.5 mm for sheathing ducts having internal diameter up to 50 mm, 75 mm and 90 mm, respectively. For bigger diameter of ducts, thickness of sheathing shall be based on recommendations of prestressing system supplier.

The sheathing shall conform to the requirements specified in **A-3** and a test certificate shall be furnished by the manufacturer.

The joints of all sheathing shall be water tight and conform to the provisions specified in **A-5**.

A-2 CORRUGATED HDPE SHEATHING DUCTS

Unless otherwise specified, the material for the ducts shall be high-density polyethylene with more than 2 percent carbon black to provide resistance to ultraviolet degradation and shall have the following properties:

Specific density	:	0.954 g/cm^3 at 23 °C
Yield stress	:	18.0 N/mm^2
Tensile strength	:	21.0 N/mm^2
Shore hardness *D*:		
a) 3 s	:	60
b) 15 s	:	58
Notch impact strength at:		
a) 23°C	:	10 kJ/m^2
b) 40°C	:	4 kJ/m^2
Coefficient of thermal expansion for 20°C – 80°C	:	1.50 × 10^{-4} /°C

The thickness of the wall shall be 2.3 ± 0.3 mm as manufactured and 1.5 mm after loss in the compression test, for duct size up to 160 mm outer diameter.

The ducts shall be corrugated on both sides. The ducts

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shall transmit full tendon strength from the tendon to the surrounding concrete over a length not greater than 40 duct diameters.

These ducts shall be joined by adopting any one or more of the following methods, as convenient to suit the individual requirements of the location, subject to the satisfactory pressure tests, before adoption:

a) Screwing together with male and female threads.
b) Joining with thick walled HDPE shrink couplers with glue. This can also be used for connection with trumpet, etc.
c) Welding with electro fusion couplers.

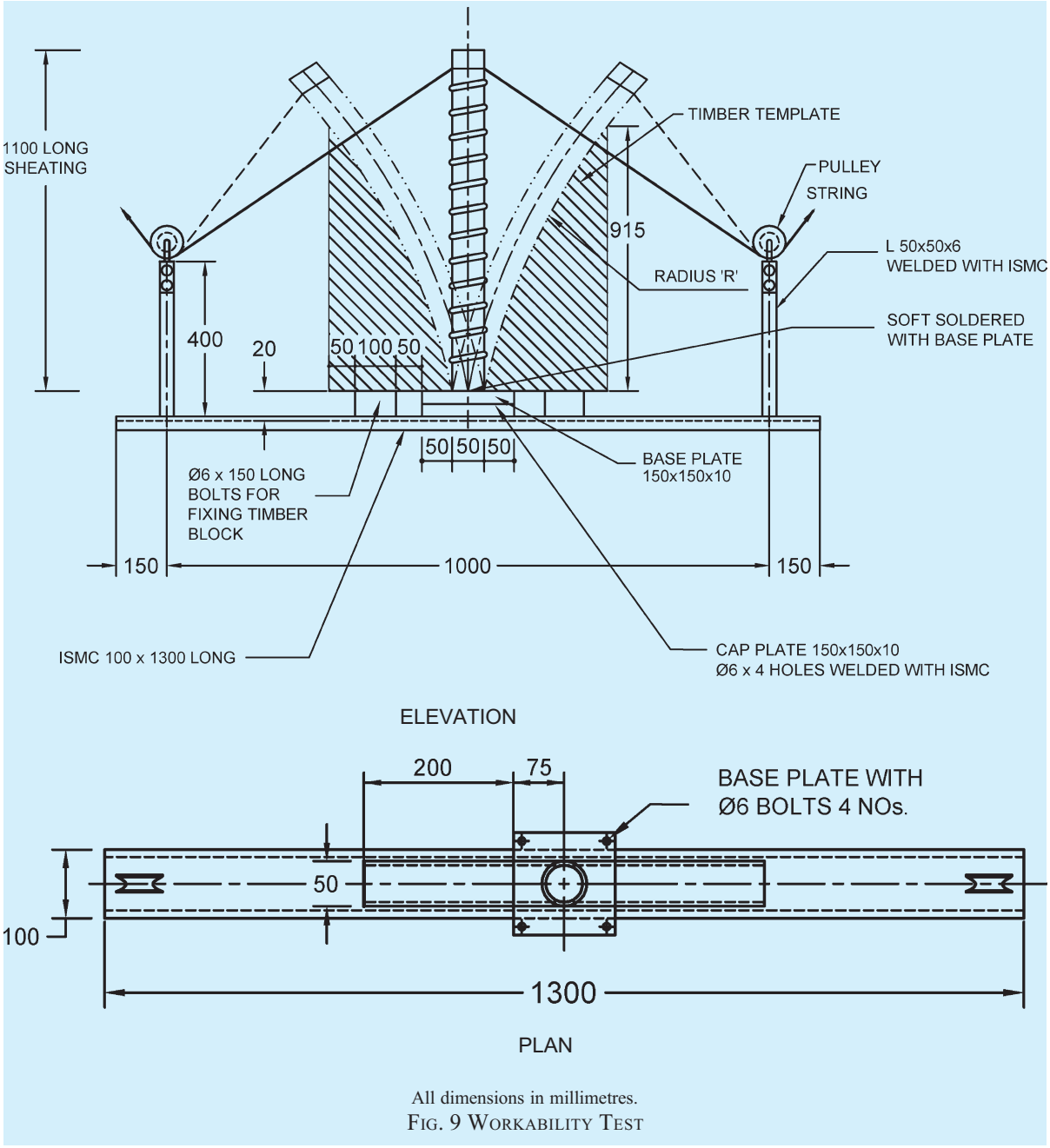
The joints shall be able to withstand an internal pressure of 0.5 kg/cm^2 for 5 min as per test procedure given in **A-3.**

A-3 TESTS ON SHEATHING DUCTS

a) All tests specified below shall be carried out on the same sample in the order given below.
b) At least 3 samples for one lot of supply (not exceeding 7 000 m length) shall be tested.

A-3.1 Workability Test

A test sample 1 100 mm long is soldered to a fixed base plate with a soft solder (*see* Fig. 9). The sample is then bent to a radius of 1 800 mm alternately on either



All dimensions in millimetres.

FIG. 9 WORKABILITY TEST

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side to complete 3 cycles. Thereafter, the sealing joints will be visually inspected to verify that no failure or opening has taken place.

A-3.2 Transverse Load Rating Test

The test ensures that stiffness of the sheathing is sufficient to prevent permanent distortion during site handling.

The sample is placed on a horizontal support 500 mm long so that the sample is supported at all points of outward corrugations.

A load as specified in the table below is applied gradually at the centre of the supported portion through a circular contact surface of 12 mm diameter:

Diameter of Sheathing mm	*Load* N
More than 25 up to 35	250
more than 35 up to 45	400
more than 45 up to 55	500
more than 55 up to 65	600
more than 65 up to 75	700
more than 75 up to 85	800
more than 85 up to 90	1 000

Couplers shall be placed so that the load is applied approximately at the centre of two corrugations (*see* Fig. 10). The load as specified below is applied in increments.

The sample is considered acceptable, if the permanent deformation is less than 5 percent.

A-3.3 Tension Load Test

The test specimen is subjected to a tensile load. The hollow core is filled with a wooden circular piece having a diameter of 95 percent of the inner diameter of the sample to ensure circular profile during test loading (*see* Fig. 11).

A coupler is screwed on and the sample loaded in increments, till specified load. If no deformation of the joints nor slippage of couplers is noticed, the test shall be considered satisfactory:

Diameter of Sheathing mm	*Load* N
more than 25 up to 35	300
more than 35 up to 45	500
more than 45 up to 55	800
more than 55 up to 65	1 100
more than 65 up to 75	1 400
more than 75 up to 85	1 600
more than 85 up to 90	1 800

A-3.4 Water Loss Test

The sample is sealed at one end. The sample is filled with water and after sealing, the end is connected to a system capable of applying a pressure of 0.05 MPa (*see* Fig. 12) and kept constant for 5 min; hand pump and pressure gauge or stand pipe system can be used.

The sample is accepted if the water loss does not exceed 1.5 percent of the volume. The volume is worked out as follows:

Another sample 500 mm long is sealed at one end and the volume of hollow space arrived at by pouring water from a measuring cylinder.

The computation of relative profile volume is worked out as follows:

$$\text{Relative profile volume} = \frac{V_p - \frac{\pi\phi^2 l}{4}}{\pi\phi l} \text{ cm}^3/\text{cm}^2$$

where

V_p = actual volume = $V_a - V_b$;
V_a = premeasured quantity of water in a measuring cylinder;
V_b = balance quantity of water left in the cylinder after completely filling of the test sample;
l = length of specimen; and
ϕ = internal diameter of sheathing.

A-4 TESTS ON CORRUGATED HDPE SHEATHING DUCTS

The additional acceptance tests for the prestressing systems employing corrugated HDPE ducts shall cover the following two tests.

A-4.1 Bond Test

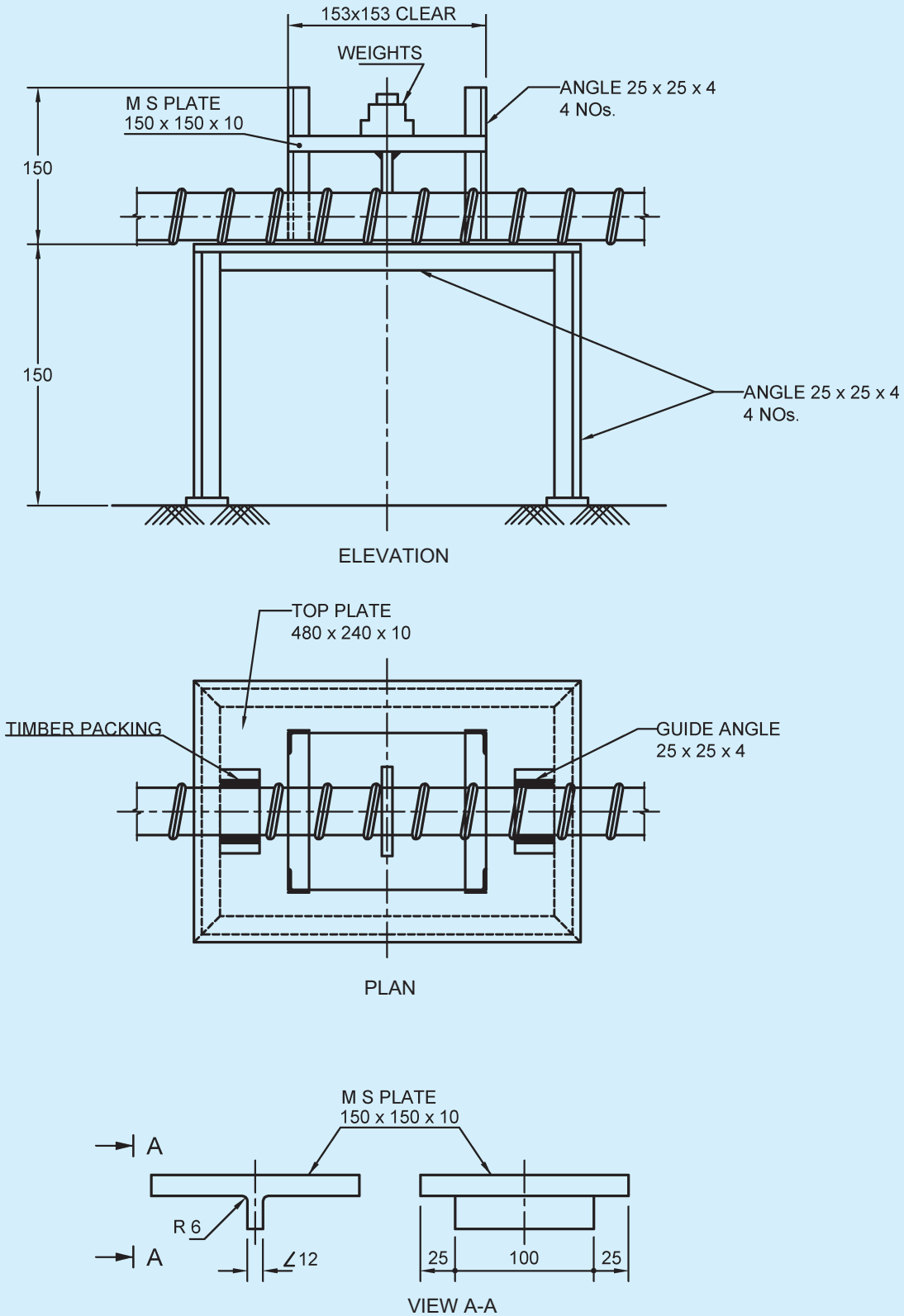
A-4.1.1 The test is carried out to establish satisfactory bond characteristics between the tendon and concrete, in the ultimate condition. The test requires the following equipment:

a) Three similarly reinforced concrete beams with a HDPE duct of length equal to 40 times the duct diameter,
b) Prestressing tendon of adequate length for stressing and for embedding in the beam,
c) Tendon anchorage system,
d) Load cells and meters, and
e) Grout constituents.

A-4.1.2 *Method*

Cast an adequately reinforced beam to withstand the prestressing operation and of length to embed 40 times the diameter of duct to suit the tendon to be adopted. Introduce the strands of the tendon by spacing them parallel by means of ply-spacers as shown in Fig. 13

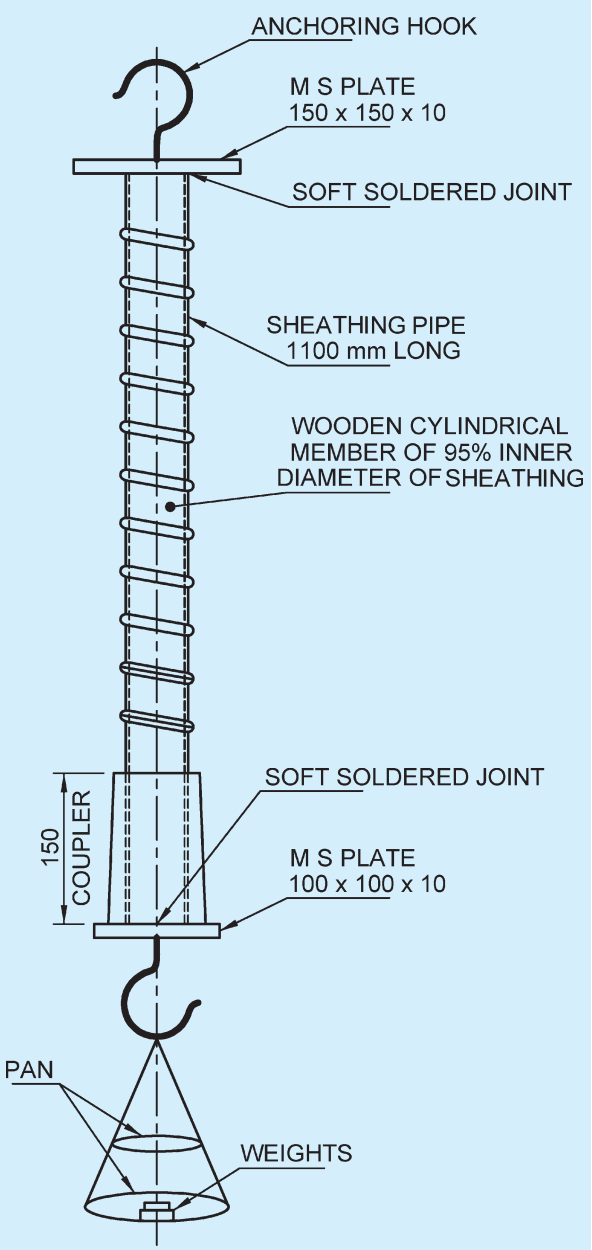
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All dimensions in millimetres.

FIG. 10 TRANSVERSE LOAD RATING TEST

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All dimensions in millimetres.

FIG. 11 TENSION LOAD TEST

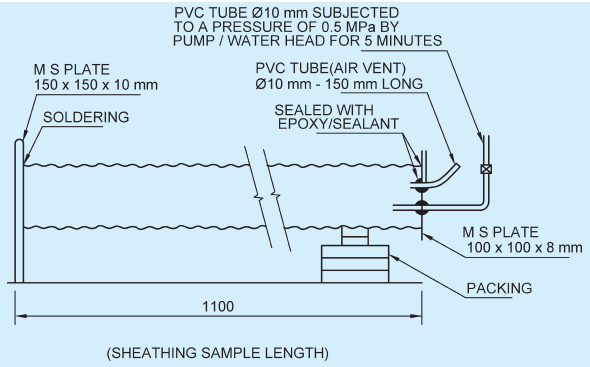


FIG. 12 TEST FOR WATER LOSS STUDY

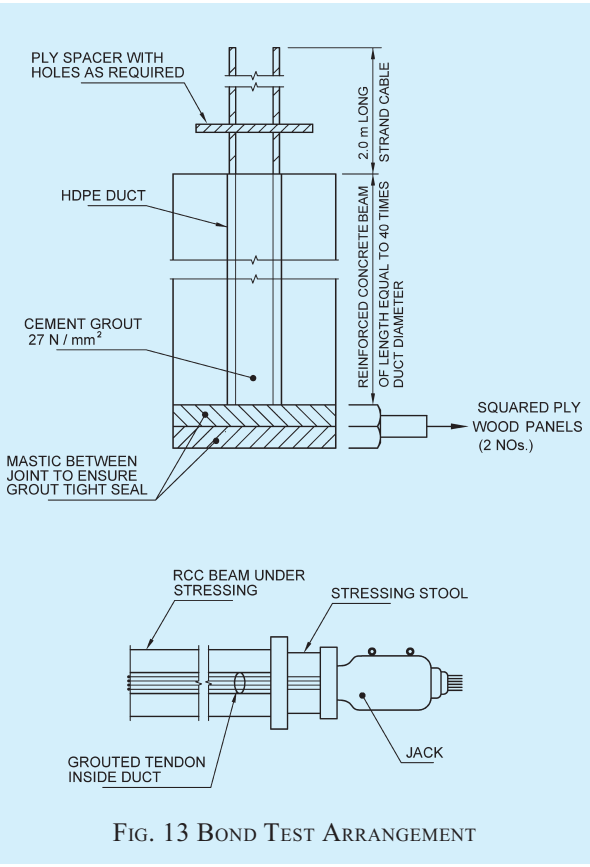


FIG. 13 BOND TEST ARRANGEMENT

and fill the duct with grout of strength not less than 27 N/mm^2. When the grout has attained the necessary strength, stress the tendon slowly increasing the load to the failure capacity. The failure capacity of the bond shall be at least equal to the anchorage efficiency or 0.95 of failure capacity of the tendon. At least 3 tests shall be carried out to ascertain the adequacy of the duct.

A-4.2 Compression Test for the Loss of Wall Thickness

A-4.2.1 The test is carried out to establish the wear and tear of the sheathing material and the rigidity of the duct surface against indentation and abrasion under concentrated line loading from the tendon constituents. The test requires the following equipment:

a) Three concrete blocks,
b) One 1 000 mm long strand forming the tendon,
c) A 3 MN press,
d) A loading beam of 300 mm length to transmit 5 kN load,
e) A rubber pad for placing between the press and the beam for uniform and constant load transfer,
f) A bearing plate with a mono strand jack to pull the strand under loaded condition, and
g) A digital caliper.

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A-4.2.2 *Method*

Cast three concrete cubes of 300 mm size, of the same strength as a main structure, with half cut HDPE sheathing ducts embedded in it at the top as shown in Fig. 14. Care shall be exercised to ensure that the duct surface has uniform contact with concrete all around. Place the concrete block over the press with a 1 000 mm length of strand forming the tendon placed in the duct and apply the 5 kN uniform load gradually as shown. Pull the strand under the stressed condition by 200 mm across the duct. Repeat the test on all the 3 ducts so embedded. Measure the indentations formed in all the 3 ducts along the length of the strand, by means of digital caliper. The residual thickness of the duct shall not be less than 1.5 mm.

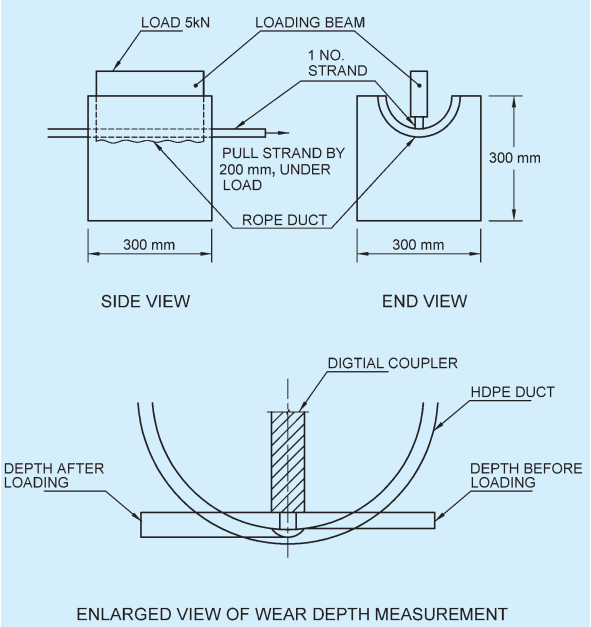


FIG. 14 COMPRESSION TEST ARRANGEMENT

A-5 SPECIFICATION FOR SHEATHING DUCT JOINTS

The sheathing ducts shall be of the spiral corrugated type. For major projects, the sheathing ducts should preferably be manufactured at the project site utilizing appropriate machines. With such an arrangement, long lengths of sheathing ducts may be used with consequent reduction in the number of joints and couplers.

Where sheathing duct joints are unavoidable, such joints shall be made cement slurry tight by the use of corrugated threaded sleeve couplers which can be tightly screwed on to the outer side of the sheathing ducts. A heat-shrink coupler could also be used if suitable.

Typical details of a sleeve coupler is shown in Fig. 15. The length of the coupler should not be less than 150 mm but should be increased upto 200 mm, wherever practicable. The joints between the ends of the coupler and the duct shall be sealed with adhesive sealing tape to prevent penetration of cement slurry during concreting. The couplers of adjacent ducts should be staggered wherever practicable. As far as possible, couplers should not be located in curved zones. The corrugated sleeve couplers are being conveniently manufactured using the sheath making machine with the next higher size of die set.

The heat-shrink coupler (*see* Fig. 16) is supplied in the form of bandage rolls which can be used for all diameters of sheathing ducts. The bandage is coated on the underside with a heat sensitive adhesive so that after heating the bandage material shrinks on to the sheathing duct and ensures formation of a leak proof joint, without the need for extra taping or support in the form of corrugated sleeve couplers. The heating is effected by means of a soft gas flame.

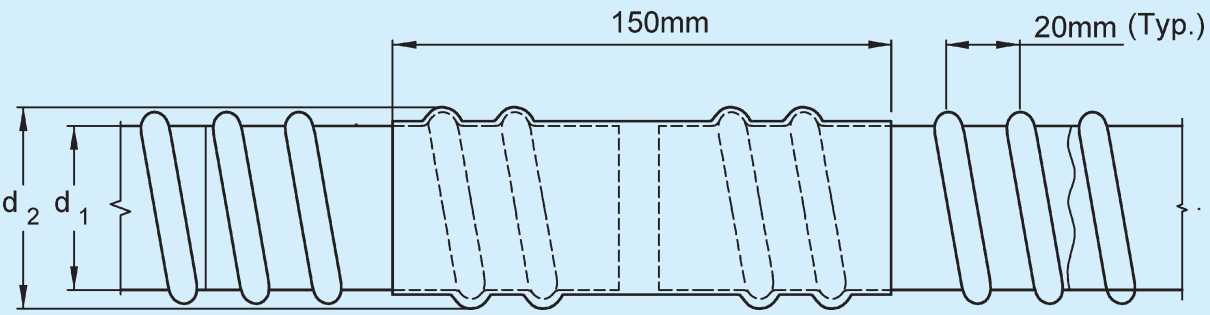


FIG. 15 TYPICAL DETAILS OF A SLEEVE COUPLER

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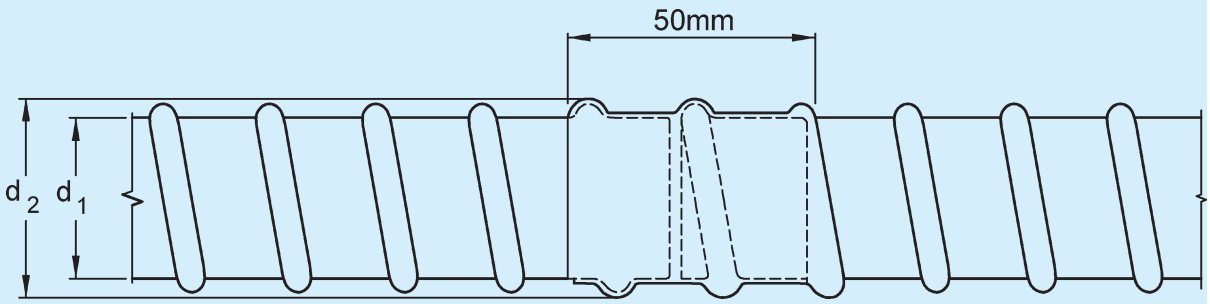


FIG. 16 TYPICAL DETAILS OF HEAT-SHRINK COUPLERE

ANNEX B

(*Clause* 12.1.4.4)

TESTING OF SYSTEMS WITH MECHANICAL ANCHORAGES

B-1 STATIC LOAD TEST WITH TENDON-ANCHORAGE ASSEMBLY

The aim of the test is to assess the performance of the tendon-anchorage assembly and to determine any decrease of the breaking load of the prestressing steel due to the influence of the anchorage. The test is also relevant for couplings.

B-1.1 Test Specimen

The tendon and anchorage to be tested should be assembled according to the envisaged application, using all the components necessary for anchoring the tendon. The geometrical configuration of the individual wires, strands or bars in the specimen should be identical to that of the actual tendon-anchorage assembly and so the following properties should be established:

a) Main geometrical and mechanical properties of the prestressing steel used in the test;
b) Actual mean breaking load;
c) Mean total elongation at maximum load;
d) Mean cross-section;
e) Surface characteristics, etc; and
f) Minimum of 3 single unit tensile tests.

Relevant geometrical and mechanical properties of anchorage components should also be determined. The free length of the individual wires, strands or bars in the specimen to be tested should be not less than 3.0 m.

If one grade of prestressing steel of the same type is to be used with the same type of anchorage, the tests should be performed using the grade with the highest characteristic tensile strength.

B-1.2 Test Procedure

The tendon specimen is mounted in a calibrated test rig or testing machine and should be stressed in increments of force corresponding to 20 percent, 40 percent, 60 percent and 80 percent of the characteristic tensile strength of the prestressing steel, f_p. In each increment the force is increased at a constant force rate corresponding to about 100 MPa per min. At the 80 percent level, the force is held constant for 1 h. Subsequently, the force is increased gradually to total failure.

The described test procedure is normally applicable to systems where the prestressing steel is connected to the anchorage before applying the stressing force. In systems where the prestressing level is locked in the anchorage after the stressing force has been applied, the above test procedure should be adapted as follows:

a) The tendon should be mounted in the test rig or testing machine, using an identical geometrical configuration of the individual wires, strands or bars in the specimen to that in the actual tendon-anchorage assembly.
b) The tendon should be stressed at one end with the equipment used on the construction site in steps as described to 80 percent of the characteristic tensile strength of prestressing steel, f_p.

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c) After the tendon has been locked at this force, the further testing procedure should be as previously described.

The test can be carried out in the manner described in the first instance if it can be proved that locking the prestressing steel in anchorage after the stressing force has been applied has no significant influence on the behaviour of the tendon-anchorage assembly.

B-1.3 Measurements and Observations

The following measurements and observations should be made and recorded:

a) Relative force and time dependent displacement Δa of the prestressing steel with respect to the anchorage (*see* Fig. 17),
b) Relative force and time dependent displacement Δb between the individual components of the anchorage (*see* Fig. 17),
c) Deformation of the anchorage components,
d) Elongation of the tendon on free length up to failure,
e) Measured ultimate force F_{Tu}, and
f) Location and mode of failure.

B-1.4 Test Requirements

The test result should meet the following requirements:

a) Residual deformations of anchorage components after the test should confirm the reliability of the anchorage.
b) The increase in the displacements between the anchorage components as well as between the prestressing steel and anchorage components should not be disproportionate to the increase in tendon force.
c) The above relative displacements during the 0.8 f_{pk} load stage should stabilize within the first 30 min of the load duration of 1 h.
d) The mode of failure of tendon should be by the fracture of the prestressing steel. Failure of the tendon should not be induced by the failure of anchorage components.
e) The measured anchorage efficiency is:

$$\eta_A = \frac{F_{Tu}}{F_{pm}} \geq 0.95$$

where

F_{pm} = actual mean breaking load.

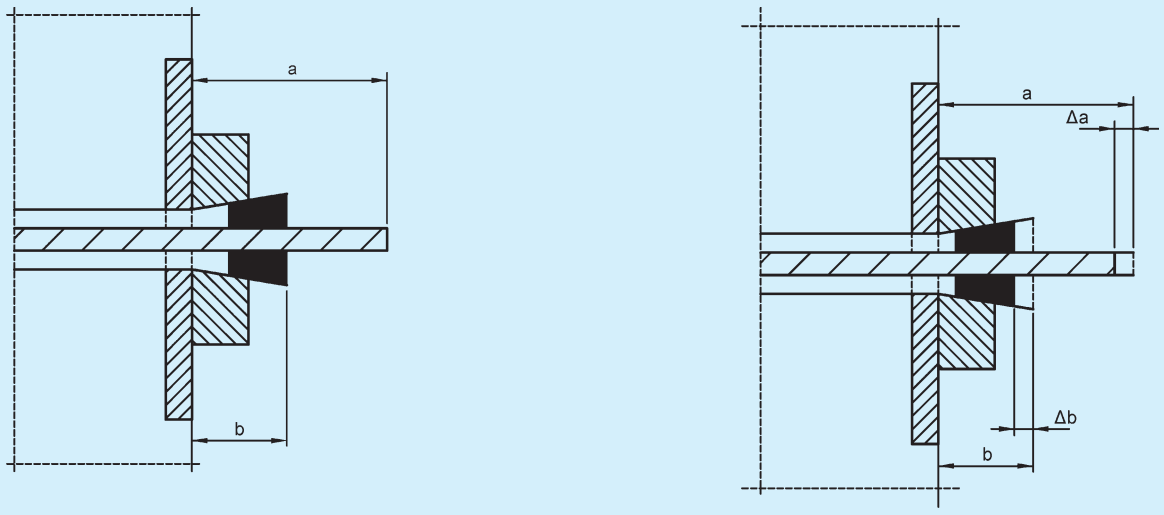
The total elongation in free length of the tendon under the load F_{Tu} should be not less than 2 percent.

B-2 DYNAMIC LOAD TEST WITH TENDON-ANCHORAGE ASSEMBLY

The aim of the test is to determine the capacity of the tendon-anchorage assembly under load fluctuations as an indication of the reliability and durability of the assembly.

B-2.1 Test Specimen

The type of specimen should correspond to the requirements of section **B-1.1**. If one grade of prestressing steel of the same type is to be used with the same type of anchorage, the tests should be performed with prestressing steel using the grade with the highest characteristic tensile strength.



17A BEFORE LOCKING

17B BEFORE LOCKING

FIG. 17 DISPLACEMENTS DURING TESTING

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Where the capacity of the testing machine to be used could be exceeded, the number of wires, strands or bars in the tendon-anchorage assembly to be tested may be reduced, provided that the prestressing steel units with the most severe angular deviation of tendon axis from the prescribed are included and that the test results are representative for the complete tendon.

B-2.2 Test Procedure

The test should be performed in a tensile testing machine with a pulsator at a constant force frequency of not more than 500 load cycles per min, and with a constant upper force of 65 percent of the characteristic strength of the prestressing steel. The range of forces, $\Delta f = F_{max} - F_{min}$ should be maintained at a constant level throughout testing.

The specimen should be tested in such a way that secondary oscillations are precluded. When assembling the specimen and fitting it in the testing machine, special care should be taken to ensure that the force is evenly distributed to all the tensile elements of the tendon. In the case of grouted tendons special devices may be used to avoid premature fretting failure of the prestressing steel remote from the anchorage.

B-2.3 Measurements and Observations

The following measurements and observations should be made and recorded:

a) Relative displacement between prestressing steel and individual anchorage components as well as between the anchorage components themselves, depending on load and on number of load cycles (*see* Fig. 17).

b) Examination of anchorage components and prestressing steel after test with respect to fatigue damage and deformation.

B-2.4 Steel Requirements

Each test result should meet the following requirements:

a) Fatigue failure of anchorage components should not occur.

b) The minimum fatigue strength of a post-tensioning system should be $\Delta\sigma_{p\,Min} = 80$ MPa.

The fatigue strength is defined as the stress range $\Delta\sigma_p$ which is endured for 2 million cycles without failure of 5 percent of the initial cross-section of the tested tendon at beginning of the test.

B-3 LOAD TRANSFER TEST

With the load transfer test, the transfer of the prestressing force from the mechanical anchorage and its components to the concrete should be verified.

B-3.1 Test Specimen

The test specimen is schematically depicted in Fig. 18. The specimen should contain those anchorage components which will also be embedded in the structural concrete. Their arrangement should comply with the practical application and with the prestressing contractor's specification.

The test specimen should be a concrete prism tested in axial compression.

The part of the specimen containing the anchorage should be provided with bursting reinforcement of the same size and configuration as specified for the particular system and tendon, respectively. Reinforcement may be used for the assembly of the bursting reinforcement. It should not be considered part of the technical approval, if the following conditions are not complied with:

a) Longitudinal bars have a total cross-section more than 200 mm^2.

b) Stirrups, that is, the secondary reinforcement, uniformly distributed along the height of specimen, should constitute more than 0.05 t steel per cubic metre of concrete.

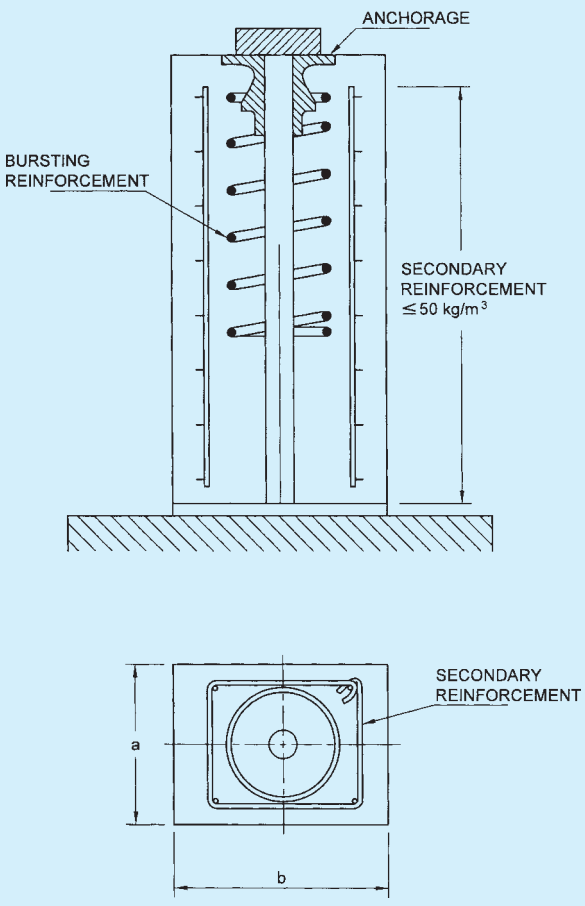


FIG. 18 TEST SPECIMEN FOR LOAD TRANSFER TEST

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The concrete of the test specimen should correspond to the actual concrete used for prestressed concrete structures with respect to materials, composition, compaction and its characteristic strength f_{ck}. After casting, the specimen should be demoulded after one day and then moist-cured until testing. The cubes cast for the determination of compressive strength should be treated similarly.

B-3.2 Test Procedure

The specimen should be mounted in a calibrated test rig or testing machine. The load should be applied corresponding to actual loading conditions in the structure either by loading the tendon or by applying the force directly to the anchorage. The force is increased in increments of 20 percent from 0 percent up to 80 percent of the characteristic strength of the prestressing steel, f_p (*see* Fig. 19).

After reaching the load 0.8 f_p at least ten slow load cycles should be performed, with at least 0.8 f_p and 0.12 f_p being the upper and lower load limits, respectively. The necessary number of load cycles depends upon the stabilization of strain readings and crack widths as described below. Following cyclic loading, the specimen should be loaded incrementally to failure.

During cyclic loading, measurements should be taken at the upper and lower loads of several cycles in order to decide whether a satisfactory stabilization of strains and crack widths is being attained. Cyclic loading should be continued until stabilization is satisfactory (*see* **B-3.4**). Figure 19 shows the sequence of loading and measurements.

At the final test to failure the mean compressive strength ($f_{cm.e}$) of concrete of specimen should be:

$$f_{cm.e} \leq f_{ck.o} \text{ and } f_{cm.e} \leq 0.85 f_{ck}$$

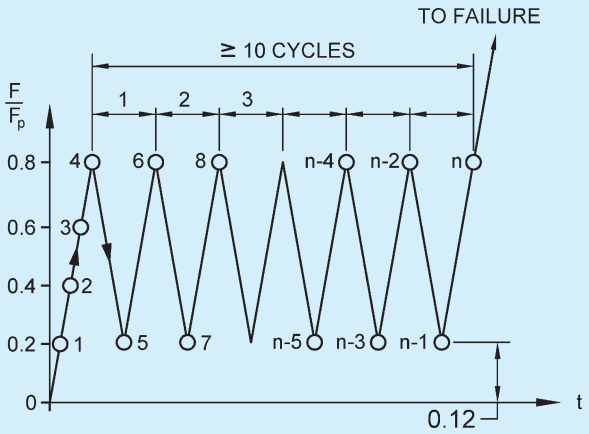


FIG. 19 PROCEDURE FOR THE LOAD TRANSFER TEST

B-3.3 Measurements and Observations

The following measurements and observations should be taken and recorded:

a) Longitudinal and transverse concrete strains on the side faces of the specimen in the region of maximum bursting effect under the upper and lower load at different times for increasing numbers of load cycles.

b) Formation, width and propagation of cracks on the side faces of the specimen, as mentioned above.

c) Visual inspection and/or measurement of deformation of anchorage components in contact with the concrete.

d) Location and mode of failure.

B-3.4 Requirements

Each specimen should meet the following requirements (*see* Fig. 20):

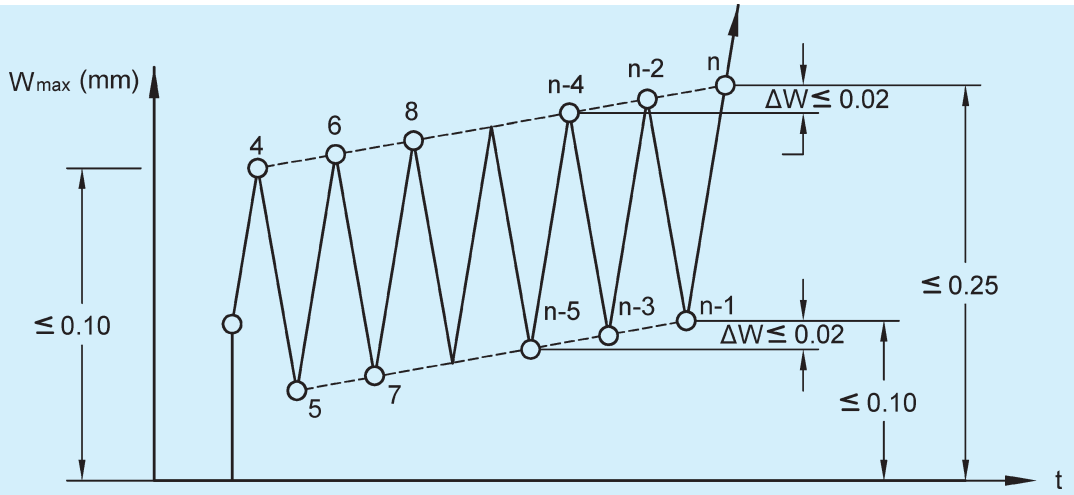


FIG. 20 REQUIREMENTS FOR CRACK WIDTHS

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a) Crack width upon first attainment of upper force 0.8 (load point 4) should be ≤ 0.10 mm.

b) Crack width upon last attainment of lower force 0.12 (load point n-1) should be ≤ 0.10 mm.

c) Crack width upon final attainment of upper force 0.8 (load point n) should be ≤ 0.25 mm.

d) Readings of longitudinal and transverse strains should have stabilized during cyclic loading. The strains can be assumed to have stabilized if the increase of strain in last two load cycles is less than 5 percent.

e) Readings of crack widths should have stabilized during cyclic loading. The crack widths can be assumed to have stabilized if the crack width does not increase by 0.02 mm in the last two load cycles.

f) The measured failure load F_u shall meet each of the following requirements:

$$F_u \geq F_p \frac{f_{cm.e}}{f_{ck.o}} \text{ and } F_u \geq 1.1F_p$$

ANNEX C

(*Clauses* 18.6.2.2 *and* 22.1.2)

MOMENTS OF RESISTANCE FOR RECTANGULAR AND T-SECTIONS

C-1 The moment of resistance of rectangular sections or T-sections in which neutral axis lies within the flange may be obtained as follows:

$$M_u = f_{pb} A_{ps} (d - 0.42x_u)$$

where

M_u = moment of resistance of the section,

f_{pb} = tensile stress in the tendon at failure,

f_{pe} = effective prestress in tendon,

A_{ps} = area of pretensioning tendons in the tension zone,

d = effective depth to the centroid of the steel area, and

x_u = neutral axis depth.

For pre-tensioned members and for post-tensioned members with effective bond between the concrete and tendons, values of f_{pb} and x_u are given in Table 11. It shall be ensured that the effective prestress after all losses is not less than 0.45 f_{pu}, where f_{pu} is the characteristic tensile strength of tendon. Prestressing tendons in the compression zone should be ignored in the strength calculations when using this method.

Table 11 Conditions at the Ultimate Limit State for Rectangular Beams With Pre-Tensioned Tendons or With Post-Tensioned Tendons Having Effective Bond

(*Clause* C-1)

Sl No.	$\frac{A_{ps} \cdot f_{pu}}{bd \cdot f_{ck}}$	Stress in Tendon as a Proportion of the Design Strength $\frac{f_{pb}}{0.87 \cdot f_{pu}}$		Ratio of the Depth of Neutral Axis to that of the Centroid of the Tendon in the Tension Zone x_u/d	
		Pre-Tensioning	Post-Tensioning with Effective Bond	Pre-Tensioning	Post-Tensioning with Effective Bond
(1)	(2)	(3)	(4)	(5)	(6)
i)	0.025	1.0	1.0	0.054	0.054
ii)	0.05	1.0	1.0	0.109	0.109
iii)	0.10	1.0	1.0	0.217	0.217
iv)	0.15	1.0	1.0	0.326	0.316
v)	0.20	1.0	0.95	0.435	0.414[1)]
vi)	0.25	1.0	0.90	0.542	0.488[1)]
vii)	0.30	1.0	0.85	0.655	0.558[1)]
viii)	0.40	0.9	0.75	0.783	0.653[1)]

[1)] The neutral axis depth in these cases is too low to provide the necessary elongation for developing 0.87 f_{pu} stress level. Hence, it is essential that the strength provided exceeds the required strength by 15 percent for these cases.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Subsection.

	IS No.	*Title*
(1)	4845 : 1968	Definitions and terminology relating to hydraulic cement
	6461	Glossary of terms relating to cement concrete:
	(Part 1) : 1972	Concrete aggregates
	(Part 2) : 1972	Materials (other than cement and aggregate)
	(Part 3) : 1972	Concrete reinforcement
	(Part 4) : 1972	Types of concrete
	(Part 5) : 1972	Formwork for concrete
	(Part 6) : 1972	Equipment, tools and plant
	(Part 7) : 1973	Mixing, laying, compaction, curing and other construction aspects
	(Part 8) : 1973	Properties of concrete
	(Part 9) : 1972	Structural aspects
	(Part 10) : 1973	Tests and testing apparatus
	(Part 11) : 1973	Prestressed concrete
	(Part 12) : 1973	Miscellaneous
(2)	269 : 2015	Specification for ordinary Portland cement (*sixth revision*)
	8041 : 1990	Specification for rapid hardening Portland cement (*second revision*)
	455 : 2015	Specification for Portland slag cement (*fifth revision*)
	1489	Specification for Portland pozzolana cement:
	(Part 1) : 2015	Fly ash based (*fourth revision*)
	(Part 2) : 2015	Calcined clay based (*fourth revision*)
	8043 : 1991	Specification for hydrophobic Portland cement (*second revision*)
	12600 : 1989	Specification for low heat Portland cement
	12330 : 1988	Specification for sulphate resisting Portland cement
(3)	12600 : 1989	Specification for low heat Portland cement
(4)	6452 : 1989	Specification for high alumina cement for structural use (*first revision*)
(5)	6909 : 1990	Specification for supersulphated cement (*first revision*)
(6)	383 : 2016	Specification for coarse and fine aggregates for concrete (*third revision*)
(7)	1785(Part 1) : 1983	Specification for plain hard drawn steel wire for prestressed concrete: Part 1 Cold drawn stress relieved wire (*second revision*)
	6003 : 2010	Specification for indented wire for prestressed concrete (*second revision*)
	2090 : 1983	Specification for high tensile steel bars used in prestressed concrete (*first revision*)
	6006 : 2014	Specification for uncoated stress relieved strand for prestressed concrete (*second revision*)
	14268 : 1995	Specification for uncoated stress relieved low relaxation seven ply strand for prestressed concrete
(8)	432 (Part 1) : 1982	Specification for mild steel and medium tensile steel bars and hard-drawn steel wire for concrete reinforcement: Part 1 Mild steel and medium tensile steel bars (*third revision*)
	1786 : 2008	Specification for high strength deformed steel bars and wire for concrete reinforcement (*fourth revision*)
	1566 : 1982	Specification for hard-drawn steel wire fabric for concrete reinforcement (*second revision*)
(9)	4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
(10)	516 : 1959	Method of test for strength of concrete
	5816 : 1999	Method of test for splitting tensile strength of concrete (*first revision*)
(11)	1489 (Part 1) : 2015	Specification for Portland pozzolana cement: Part 1 Fly ash based (*fourth revision*)
(12)	455 : 2015	Specification for Portland slag cement (*fifth revision*)

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IS No.	*Title*
(13) 3812 (Part 1) : 2013	Specification for pulverized fuel ash: Part 1 For use as pozzolana in cement, cement mortar and concrete (*third revision*)
(14) 12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
(15) 4925 : 2004	Specification for concrete batching and mixing plant (*first revision*)
(16) 4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
(17) 2386 (Part 3) : 1963	Methods of test for aggregates for concrete: Part 3 Specific gravity, density, voids, absorption and bulking
(18) 1791 : 1985	General requirements for batch type concrete mixers (*second revision*)
12119 : 1987	General requirements for pan mixers for concrete
(19) 1199 : 1959	Methods of sampling and analysis of concrete
(20) 9103 : 1999	Specification for admixtures for concrete (*first revision*)
(21) 7861	Code of practice for extreme weather concreting:
(Part 1) : 1975	Recommended practice for hot weather concreting
(Part 2) : 1981	Recommended practice for cold weather concreting
(22) 516 : 1959	Method of test for strength of concrete

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 6 Steel

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Section 6) covers the structural design aspects of steel structures in buildings.

This Section covers the use of hot-rolled structural steel sections and steel tubes in buildings. It covers the design by limit state method and plastic theory, and also enables design by working stress method.

This Section is based on IS 800 : 2007 'Code of practice for general construction in steel (*third revision*)' and IS 806 : 1968 'Code of practice for use of steel tubes in general building construction (*first revision*)'.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005. In the 2005 version, the detailed design provisions were not included as IS 800 : 1984 'Code of practice for general construction in steel (*second revision*)' was under revision at that time. This Section, therefore, then referred to the 1984 version of IS 800 with the remarks that the latest version would prevail, as and when published. It, however, covered the philosophical aspects of limit state design which was being introduced in the revision of IS 800. IS 800 was subsequently revised and published as IS 800 : 2007 and hence, became the prevailing version for use under this Section.

In the revision of IS 800 in 2007, in view of the development and production of new varieties of medium and high tensile structural steels in the country, the scope of the standard was modified permitting the use of any variety of structural steel provided the relevant provisions of the standard were satisfied. IS 800 : 2007 makes reference to the latest Indian Standards available for rivets, bolts and other fasteners. The standard is based on limit state method, reflecting the latest developments.

This revision of the Section is intended to bring it in line with the revised version of IS 800 : 2007 read with its Amendment No. 1 and to take care of further improvements and incorporations required. In this revision, therefore, the following major modifications have been made:

a) The table on tensile properties of structural steel products has been updated by including yield stress values of bolts of sizes 3.6 to 6.8 mm as per IS 1367 (Part 3) 'Mechanical properties of fasteners made of carbon steel and alloy steel – bolts, screws and studs (*fourth revision*)' and aligning the corresponding provisions of the table with those given in IS 2062 : 2011 'Hot rolled low, medium and high tensile structural steel (*seventh revision*)'.
b) Provisions relating to mechanical properties of structural steel have been elaborated.
c) Provisions related to effective wind pressure on exposed circular tube members have been included.
d) Provisions related to requirement of temperature stress analysis have been updated.
e) Provisions related to slender cross-sections have been updated, with the inclusion of two new figures on effective sections of slender members under pure and flexural compression.
f) The table on deflection limits has been suitably updated with respect to the load nomenclature of the load and their combinations.
g) The term 'imposed load' has been substituted for 'live load' in coherence with the use of terminology in other published standards.
h) Warping restraint conditions in the table on effective lengths for simply supported beams have been clarified.
j) The provision on assessment of conditions under which fatigue assessment is to be done, is covered comprehensively in **19.2.1.2** 'Necessity for Fatigue Assessment', which takes care of **13.5.1** of IS 800 : 2007 as well.
k) Provisions related to design of end panels in stiffened web panels have been updated.
m) Provisions related to design for earthquake loads relating to load and load combinations, response reduction factor for various types of frames, connections in the critical zones of frames, and bracing members have been updated.
n) The nominal bearing pressure between the column base plate and the support has been updated to bring

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it line with the corresponding provisions of IS 456 : 2000 'Code of practice for plain and reinforced concrete (*fourth revision*)'.

p) Provisions related to design of single angle struts loaded through one leg have been revised.

q) Provisions related to non-ductile braced and moment resisting frames have been included.

r) Provisions on ductile designing with respect to column base connections have been updated.

s) Reference design conditions under fatigue for S-N curve have been modified.

t) Provisions on clearances related to fabrication procedures have been updated.

u) Sketches of the restraint conditions under table on effective lengths of single stepped columns have been updated.

w) Certain terminologies, symbols and figures have been updated based on the changes incorporated.

y) List of Indian Standards cross-referred in this Section has been updated.

The revised Section will enhance the confidence of designers, engineers, contractors, technical institutions, professional bodies and the industry and will open a new era in safe and economic construction in steel.

In the earlier versions of this Code, the provisions relating to the use of steel tubes in general building construction was based on IS 806 : 1968 'Code of practice for use of steel tubes in general building construction', which was complementary to IS 800. The design using tubular steel in structural applications may be carried using the limit state design provisions in this Section until IS 806 is revised as per limit state design method.

The design of cold-formed steel members is based on the provisions of IS 801 : 1975 'Code of practice for use of cold formed light gauge steel structural members in general building construction'. The standard is currently under revision to be based on the limit state design practice. Until the revised IS 801 is published, the cold formed steel members may be designed using the current IS 801, based on the working stress method.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 6 Steel

SECTION 6(a) GENERAL

1 SCOPE

1.1 This Code (Part 6/Section 6) covers the structural design aspects of steel structures in buildings. This Section applies to general construction using hot rolled steel sections and steel tubes joined using riveting, bolting and welding. Cold formed light gauge steel sections, etc, are covered in separate standards. This Section covers the design by limit state method and plastic theory, and also enables design by working stress method.

1.2 This Section gives only general guidance as regards to the various loads to be considered in design. For the actual loads, such as dead, live, snow, wind and earthquake loads and load combinations to be used, reference may be made to Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

1.3 Fabrication and erection requirements covered in this Section are general and the minimum necessary quality of material and workmanship consistent with assumptions in the design rules. The actual requirements may be further developed as per other standards or the project specification, the type of structure and the method of construction.

1.4 For seismic design, recommendations pertaining to steel frames only are covered in this section. For more detailed information on seismic design of other structural and non-structural components, reference may be made to **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code and other special publications on the subject.

2 TERMINOLOGY

For the purpose of this Section, the definitions given below shall apply.

2.1 Accidental Loads — Loads due to explosion, impact of vehicles, or other rare loads for which the structure is considered to be vulnerable as per the user.

2.2 Accompanying Load — Live (imposed) load acting along with leading imposed load but causing lower actions and/or deflections.

2.3 Action Effect or Load Effect — The internal force, axial, shear, bending or twisting moment, due to external actions and temperature loads.

2.4 Action — The primary cause for stress or deformations in a structure such as dead, live, wind, seismic or temperature loads.

2.5 Actual Length — The length between centre-to-centre of intersection points, with supporting members or the cantilever length in the case of a free standing member.

2.6 Beam — A member subjected predominantly to bending.

2.7 Bearing Type Connection — A connection made using bolts in 'snug-tight' condition, or rivets where the load is transferred by bearing of bolts or rivets against plate inside the bolt hole.

2.8 Braced Member — A member in which the relative transverse displacement is effectively prevented by bracing.

2.9 Brittle Cladding — Claddings, such as asbestos cement sheets which get damaged before undergoing considerable deformation.

2.10 Buckling Load — The load at which an element, a member or a structure as a whole, either collapses in service or buckles in a load test and develops excessive lateral (out of plane) deformation or instability.

2.11 Buckling Strength or Resistance — Force or moment, which a member can withstand without buckling.

2.12 Built-Up Section — A member fabricated by interconnecting more than one element to form a compound section acting as a single member.

2.13 Camber — Intentionally introduced pre-curving (usually upwards) in a system, member or any portion of a member with respect to its chord. Frequently, camber is introduced to compensate for deflections at a specific level of loads.

2.14 Characteristic Load (Action) — The value of specified load (action), above which not more than a specified percentage (usually 5 percent) of samples of corresponding load are expected to be encountered.

2.15 Characteristic Yield/Ultimate Stress — The minimum value of stress, below which not more than a specified percentage (usually 5 percent) of corresponding stresses of samples tested are expected to occur.

2.16 Column — A member in upright (vertical) position which supports a roof or floor system and predominantly subjected to compression.

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2.17 Compact Section — A cross-section, which can develop plastic moment, but has inadequate plastic rotation capacity needed for formation of a plastic collapse mechanism of the member or structure.

2.18 Constant Stress Range — The amplitude between which the stress ranges under cyclic loading is constant during the life of the structure or a structural element.

2.19 Corrosion — An electrochemical process over the surface of steel, leading to oxidation of the metal.

2.20 Crane Load — Horizontal and vertical loads from cranes.

2.21 Cumulative Fatigue — Total damage due to fatigue loading of varying stress ranges.

2.22 Cut-Off Limit — The stress range, corresponding to the particular detail, below which cyclic loading need not be considered in cumulative fatigue damage evaluation (corresponds to 10^8 number of cycles in most cases).

2.23 Dead Loads — The self-weights of all permanent constructions and installations including the self-weight of all walls, partitions, floors, roofs, and other permanent fixtures acting on a member.

2.24 Deflection — It is the deviation from the standard position of a member or structure.

2.25 Design Life — Time period for which a structure or a structural element is required to perform its function without damage.

2.26 Design Load/Factored Load — A load value obtained by multiplying the characteristic load with the partial safety factor for loads.

2.27 Design Spectrum — Frequency distribution of the stress ranges from all the nominal loading events during the design life (stress spectrum).

2.28 Detail Category — Designation given to a particular detail to indicate the S-N curve to be used in fatigue assessment.

2.29 Discontinuity — A sudden change in cross-section of a loaded member, causing a stress concentration at the location.

2.30 Ductility — It is the property of the material or a structure indicating the extent to which it can deform beyond the limit of yield deformation before failure or fracture. The ratio of ultimate to yield deformation is usually termed as ductility.

2.31 Durability — It is the ability of a material to resist deterioration over long periods of time.

2.32 Earthquake Loads — The inertia forces produced in a structure due to the ground movement during an earthquake.

2.33 Edge Distance — Distance from the centre of a fastener hole to the nearest edge of an element measured perpendicular to the direction of load transfer.

2.34 Effective Lateral Restraint — Restraint that produces sufficient resistance to prevent deformation in the lateral direction.

2.35 Effective Length — Actual length of a member between points of effective restraints or effective restraint and free end, multiplied by a factor to take account of the end conditions in buckling strength calculations.

2.36 Elastic Cladding — Claddings, such as metal sheets that can undergo considerable deformation without damage.

2.37 Elastic Critical Moment — The elastic moment, which initiates lateral-torsional buckling of a laterally unsupported beam.

2.38 Elastic Design — Design, which assumes elastic behaviour of materials throughout the service load range.

2.39 Elastic Limit — It is the stress below which the material regains its original size and shape when the load is removed. In steel design, it is taken as the yield stress.

2.40 End Distance — Distance from the centre of a fastener hole to the edge of an element measured parallel to the direction of load transfer.

2.41 Erection Loads — The actions (loads and deformations) experienced by the structure exclusively during erection.

2.42 Erection Tolerance — Amount of deviation related to the plumbness, alignment, and level of the element as a whole in the erected position. The deviations are determined by considering the locations of the ends of the element.

2.43 Exposed Surface Area to Mass Ratio — The ratio of the surface area exposed to the fire (in mm^2) to the mass of steel (in kg).

NOTE — In the case of members with fire protection material applied, the exposed surface area is to be taken as the internal surface area of the fire protection material.

2.44 Fabrication Tolerance — Amount of deviation allowed in the nominal dimensions and geometry in fabrication activities, such as cutting to length, finishing of ends, cutting of bevel angles, etc.

2.45 Factor of Safety — The factor by which the yield stress of the material of a member is divided to arrive at the permissible stress in the material.

2.46 Fatigue — Damage caused by repeated fluctuations of stress, leading to progressive cracking of a structural element.

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2.47 Fatigue Loading — Set of nominal loading events, cyclic in nature, described by the distribution of the loads, their magnitudes and the numbers of applications in each nominal loading event.

2.48 Fatigue Strength — The stress range for a category of detail, depending upon the number of cycles it is required to withstand during design life.

2.49 Fire Exposure Condition

a) *Three-sided fire exposure condition* — Steel member incorporated in or in contact with a concrete or masonry floor or wall (at least against on surface).

NOTES

1 Three-sided fire exposure condition is to be considered separately unless otherwise specified (*see* **22.10**).

2 Members with more than one face in contact with a concrete or masonry floor or wall may be treated as three-sided fire exposure.

b) *Four-sided fire exposure condition* — Steel member, which may be exposed to fire on all sides.

2.50 Fire Protection System — The fire protection material and its method of attachment to the steel member.

2.51 Fire Resistance — The ability of an element, component or structure, to fulfil for a stated period of time, the required stability, integrity, thermal insulation and/or other expected performance specified in a standard fire test.

2.52 Fire Resistance Level — The fire resistance grading period for a structural element or system, in minutes, which is required to be attained in the standard fire test.

2.53 Flexural Stiffness — Stiffness of a member against rotation as evaluated by the value of bending deformation moment required to cause a unit rotation while all other degrees of freedom of the joints of the member except the rotated one are assumed to be restrained.

2.54 Friction Type Connection — Connection effected by using pre-tensioned high strength bolts where shear force transfer is due to mobilization of friction between the connected plates due to clamping force developed at the interface of connected plates by the bolt pre-tension.

2.55 Gauge — The spacing between adjacent parallel lines of fasteners, transverse to the direction of load/stress.

2.56 Gravity Load — Loads arising due to gravitational effects.

2.57 Gusset Plate — The plate to which the members intersecting at a joint are connected.

2.58 High Shear — High shear condition is caused when the actual shear due to factored load is greater than a certain fraction of design shear resistance (*see* **15.2.2**).

2.59 Imposed (Live) Load — The load assumed to be produced by the intended use or occupancy including distributed, concentrated, impact, vibration and snow loads but excluding, wind, earthquake and temperature loads.

2.60 Instability — The phenomenon which disables an element, member or a structure to carry further load due to excessive deflection lateral to the direction of loading and vanishing stiffness.

2.61 Lateral Restraint for a Beam — *See* **2.34**.

2.62 Leading Imposed Load — Imposed load causing higher action and/or deflection.

2.63 Limit State — Any limiting condition beyond which the structure ceases to fulfill its intended function (*see also* **2.86**).

2.64 Live Load — *See* **2.59**.

2.65 Load — An externally applied force or action (*see also* **2.4**).

2.66 Main Member — A structural member, which is primarily responsible for carrying and distributing the applied load or action.

2.67 Mill Tolerance — Amount of variation allowed from the nominal dimensions and geometry, with respect to cross-sectional area, non-parallelism of flanges, and out of straightness such as sweep or camber, in a product, as manufactured in a steel mill.

2.68 Normal Stress — Stress component acting normal to the face, plane or section.

2.69 Partial Safety Factor — The factor normally greater than unity by which either the loads (actions) are multiplied or the resistances are divided to obtain the design values.

2.70 Period of Structural Adequacy under Fire — The time (t), in minutes, for the member to reach the limit state of structural inadequacy in a standard fire test.

2.71 Permissible Stress — When a structure is being designed by the working stress method, the maximum stress that is permitted to be experienced in elements, members or structures under the nominal/service load (action).

2.72 Pitch — The centre-to-centre distance between individual fasteners in a line, in the direction of load/stress.

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2.73 Plastic Collapse — The failure stage at which sufficient number of plastic hinges have formed due to the loads (actions) in a structure leading to a failure mechanism.

2.74 Plastic Design — Design against the limit state of plastic collapse.

2.75 Plastic Hinge — A yielding zone with significant inelastic rotation, which forms in a member, when the plastic moment is reached at a section.

2.76 Plastic Moment — Moment capacity of a cross-section when the entire cross-section has yielded due to bending moment.

2.77 Plastic Section — Cross-section, which can develop a plastic hinge and sustain plastic moment over sufficient plastic rotation required for formation of plastic failure mechanism of the member or structure.

2.78 Poisson's Ratio — It is the absolute value of the ratio of lateral strain to longitudinal strain under uniaxial loading.

2.79 Proof Stress — The stress to which high strength friction grip (HSFG) bolts are pre-tensioned.

2.80 Proof Testing — The application of test loads to a structure, sub-structure, member or connection to ascertain the structural characteristics of only that specific unit.

2.81 Prototype Testing — Testing of structure, sub-structure, members or connections to ascertain the structural characteristics of that class of structures, sub-structures, members or connections that are nominally identical (full scale) to the units tested.

2.82 Prying Force — Additional tensile force developed in a bolt as a result of the flexing of a connection component such as a beam end plate or leg of an angle.

2.83 Rotation — The change in angle at a joint between the original orientation of two linear member and their final position under loading.

2.84 Secondary Member — Member which is provided for overall stability and or for restraining the main members from buckling or similar modes of failure.

2.85 Semi-Compact Section — Cross-section, which can attain the yield moment, but not the plastic moment before failure by plate buckling.

2.86 Serviceability Limit State — A limit state of acceptable service condition exceedance of which causes serviceability failure.

2.87 Shear Force — The in-plane force at any transverse cross-section of a straight member of a column or beam.

2.88 Shear Lag — The in plane shear deformation effect by which concentrated forces tangential to the surface of a plate gets distributed over the entire section perpendicular to the load over a finite length of the plate along the direction of the load.

2.89 Shear Stress — The stress component acting parallel to a face, plane or cross-section.

2.90 Slender Section — Cross-section in which the elements buckle locally before reaching yield moment.

2.91 Slenderness Ratio — The ratio of the effective length of a member to the radius of gyration of the Cross-section about the axis under consideration.

2.92 Slip Resistance — Limit shear that can be applied in a friction grip connection before slip occurs.

2.93 S-N Curve — The curve defining the relationship between the number of stress cycles to failure (N_{sc}) at a constant stress range (S_c), during fatigue loading of a structure.

2.94 Snow Load — Load on a structure due to the accumulation of snow and ice on surfaces such as roof.

2.95 Snug Tight — The tightness of a bolt achieved by a few impacts of an impact wrench or by the full effort of a person using a standard spanner.

2.96 Stability Limit State — A limit state corresponding to the loss of static equilibrium of a structure by excessive deflection transverse to the direction of predominant loads.

2.97 Stickability — The ability of the fire protection system to remain in place as the member deflects under load during a fire test.

2.98 Stiffener — An element used to retain or prevent the out-of-plane deformations of plates.

2.99 Strain — Deformation per unit length or unit angle.

2.100 Strain Hardening — The phenomenon of increase in stress with increase in strain beyond yielding.

2.101 Strength — Resistance to failure by yielding or buckling.

2.102 Strength Limit State — A limit state of collapse or loss of structural integrity.

2.103 Stress — The internal force per unit area of the original cross-section.

2.104 Stress Analysis — The analysis of the internal force and stress condition in an element, member or structure.

2.105 Stress Cycle Counting — Sum of individual stress cycles from stress history arrived at using any rational method.

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2.106 Stress Range — Algebraic difference between two extremes of stresses in a cycle of loading.

2.107 Stress Spectrum — Histogram of stress cycles produced by a nominal loading event design spectrum, during design life.

2.108 Structural Adequacy for Fire — The ability of the member to carry the test load exposed to the standard fire test.

2.109 Structural Analysis — The analysis of stress, strain, and deflection characteristics of a structure.

2.110 Strut — A compression member, which may be oriented in any direction.

2.111 Sway — The lateral deflection of a frame.

2.112 Sway Member — A member in which the transverse displacement of one end, relative to the other is not effectively prevented.

2.113 Tensile Stress — The characteristic stress corresponding to rupture in tension, specified for the grade of steel in the appropriate Indian Standard, as listed in Table 1.

2.114 Test Load — The factored load, equivalent to a specified load combination appropriate for the type of test being performed.

2.115 Transverse — Direction along the stronger axes of the cross-section of the member.

2.116 Ultimate Limit State — The state which, if exceeded can cause collapse of a part or the whole of the structure.

2.117 Ultimate Stress — *See* **2.113**.

2.118 Wind Loads — Load experienced by member or structure due to wind pressure acting on the surfaces.

2.119 Yield Stress — The characteristic stress of the material in tension before the elastic limit of the material is exceeded, as specified in the appropriate Indian Standard, as listed in Table 1.

3 SYMBOLS

Symbols used in this section shall have the following meanings with respect to the structure or member or condition, unless otherwise defined elsewhere in this Section:

A	—	Area of cross-section
A_c	—	Area at root of threads
A_e	—	Effective cross-sectional area
A_{ef}	—	Reduced effective flange area
A_f	—	Total flange area
A_g	—	Gross cross-sectional area
A_{gf}	—	Gross cross-sectional area of flange
A_{go}	—	Gross cross-sectional area of outstanding (not connected) leg of a member
A_n	—	Net area of the total cross-section
A_{nb}	—	Net tensile cross-sectional area of bolt
A_{nc}	—	Net cross-sectional area of the connected leg of a member
A_{nf}	—	Net cross-sectional area of each flange
A_{no}	—	Net cross-sectional area of outstanding (not connected) leg of a member
A_{pb}	—	Nominal bearing area of bolt on any plate
A_q	—	Cross-sectional area of a bearing (load carrying) stiffener in contact with the flange
A_s	—	Tensile stress area
A_{sb}	—	Gross cross-sectional area of a bolt at the shank
A_{tg}	—	Gross sectional area in tension from the centre of the hole to the toe of the angle section/channel section, etc (Block shear failure, *see* **12.4**) perpendicular to the line of force
A_{tn}	—	Net sectional area in tension from the centre of the hole to the toe of the angle perpendicular to the line of force Block shear failure (*see* **12.4**)
A_v	—	Shear area
A_{vg}	—	Gross cross-sectional area in shear along the line of transmitted force (*see* **12.4**)
A_{vn}	—	Net cross-sectional area in shear along the line of transmitted force (*see* **12.4**)
a, b	—	Larger and smaller projection of the slab base beyond the rectangle circumscribing the column, respectively (*see* **13.4**)
a_o	—	Peak acceleration
a_1	—	Unsupported length of individual elements being laced between lacing points
B	—	Length of side of cap or base plate of a column
b	—	Outstand/width of the element
b_1	—	Stiff bearing length
b_e	—	Effective width of flange between pair of bolts

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b_f — Width of the flange

b_i — Width of flange as an internal element

b_o — Width of flange outstand

b_p — Panel zone width between column flanges at beam-column junction

b_s — Shear lag distance

b_t — Width of tension field

b_w — Width of outstanding leg

C — Centre-to-centre longitudinal distance of battens

C_m — Coefficient of thermal expansion

c — Spacing of transverse stiffener

c_b — Moment amplification factor for braced member

c_m — Moment reduction factor for lateral torsional buckling strength calculation

c_s — Moment amplification factor for sway frame

D — Overall depth/diameter of the cross-section

d — Depth of web, nominal diameter

d_2 — Twice the clear distance from the compression flange angles, plates or tongue plates to the neutral axis

d_h — Diameter of a bolt/ rivet hole

d_o — Nominal diameter of the pipe column or the dimensions of the column in the depth direction of the base plate

d_p — Panel zone depth in the beam-column junction

E — Modulus of elasticity for steel

$E(T)$ — Modulus of elasticity of steel at T°C

$E(20)$ — Modulus of elasticity of steel at 20°C

E_p — Modulus of elasticity of the panel material

F_{cdw} — Buckling strength of un-stiffened beam web under concentrated load

F_d — Factored design load

F_n — Normal force

F_o — Minimum proof pretension in high strength friction grip bolts

F_{psd} — Bearing capacity of load carrying stiffener

F_q — Stiffener force

F_{qd} — Stiffener buckling resistance

F_{test} — Test load

$F_{test,a}$ — Load for acceptance test

$F_{test, Min}$ — Minimum test load from the test to failure

$F_{test, R}$ — Test load resistance

$F_{test, S}$ — Strength test load

F_w — Design capacity of the web in bearing

F_x — External load, force or reaction

F_{xd} — Buckling resistance of load carrying web stiffener

f — Actual normal stress range for the detail category

f_1 — Frequency for a simply supported one way system

f_2 — Frequency of floor supported on steel girder perpendicular to the joist

f_a — Calculated stress due to axial force at service load

f_{abc} — Permissible bending stress in compression at service load

f_{ac} — Permissible compressive stress at service load

f_{abt} — Permissible bending stress in tension at service load

f_{apb} — Permissible bearing stress of the bolt at service load

f_{asb} — Permissible stress of the bolt in shear at service load

f_{at} — Permissible tensile stress at service load

f_{atb} — Permissible tensile stress of the bolt at service load

f_{aw} — Permissible stress of the weld at service load

f_b — Actual bending stress at service load

f_{bc} — Actual bending stress in compression at service load

f_{bd} — Design bending compressive stress corresponding to lateral buckling

f_{br} — Actual bearing stress due to bending at service load

f_{bt} — Actual bending stress in tension at service load

f_{bs} — Permissible bending stress in column base at service load

f_c — Actual axial compressive stress at service load

f_{cc} — Elastic buckling stress of a column, Euler buckling stress

f_{cd} — Design compressive stress

$f_{cr,b}$ — Extreme fibre compressive stress

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corresponding to elastic lateral buckling moment

f_e — Equivalent stress at service load

f_f — Fatigue stress range corresponding to 5×10^6 cycles of loading

f_{feq} — Equivalent constant amplitude stress

f_{fd} — Design normal fatigue strength

$f_{f, Max}$ — Highest normal stress range

f_{fn} — Normal fatigue stress range

f_{nw} — Normal stress in weld at service load

f_o — Proof stress

f_p — Actual bearing stress at service load

f_{pb} — Actual bearing stress in bending at service load

f_{psd} — Bearing strength of the stiffeners

f_r — Frequency

f_{sb} — Actual shear stress in bolt at service load

f_t — Actual tensile stress at service load

f_{tb} — Actual tensile stress of the bolt at service load

f_u — Characteristic ultimate tensile stress

f_{ub} — Characteristic ultimate tensile stress of the bolt

f_{um} — Average ultimate stress of the material as obtained from test

f_{up} — Characteristic ultimate tensile stress of the connected plate

f_v — Applied shear stress in the panel designed utilizing tension field action

f_w — Actual stress of weld at service load

f_{wd} — Design stress of weld at service load

f_{wn} — Nominal strength of fillet weld

f_x — Maximum longitudinal stress under combined axial force and bending

f_y — Characteristic yield stress

$f_y(T)$ — Yield stress of steel at T °C

$f_y(20)$ — Yield stress of steel at 20°C

f_{yb} — Characteristic yield stress of bolt

f_{yf} — Characteristic yield stress of flange

f_{ym} — Average yield stress as obtained from test

f_{yp} — Characteristic yield stress of connected plate

f_{yq} — Characteristic yield stress of stiffener material

f_{yw} — Characteristic yield stress of the web material

G — Modulus of rigidity for steel

g — Gauge length between centres of the holes perpendicular to the load direction, acceleration due to gravity

h — Depth of the section

h_b — Total height from the base to the floor level concerned

h_c — Height of the column

h_e — Effective thickness

h_f — Centre-to-centre distance of flanges

h_i — Thickness of fire protection material

h_L — Height of the lip

h_s — Storey height

h_y — Distance between shear centre of the two flanges of a cross-section

I — Moment of inertia of the member about an axis perpendicular to the plane of the frame

I_{fc} — Moment of inertia of the compression flange of the beam about the axis parallel to the web

I_{ft} — Moment of inertia of the tension flange of the beam about minor axis

I_q — Moment of inertia of a pair of stiffener about the centre of the web, or a single stiffener about the face of the web.

I_s — Second moment of inertia

I_{so} — Second moment of inertia of the stiffener about the face of the element perpendicular to the web

I_T — Transformed moment of inertia of the one way system (in terms of equivalent steel, assuming the concrete flange of width equal to the spacing of the beam to be effective)

I_t — St. Venant's torsion constant

I_w — Warping constant

I_y — Moment of inertia about the minor axis of the cross-section

I_z — Moment of inertia about the major axis of the cross-section

K_b — Effective stiffness of the beam and column

K_h — Reduction factor to account for the high strength friction grip connection bolts in oversized and slotted holes

KL — Effective length of the member

KL/r — Appropriate effective slenderness ratio of the section

KL/r_y — Effective slenderness ratio of the

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section about the minor axis of the section

KL/r_z — Effective slenderness ratio of the section about the major axis of the section

$\left(\frac{KL}{r}\right)_o$ — Actual maximum effective slenderness ratio of the laced column

$\left(\frac{KL}{r}\right)_e$ — Effective slenderness ratio of the laced column accounting for shear deformation

K_v — Shear buckling coefficient

K_w — Warping restraint factor

k — Regression coefficient

k_{sm} — Exposed surface area to mass ratio

K_y, K_z, K_{LT} — Moment amplification factors (*see* **10.4.2**, **10.4.3.1**, **10.4.3.3** and **15.3.2.2**)

L — Actual length, unsupported length, length centre-to-centre distance of the intersecting members, cantilever length

L_c — Length of end connection in bolted and welded members, taken as the distance between outermost fasteners in the end connection, or the length of the end weld, measured along the length of the member

L_{LT} — Effective length for lateral torsional buckling

L_m — Maximum distance from the restraint to the compression flange at the plastic hinge to an adjacent restraint (limiting distance)

L_o — Length between points of zero moment (inflection) in the span

l — Centre-to-centre length of the supporting member

l_e — Distance between prying force and bolt centre line

l_g — Grip length of bolts in a connection

l_j — Length of the joint

l_s — Length between points of lateral support to the compression flange in a beam.

l_v — Distance from bolt centre line to the toe of fillet weld or to half the root radius for a rolled section

l_w — Length of weld

M — Bending moment

M_a — Applied bending moment

M_{cr} — Elastic critical moment corresponding to lateral torsional buckling of the beam

M_d — Design flexural strength

M_{dv} — Moment capacity of the section under high shear

M_{dy} — Design bending strength about the minor axis of the cross-section

M_{dz} — Design bending strength about the major axis of the cross-section

M_{eff} — Reduced effective moment

M_{fr} — Reduced plastic moment capacity of the flange plate

M_{fd} — Design plastic resistance of the flange alone

M_{nd} — Design bending strength under combined axial force and uniaxial moment

M_{ndy}, M_{ndz} — Design bending strength under combined axial force and the respective uniaxial moment acting alone

M_p — Plastic moment capacity of the section

M_{pb} — Moment in the beam at the intersection of the beam and column centre lines

M_{pc} — Moments in the column above and below the beam surfaces

M_{pd} — Plastic design strength

M_{pdf} — Plastic design strength of flanges only

M_q — Applied moment on the stiffener

M_s — Moment at service (working) load

M_{tf} — Moment resistance of tension flange

M_y — Factored applied moment about the minor axis of the cross-section

M_{yq} — Moment capacity of the stiffener based on its elastic modulus

M_z — Factored applied moment about the major axis of the cross-section

N — Number of parallel planes of battens

N_d — Design strength in tension or in compression

N_f — Axial force in the flange

N_{SC} — Number of stress cycles

n — Number of bolts in the bolt group/ critical section

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n_e — Number of effective interfaces offering frictional resistance to slip

n_n — Number of shear planes with the threads intercepting the shear plane in the bolted connection

n_s — Number of shear planes without threads intercepting the shear plane in the bolted connection

P — Factored applied axial force

P_{cc} — Elastic buckling load

P_d — Design axial compressive strength

P_{dy}, P_{dz} — Design compression strength as governed by flexural buckling about the respective axis

P_e — Elastic Euler buckling load

P_{min} — Minimum required strength for each flange splice

P_r — Required compressive strength

P_s — Actual compression at service load

P_y — Yield strength of the cross-section under axial compression

p — Pitch length between centres of holes parallel to the direction of the load

p_s — Staggered pitch length along the direction of the load between lines of the bolt holes (*see* Fig. 5)

Q — Prying force

Q_a — Accidental load (Action)

Q_c — Characteristic loads (Action)

Q_d — Design load (Action)

Q_p — Permanent loads (Action)

Q_v — Variable loads (Action)

q — Shear stress at service load

R — Ratio of the mean compressive stress in the web (equal to stress at mid depth) to yield stress of the web; reaction of the beam at support

R_d — Design strength of the member at room temperature

R_i — Net shear in bolt group at bolt 'i'

R_r — Response reduction factor

R_{tf} — Flange shear resistance

R_u — Ultimate strength of the member at room temperature

r — Appropriate radius of gyration

r_1 — Minimum radius of gyration of the individual element being laced together

r_f — Ratio of the design action on the member under fire to the design capacity

r_{vv} — Radius of gyration about the minor axis (v-v) of angle section.

r_y — Radius of gyration about the minor axis

r_z — Radius of gyration about the major axis

S — Minimum transverse distance between the centroid of the rivet or bolt group or weld group

S_c — Constant stress range

S_d — Design strength

S_o — Original cross-sectional area of the test specimen

S_p — Spring stiffness

S_u — Ultimate strength

s_c — Anchorage length of tension field along the compression flange

s_t — Anchorage length of tension field along the tension flange

s_a — Actual stiffener spacing

T — Temperature, in degree Celsius; Factored tension

T_b — Applied tension in bolt

T_{cf} — Thickness of compression flange

T_d — Design strength under axial tension

T_{dg} — Yielding strength of gross section under axial tension

T_{dn} — Rupture strength of net section under axial tension

T_{db} — Design strength of bolt under axial tension, block shear strength at end connection

T_e — Externally applied tension

T_f — Factored tension force of friction type bolt

T_l — Limiting temperature of the steel

T_{nb} — Nominal strength of bolt under axial tension

T_{nd} — Design tension capacity

T_{ndf} — Design tension capacity of friction type bolt

T_{nf} — Nominal tensile strength of friction type bolt

T_s — Actual tension under service load

t — Thickness of element/angle, time in minutes

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t_f — Thickness of flange

t_p — Thickness of plate

t_{pk} — Thickness of packing

t_q — Thickness of stiffener

t_s — Thickness of base slab

t_t — Effective throat thickness of welds

t_w — Thickness of web,

V — Factored applied shear force

V_b — Shear in batten plate

V_{bf} — Factored frictional shear force in friction type connection

V_{cr} — Critical shear strength corresponding to web buckling

V_d — Design shear strength

V_{db} — Block shear strength

V_{nb} — Nominal shear strength of bolt

V_{nbf} — Bearing capacity of bolt for friction type connection

V_p — Plastic shear resistance under pure shear

V_n — Nominal shear strength

V_{npb} — Nominal bearing strength of bolt

V_{nsb} — Nominal shear capacity of a bolt

V_{nsf} — Nominal shear capacity of bolt as governed by slip in friction type connection

V_s — Transverse shear at service load

V_{sb} — Factored shear force in the bolt

V_{sd} — Design shear capacity

V_{sdf} — Design shear strength in friction type bolt

V_{sf} — Factored design shear force of friction bolts

V_t — Applied transverse shear

V_{tf} — Shear resistance in tension field

W — Total load

w — Uniform pressure from below on the slab base due to axial compression under the factored load

w_{tf} — Width of tension field

x_t — Torsional index

Z_e — Elastic section modulus

Z_{ec} — Elastic section modulus of the member with respect to extreme compression fibre

Z_{et} — Elastic section modulus of the member with respect to extreme tension fibre

Z_p — Plastic section modulus

Z_v — Contribution to the plastic section modulus of the total shear area of the cross-section

y_g — Distance between point of application of the load and shear centre of the cross-section

y_s — Coordinate of the shear centre in respect to centroid

α — Imperfection factor for buckling strength in columns and beams

α_t — Coefficient of thermal expansion

β_M — Ratio of smaller to the larger bending moment at the ends of a beam column

β_{My}, β_{Mz} — Equivalent uniform moment factor for flexural buckling for y-y and z-z axes, respectively

β_{MLT} — Equivalent uniform moment factor for lateral torsional buckling

χ — Strength reduction factor to account for buckling under compression

χ_m — Strength reduction factor, χ, at f_{ym}

χ_{LT} — Strength reduction factor to account for lateral torsional buckling of beams

δ — Storey deflection

δ_L — Horizontal deflection of the bottom of storey due to combined gravity and notional load

δ_p — Load amplification factor

δ_u — Horizontal deflection of the top of storey due to combined gravity and notional load

ϕ — Inclination of the tension field stress in web

γ — Unit weight of steel

γ_f — Partial safety factor for load

γ_m — Partial safety factor for material

γ_{m0} — Partial safety factor against yield stress and buckling

γ_{m1} — Partial safety factor against ultimate stress

γ_{mb} — Partial safety factor for bolted connection with bearing type bolts

γ_{mf} — Partial safety factor for bolted connection with high strength friction grip bolts

γ_{fft} — Partial safety factor for fatigue load

γ_{mft} — Partial safety factor for fatigue strength

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γ_{mv} — Partial safety factor against shear failure

γ_{mw} — Partial safety factor for strength of weld

ε — Yield stress ratio $(250 / f_y)^{1/2}$

λ — Non dimensional slenderness ratio

$$= \sqrt{f_y (KL/r)^2 / \pi^2 E} = \sqrt{f_y / f_{cc}}$$

$$= \sqrt{P_y / P_{cc}}$$

λ_{cr} — Elastic buckling load factor

λ_e — Equivalent slenderness ratio

λ_{LT} — Non-dimensional slenderness ratio in lateral bending

λ_{scr} — Elastic buckling load factor of each storey

μ — Poisson's ratio

μ_c — Correction factor

μ_f — Coefficient of friction (slip factor)

μ_r — Capacity reduction factor

θ — Ratio of the rotation at the hinge point to the relative elastic rotation of the far end of the beam segment containing plastic hinge

ρ — Unit mass of steel

τ — Actual shear stress range for the detail category

τ_b — Buckling shear stress

τ_{ab} — Permissible shear stress at the service load

$\tau_{cr,e}$ — Elastic critical shear stress

τ_f — Fatigue shear stress range

$\tau_{f, Max}$ — Highest shear stress range

τ_{fd} — Design shear fatigue strength

τ_{fn} — Fatigue shear stress range at N_{SC} cycle for the detail category

τ_v — Actual shear stress at service load

ψ — Ratio of the moments at the ends of the laterally unsupported length of a beam

Γ — Frame buckling load factor

NOTE — The subscripts y, z denote the y-y and z-z axes of the section, respectively. For symmetrical sections, y-y denotes the minor principal axis whilst z-z denotes the major principal axis (*see* **7**).

4 UNITS

For the purpose of design calculations the following units are recommended:

a) Forces and loads, in kN, kN/m, kN/m^2;

b) Unit mass, in kg/m^3;

c) Unit weight, in kN/m^3;

d) Stresses and strengths, in N/mm^2 (MN/m^2 or MPa); and

e) Moments (bending, etc), in kNm.

For conversion of one system of units to another system, accepted standard [6-6(1)] may be referred.

5 STANDARD DIMENSIONS, FORM AND WEIGHT

The dimensions, form, weight, tolerances of all rolled shapes, all rivets, bolts, nuts, studs, and welds and other members used in any steel structure shall conform to accepted standards [6-6(2)], wherever applicable.

6 PLANS AND DRAWINGS

6.1 Plans, drawings and stress sheet shall be prepared according to accepted standards [6-6(3)].

6.1.1 *Plans*

The plans (design drawings) shall show the sizes, sections, and the relative locations of the various members. Floor levels, column centres, and offsets shall be dimensioned. Plans shall be drawn to a scale large enough to convey the information adequately. Plans shall indicate the type of construction to be employed; and shall be supplemented by such data on the assumed loads, shears, moments and axial forces to be resisted by all members and their connections, as may be required for the proper preparation of shop drawings. Any special precaution to be taken in the erection of structure, from the design consideration shall also be indicated in the drawing.

6.1.2 *Shop Drawings*

Shop drawings, giving complete information necessary for the fabrication of the component parts of the structure including the location, type, size, length and detail of all welds and fasteners shall be prepared in advance of the actual fabrication. They shall clearly distinguish between shop and field rivets, bolts and welds. For additional information to be included on drawings for designs based on the use of welding, reference shall be made to appropriate Indian Standards. Shop drawings shall be made in conformity with accepted standard [6-6(4)]. A marking diagram allotting distinct identification marks to each separate part of steel work shall be prepared. The diagram shall be sufficient to ensure convenient assembly and erection at site.

6.2 Symbols used for welding on plans and shop drawings shall be according to good practice [6-6(5)].

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7 CONVENTION FOR MEMBER AXES

Unless otherwise specified convention used for member axes is as follows (*see* Fig. 1):

a) *x-x* along the member.

b) *y-y* an axis of the cross-section,
   1) perpendicular to the flanges, and
   2) perpendicular to the smaller leg in an angle section.

c) *z-z* an axis of the cross-section
   1) axis parallel to flanges, and
   2) axis parallel to smaller leg in angle section.

d) *u-u* major axis (when it does not coincide with *z-z* axis).

e) *v-v* minor axis (when it does not coincide with *y-y* axis).

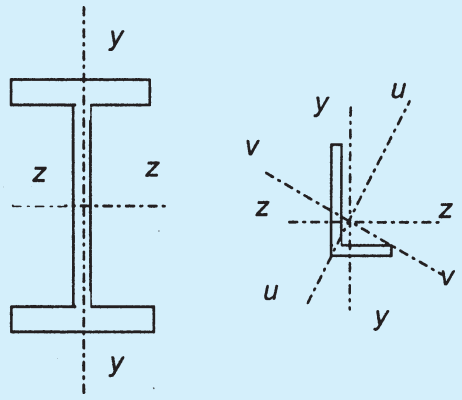


FIG. 1 AXES OF MEMBERS

SECTION 6(b) MATERIALS

8 GENERAL

8.1 The material properties given in this Section are nominal values, to be accepted as characteristic values in design calculations.

8.2 Structural Steel

8.2.1 The provisions in this Section are applicable to the steels commonly used in steel construction namely, structural mild steel and high tensile structural steel.

8.2.2 All the structural steel used in general construction, coming under the purview of this standard shall before fabrication conform to accepted standard [6-6(6)].

8.2.3 Structural steel other than those specified in **8.2.2** may also be used provided that the permissible stresses and other design provisions are suitably modified and the steel is also suitable for the type of fabrication adopted.

8.2.3.1 Steel that is not supported by mill test result may be used only in unimportant members and details, where their properties such as ductility and weldability would not affect the performance requirements of the members and the structure as a whole.

However, such steels may be used in structural system after confirming their quality by carrying out appropriate tests in accordance with the method specified in accepted standard [6-6(7)].

8.2.4 *Properties*

The properties of structural steel for use in design may be taken as given in **8.2.4.1** and **8.2.4.2**.

8.2.4.1 Physical properties of structural steel irrespective of its grade may be taken as:

a) Unit mass of steel, $\rho = 7\ 850\ kg/m^3$

b) Modulus of elasticity, $E = 2.0 \times 10^5\ N/mm^2$ (MPa)

c) Poisson ratio, $\mu = 0.3$

d) Modulus of rigidity, $G = 0.769 \times 10^5\ N/mm^2$ (MPa)

e) Coefficient of thermal expansion $\alpha_t = 12 \times 10^{-6}/°C$

8.2.4.2 *Mechanical properties of structural steel*

The principal mechanical properties of the structural steel important in design are the yield stress, f_y; the tensile or ultimate stress, f_u; the maximum percent elongation on a standard gauge length and notch toughness. Except for notch toughness, the other properties are determined by conducting tensile tests on samples cut from the plates, sections, etc, in accordance with accepted standard [6-6(7)]. Commonly used properties for the common steel products of different specifications are summarized in Table 1.

8.2.4.2.1 *Steel tubes*

Steel tubes used in building construction shall be hot finished tubes conforming to the requirements specified in accepted standard [6-6(8)].

8.2.4.2.2 Tubes made by other than hot finishing processes, or which have been subjected to cold working, shall be regarded as hot finished if they have subsequently been heat-treated and are supplied in the normalized conditions.

NOTE — Grade ERW YSt 22 tubes specified in accepted standard [6-6(8)] with a carbon content less than 0.30 percent, may be considered as hot finished for the purpose of **8.2.4.2.2**.

8.2.4.2.3 *Electrodes*

The electrodes used for welding steel tubes shall conform to the requirements of accepted standard [6-6(9)].

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8.3 Rivets

8.3.1 Rivets shall be manufactured from steel conforming to accepted standard [6-6(10)]. They may also be manufactured from steel conforming to accepted standard [6-6(6)] provided that the steel meets the requirements given in accepted standard [6-6(11)].

8.3.2 Rivets shall conform to accepted standards [6-6(12)] as appropriate.

8.3.3 *High Tensile Steel Rivets*

High tensile steel rivets, shall be manufactured from steel conforming to accepted standard [6-6(13)].

8.4 Bolts, Nuts and Washers

Bolts, nuts and washers shall conform as appropriate, to accepted standards [6-6(14)]. The recommendations in good practice [6-6(15)] shall be followed.

8.5 Steel Casting

Steel casting shall conform to accepted standard [6-6(16)] or accepted standard [6-6(17)].

8.6 Welding Consumable

8.6.1 Covered electrodes shall conform to accepted standards [6-6(18)] or [6-6(19)], as appropriate.

8.6.2 Filler rods and wires for gas welding shall conform to accepted standard [6-6(20)].

8.6.3 The supply of solid filler wires for submerged arc welding of structural steels shall conform to accepted standard [6-6(21)].

8.6.4 The bare wire electrodes for submerged arc welding shall conform to accepted standard [6-6(22)]. The combination of wire and flux shall satisfy the requirements of accepted standard [6-6(22)].

8.6.5 Filler rods and bare electrodes for gas shielded metal arc welding shall conform to accepted standards [6-6(23)], as appropriate.

8.7 Other Materials

Other materials used in association with structural steel work shall conform to appropriate Indian standards.

SECTION 6(c) GENERAL DESIGN REQUIREMENTS

9 GENERAL DESIGN REQUIREMENTS

9.1 Basis for Design

9.1.1 *Design Objective*

The objective of design is the achievement of an acceptable probability that structures will perform satisfactorily for the intended purpose during the design life. With an appropriate degree of safety, they should sustain all the loads and deformations, during construction and use and have adequate resistance to certain expected accidental loads and fire. Structure should be stable and have alternate load paths to prevent disproportionate overall collapse under accidental loading.

9.1.2 *Methods of Design*

9.1.2.1 Structure and its elements shall normally, be designed by the limit state method. Account should be taken of accepted theories, experimental information and experience and the need to design for durability. Calculations alone may not produce safe, serviceable and durable structures. Suitable materials, quality control, adequate detailing and good supervision are equally important.

9.1.2.2 Where the limit states method cannot be conveniently adopted; the working stress design [*see* Section 6(m)] may be used.

9.1.3 *Design Process*

Structural design, including design for durability, construction and use should be considered as a whole. The realization of design objectives requires compliance with clearly defined standards for materials, fabrication, erection and in-service maintenance.

9.2 Loads and Forces

9.2.1 For the purpose of designing any element, member or a structure, the following loads (actions) and their effects shall be taken into account, where applicable, with partial safety factors and combinations (*see* **11.3.3**).

a) Dead loads;
b) Imposed loads (live load, crane load, snow load, dust load, wave load, earth pressures, etc);
c) Wind loads;
d) Earthquake loads;
e) Erection loads;
f) Accidental loads such as those due to blast, impact of vehicles, etc; and
g) Secondary effects due to contraction or expansion resulting from temperature changes, differential settlements of the structure as a whole or of its components, eccentric connections, rigidity of joints differing from design assumptions.

9.2.1.1 Dead loads should be assumed in design as specified in **2** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

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Table 1 Tensile Properties of Structural Steel Products

(*Clauses* 2.113, 2.119 *and* 8.2.4.2)

Sl No.	Accepted Standard	Grade / Classification	Properties		
			Yield Stress MPa *Min*	Ultimate Tensile Stress MPa *Min*	Elongation Percent *Min*
(1)	(2)	(3)	(4)	(5)	(6)
i)	[6-6(24)]	O	—	—	—
		D	280	270-410	28
		DD	250	270-370	32
		EDD	220	270-350	35
ii)	[6-6(18)]	Ex40xx	330	410-540	16
		Ex41xx	330	410-540	20
		Ex42xx	330	410-540	22
		Ex43xx	330	410-540	24
		Ex44xx	330	410-540	24
		Ex50xx	360	510-610	16
		Ex51xx	360	510-610	18
		Ex52xx	360	510-610	18
		Ex53xx	360	510-610	20
		Ex54xx	360	510-610	20
		Ex55xx	360	510-610	20
		Ex56xx	360	510-610	20
iii)	[6-6(25)]	O	—	—	—
		D	—	240-400	25
		DD	—	260-390	28
		EDD	—	260-380	32
iv)	[6-6(26)]	3.6	180	330	25
		4.6	240	400	22
		4.8	320	420	—
		5.6	300	500	20
		5.8	400	520	—
		6.8	480	600	—
		8.8 ($d \leq 16$mm)	640 [1)]	800	12
		8.8 ($d > 16$mm)	660 [1)]	830	12
		9.8	720 [1)]	900	10
		10.9	940 [1)]	1 040	9
		12.9	1 100 [1)]	1 220	8
v)	[6-6(27)]	1	200	370	26
		1A	220	410	25
		2	230	430	24
		2A	250	460	22
		3	270	490	21
		3A	280	540	20
		4	320	620	15
		5	350	710	13
		6	370	740	10
			d or *t*		
			≤ 20 / > 20		
vi)	[6-6(28)]	S_t 37	220 / 200	360-440	26
		S_t 42	250 / 240	410-500	23
			t	*t*	*t*
			≤16 / >16 and ≤40 / >40 and ≤60 / >60 and ≤100 / >100 and ≤350	≤60 / >60 and ≤100 / >100 and ≤350	≤60 / >60 and ≤350
vii)	[6-6(29)]	1	235 / 225 / 215 / 200 / 185	360-480 / 360-480 / 350-480	24 / 23
		2	265 / 255 / 245 / 215 / 200	410-530 / 410-530 / 400-530	22 / 21
		3	290 / 285 / 280 / 255 / 230	460-580 / 450-570 / 440-570	21 / 20

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Table 1 — (*Concluded*)

(1)	(2)	(3)	(4)			(5)	(6)
			d or *t*				
			<20	20-40	> 40	410	23
		E250 (A, BR, B0, C)	250	240	230	430	22
		E275 (A, BR, B0, C)	275	265	255	440	22
viii)	[6-6(6)]	E300 (A, BR, B0, C)	300	290	280	490	22
		E350 (A, BR, B0, C)	350	330	320	540	20
		E410 (A, BR, B0, C)	410	390	380	570	20
		E450 (A, BR)	450	430	420		
			d or *t*				
			≤ 25	> 25 and ≤ 50			
		I	230	220		400-490	22
ix)	[6-6(30)]	II	235	235		400-490	22
		III	235	235		400-490	22
x)	[6-6(31)]	Grade 1	240			350-450	25
		Grade 2	245			360-450	34
xi)	[6-6(10)]	Annealed Condition	160			330 - 410	30
		As-Drawn Condition	190			410 - 490	20
xii)	[6-6(32)]	HFC 210/CDS 210/ERW210	210			330	20
		HFC 240/CDS 240/ERW240	240			410	18
		HFC 310/CDS 310/ERW310	310			450	15
xiii)	[6-6(33)]	1	170			290	30
		2	210			330	28
		3	240			410	25
		4	275			430	20
		5	310			490	15

NOTES

1 Percentage of elongation shall be taken over the gauge length of $5.65\sqrt{S_0}$, where S_0 = original cross-sectional area of the test specimen.

2 Abbreviations: O = Ordinary, D = Drawing, DD = Deep Drawing, EDD = Extra Deep Drawing.

[1)] Stress at 0.2 percent non-proportional elongation, *Min.*

9.2.1.2 Imposed loads for different types of occupancy and function of structures shall be taken as recommended in **3** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. Imposed loads arising from equipment, such as cranes and machines should be assumed in design as per manufacturers/suppliers data (*see* **9.5.4**). Snow load shall be taken as per in **6** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

9.2.1.3 Wind loads on structures shall be taken as per the provisions of **4** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

9.2.1.3.1 *Wind pressure*

In calculating the effective wind pressure on exposed circular tube members of a structure, the effective area shall be taken as 0.6 times the projected area of the member (*see* **4** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

9.2.1.4 Earthquake loads shall be assumed as per the recommendations of **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

9.2.1.5 The erection loads and temperature effects shall be considered as specified in **9.3** and **9.4,** respectively.

9.3 Erection Loads

All loads required to be carried by the structure or any part of it due to storage or positioning of construction material and erection equipment, including all loads due to operation of such equipment shall be considered as erection loads. Proper provision shall be made,

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including temporary bracings, to take care of all stresses developed during erection. Dead load, wind load and also such parts of the imposed load as would be imposed on the structure during the period of erection shall be taken as acting together with the erection loads. The structure as a whole and all parts of the structure in conjunction with the temporary bracings shall be capable of sustaining these loads during erection.

9.4 Temperature Effects

9.4.1 Expansion and contraction due to changes in temperature of the members and elements of a structure shall be considered and adequate provision made for such effect.

9.4.2 The temperature range varies for different localities and under different diurnal and seasonal conditions. The absolute maximum and minimum temperatures, which may be expected in different localities of the country, may be obtained from the India Meteorological Department and used in assessing the maximum variations of temperature for which provision for expansion and contraction has to be made in the structure.

9.4.3 The range of variation in temperature of the building materials may be appreciably greater or lesser than the variation of air temperature and is influenced by the condition of exposure and the rate at which the materials composing the structure absorb or radiate heat. This difference in temperature variations of the material and air shall be given due consideration. The effect of differential temperature within an element or member, due to part exposure to direct sunlight shall also be considered.

9.4.4 The coefficient of thermal expansion for steel is as given in **8.2.4.1**(e).

9.5 Load Combinations

9.5.1 Load combinations for design purposes shall be those that produce maximum forces and effects and consequently maximum stresses and deformations. The following combination of loads with appropriate partial safety factors (*see* Table 4) may be considered:

a) Dead load + Imposed load,

b) Dead load + Imposed load + Wind or Earthquake load,

c) Dead load + Wind or Earthquake load, and

d) Dead load + Erection load.

NOTE — In the case of structures supporting cranes, imposed loads shall include the crane effects as given in **9.5.4**.

9.5.2 Wind load and earthquake loads shall not be assumed to act simultaneously. The effect of each shall be considered separately.

9.5.3 The effect of cranes to be considered under imposed loads shall include the vertical loads, eccentricity effects induced by the vertical loads, impact factors, lateral (surge) and the longitudinal (horizontal) thrusts, not acting simultaneously, across and along the crane rail, respectively [*see* **3** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code].

9.5.4 The crane loads and their combinations to be considered shall be as indicated by the customer. In the absence of any specific indications, the load combinations shall be in accordance with the provisions in **3** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code or as given below:

a) Vertical loads with full impact from one loaded crane or two cranes in case of tandem operation, together with vertical loads without impact from as many loaded cranes as may be positioned for maximum effect, along with maximum horizontal thrust from one crane only or two in case of tandem operation;

b) Loads as specified in **9.5.4** (a), subject to cranes in maximum of any two bays of the building cross-section shall be considered for multi-bay multi-crane gantries;

c) The longitudinal thrust on a crane track rail shall be considered for a maximum of two loaded cranes on the track; and

d) Lateral thrust (surge) and longitudinal thrust acting across and along the crane rail, respectively shall be assumed not to act simultaneously. The effect of each force, shall however be investigated separately.

9.5.5 While investigating the effect of earthquake forces, the resulting effect from dead loads of all cranes parked in each bay, positioned to cause maximum effect shall be considered.

9.5.6 The crane runway girders supporting bumpers shall be checked for bumper impact loads also, as specified by the manufacturers.

9.5.7 Stresses developed due to secondary effects such as handling; erection, temperature and settlement of foundations, if any, shall be appropriately added to the stresses calculated from the combination of loads stated in **9.5.1**, with appropriate partial safety factors.

9.6 Geometrical Properties

9.6.1 *General*

The geometrical properties of the gross and the effective cross-sections of a member or part thereof, shall be calculated on the following basis:

a) The properties of the gross cross-section shall be calculated from the specified size of the

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member or part thereof or read from appropriate table.

b) The properties of the effective cross-section shall be calculated by deducting from the area of the gross cross-section, the following:

1) The sectional area in excess of effective plate width, in case of slender sections (*see* **9.7.2**).

2) The sectional areas of all holes in the section except for parts in compression. In case of punched holes, hole size 2 mm in excess of the actual diameter may be deducted.

9.7 Classification of Cross-Sections

9.7.1 Plate elements of a cross-section may buckle locally due to compressive stresses. The local buckling can be avoided before the limit state is achieved by limiting the width to thickness ratio of each element of a cross-section subjected to compression due to axial force, moment or shear.

9.7.1.1 When plastic analysis is used, the members shall be capable of forming plastic hinges with sufficient rotation capacity (ductility) without local buckling, to enable the redistribution of bending moment required before formation of the failure mechanism.

9.7.1.2 When elastic analysis is used, the member shall be capable of developing the yield stress under compression without local buckling.

9.7.2 On basis of the above, four classes of sections are defined as follows:

a) *Class 1* (*Plastic)* — Cross-sections, which can develop plastic hinges and have the rotation capacity required for failure of the structure by formation of plastic mechanism. The width to thickness ratio of plate elements shall be less than that specified under Class 1 (Plastic), in Table 2.

b) *Class 2 (Compact)* — Cross-sections, which can develop plastic moment of resistance, but have inadequate plastic hinge rotation capacity for formation of plastic mechanism, due to local buckling. The width to thickness ratio of plate elements shall be less than that specified under Class 2 (Compact), but greater than that specified under Class 1 (Plastic), in Table 2.

c) *Class 3* (*Semi-compact)* — Cross-sections, in which the extreme fiber in compression can reach yield stress, but cannot develop the plastic moment of resistance, due to local buckling. The width to thickness ratio of plate elements shall be less than that specified under Class 3 (Semi-compact), but greater than that specified under Class 2 (Compact), in Table 2.

d) *Class 4 (Slender)* — Cross-sections in which the elements buckle locally even before reaching yield stress. The width to thickness ratio of plate elements shall be greater than that specified under Class 3 (Semi-compact), in Table 2. In such cases, the effective sections for design shall be calculated either by following the provisions of good practice [6-6(34)] to account for the post-local-buckling strength or by conservatively deducting width of the compression plate element in excess of the semi-compact section limit (*see* Fig. 2B and Fig. 2C).

The design of slender web elements in flexural members may be done as given in **14.2.1.1** for flexure and **14.4.2.2** for shear.

When different elements of a cross-section fall under different classes, the section shall be classified as governed by the most critical element.

The maximum value of limiting width to thickness ratios of elements for different classifications of sections are given in Fig. 2A. The effective section in case of class 4 (slender elements) may be conservatively taken as shown in Fig. 2B and Fig. 2C.

9.7.3 *Types of Elements*

a) *Internal elements* — These are elements attached along both longitudinal edges to other elements or to longitudinal stiffeners connected at suitable intervals to transverse stiffeners; for example web of I-section and flanges and web of box section.

b) *Outside elements or outstands* — These are elements attached along only one of the longitudinal edges to an adjacent element, the other edge being free to displace out of plane, for example flange overhang of an I-section, stem of T-section and legs of an angle section.

c) *Tapered elements* — These may be treated as flat elements having average thickness as defined in accepted standard [6-6(35)].

The design of slender compression element (Class 4) considering the strength beyond elastic local buckling of element is outside the scope of this section. Reference may be made to in good practice [6-6(34)] for such design provisions. The design of slender web elements may be made as given in **14.2.1.1** for flexure and **14.4.2.2** for shear.

9.7.4 *Compound Elements in Built-up Section* (*see* Fig. 2)

In case of compound elements consisting of two or more elements bolted or welded together, the limiting width

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to thickness ratios as in Table 2 should be considered on basis of the following:

a) Outstanding width of compound element (b_e) to its own thickness.

b) The internal width of each added plate between the lines of welds or fasteners connecting it to the original section to its own thickness.

c) Any outstand of the added plates beyond the line of welds or fasteners connecting it to original section to its own thickness.

9.8 Maximum Effective Slenderness Ratio

9.8.1 The maximum effective slenderness ratio, *KL/r,* values of a beam, strut or tension member shall not exceed those given in Table 3. '*KL*' is the effective length of the member and '*r*' is appropriate radius of

Table 2 Limiting Width to Thickness Ratio

(*Clauses* 9.7.2 *and* 9.7.4)

Sl No.	Compression Element			Ratio	Class of Section		
					Class 1 Plastic	Class 2 Compact	Class 3 Semi-Compact
(1)	(2)			(3)	(4)	(5)	(6)
i)	Outstanding element of compression flange		Rolled section	b/t_f	9.4ε	10.5ε	15.7ε
			Welded section	b/t_f	8.4ε	9.4ε	13.6ε
ii)	Internal element of compression flange		Compression due to bending	b/t_f	29.3ε	33.5ε	42ε
			Axial compression	b/t_f	42ε	42ε	
iii)	Web of an I, H or box section	Neutral axis at mid-depth		d/t_w	84ε	105ε	126ε
		Generally	If r_1 is negative	d/t_w	$\frac{84\varepsilon}{1+r_1}$ but ≥ 42ε	$\frac{105.0\varepsilon}{1+r_1}$	$\frac{126.0\varepsilon}{1+2\ r_2}$ but ≥ 42ε
			If r_1 is positive	d/t_w		$\frac{105.0\varepsilon}{1+1.5r_1}$ but ≥ 42ε	
		Axial compression		d/t_w	42ε	42ε	42ε
iv)	Web of a channel			d/t_w	42ε	42ε	42ε
v)	Angle, compression due to bending (Both criteria should be satisfied)			b/t d/t	9.4ε 9.4 ε	10.5ε 10.5ε	15.7ε 15.7ε
vi)	Single angle, or double angles with the components separated, axial compression (All three criteria should be satisfied)			b/t d/t $(b+d)/t$	15.7ε 15.7ε 25ε	15.7ε 15.7ε 25ε	15.7ε 15.7ε 25ε
vii)	Outstanding leg of an angle in contact back-to-back in a double angle member			d/t	9.4ε	10.5ε	15.7ε
viii)	Outstanding leg of an angle with its back in continuous contact with another component			d/t	9.4ε	10.5ε	15.7ε
ix)	Stem of a T-section, rolled or cut from a rolled I-or H-section			d/t	8.4ε	9.4ε	18.9ε
x)	Circular hollow tube, including welded tube subjected to: a) moment			D/t	$42\varepsilon^2$	$52\varepsilon^2$	$146\varepsilon^2$
	b) axial compression			D/t	Not applicable		$88\varepsilon^2$

NOTES

1 Elements which exceed semi-compact limits are to be taken as of slender Cross-section

2 $\varepsilon = (250 / f_y)^{1/2}$

3 Webs shall be checked for shear buckling in accordance with **14.4.2** when $d/t > 67\varepsilon$. Where, b is the width of the element may be taken as clear distance between lateral supports or between lateral support and free edge, as appropriate, t is the thickness of element, d is the depth of the web, D is the outer diameter of the element (*see* Fig 2, **9.7.3** and **9.7.4**).

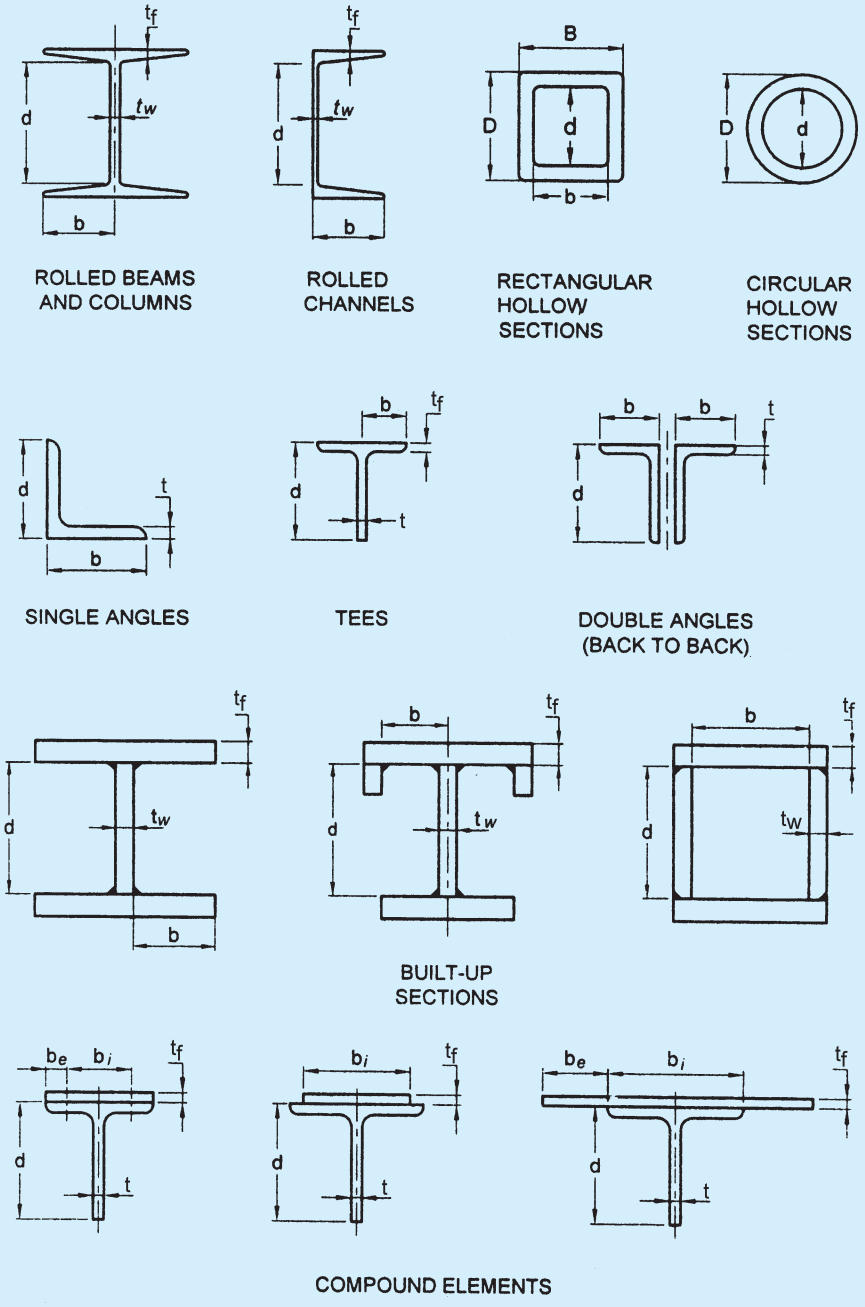
4 Different elements of a cross-section can be in different classes. In such cases the section is classified based on the least favourable classification.

5 The stress ratio r_1 and r_2 are defined as:

$$r_1 = \frac{\text{Actual average axial stress (negative, if tensile)}}{\text{Design compressive stress of web alone}}$$

$$r_2 = \frac{\text{Actual average axial stress (negative, if tensile)}}{\text{Design compressive stress of overall section}}$$

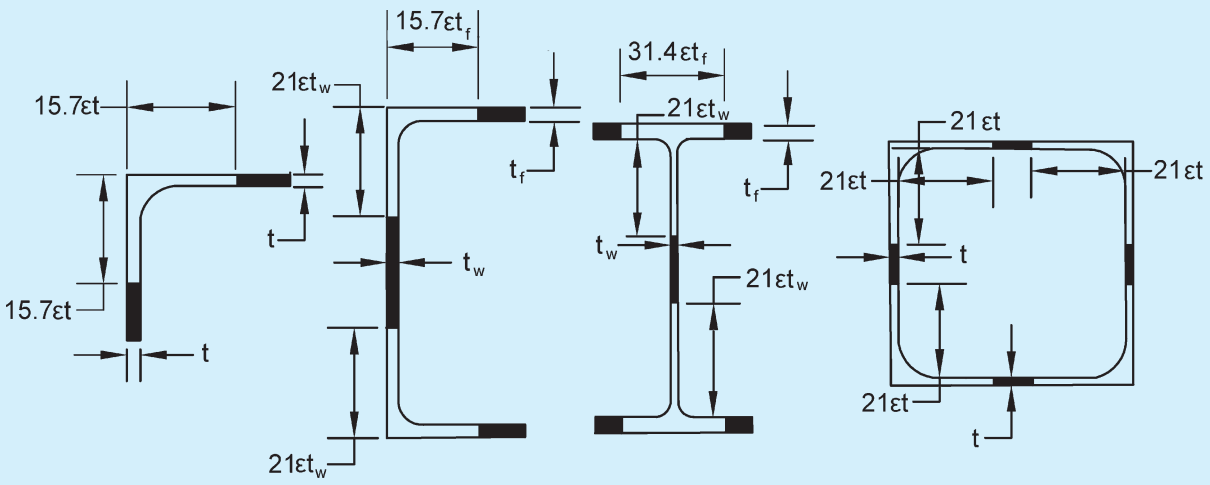
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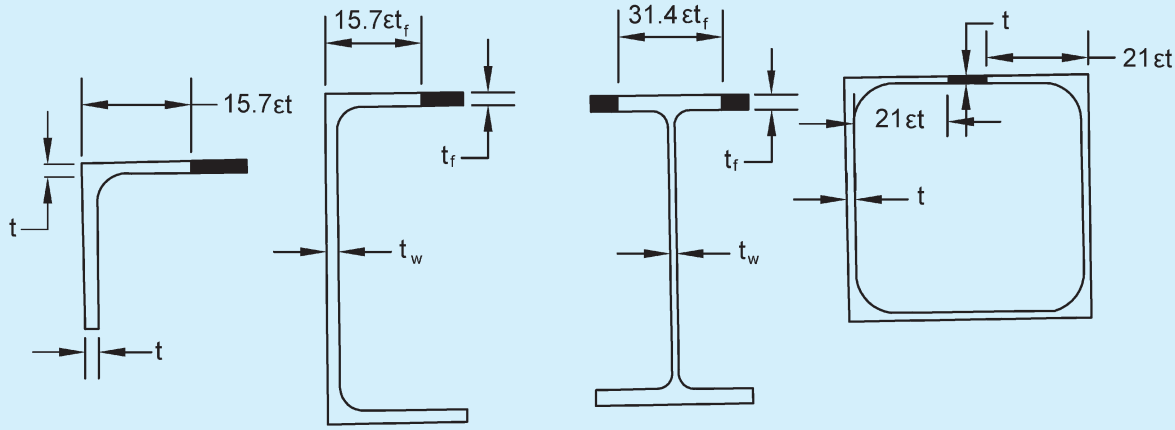
2A DIMENSIONS OF SECTIONS

FIG. 2 CLASSIFICATION OF SECTIONS — (*Continued*)

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2B EFFECTIVE SECTION OF SLENDER MEMBERS UNDER COMPRESSION, PURE



2C EFFECTIVE SECTION OF SLENDER MEMBERS UNDER COMPRESSION, FLEXURAL

FIG. 2 CLASSIFICATION OF SECTIONS

gyration based on the effective section as defined in **9.6.1**.

9.9 Resistance to Horizontal Forces

9.9.1 In designing the steel frame work of a building, provision shall be made (by adequate moment connections or by a system of bracing) to effectively transmit to the foundations all the horizontal forces, giving due allowance for the stiffening effect of the walls and floors, where applicable.

9.9.2 When the walls, or walls and floors and/or roofs are capable of effectively transmitting all the horizontal forces directly to the foundations, the structural steel framework may be designed without considering the effect of wind or earthquake.

9.9.3 Wind and earthquake forces are reversible and therefore call for rigidity and strength under force reversal in both longitudinal and transverse directions. To resist torsional effects of wind and earthquake forces, bracings in plan should be provided and integrally connected with the longitudinal and transverse bracings, to impart adequate torsional resistance to the structure.

9.9.3.1 In shed type steel mill buildings, adequate bracings shall be provided to transfer the wind or earthquake loads from their points of action to the appropriate supporting members. Where the connections to the interior columns or frames are designed such that the wind or earthquake loads will not be transferred to the interior columns, the exterior columns or frames shall be designed to resist the total wind or earthquake loads. Where the connections to the interior columns and frames are designed such that the wind or earthquake effects are transferred to the interior columns also, and where adequate rigid diaphragm action can be mobilized as in the case of the cast-in place RC slab, both exterior and interior

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Table 3 Maximum Values of Effective Slenderness Ratios

(*Clause* 9.8.1)

Sl No.	Member	Maximum Effective Slenderness Ratio *KL/r*
(1)	(2)	(3)
i)	A member carrying compressive loads resulting from dead loads and imposed loads	180
ii)	A tension member in which a reversal of direct stress occurs due to loads other than wind or seismic forces	180
iii)	A member subjected to compression forces resulting only from combination with wind/earthquake actions, provided the deformation of such member does not adversely affect the stress in any part of the structure	250
iv)	Compression flange of a beam against lateral torsional buckling	300
v)	A member normally acting as a tie in a roof truss or a bracing system not considered effective when subject to possible reversal of stress into compression resulting from the action of wind or earthquake forces[1)]	350
vi)	Members always under tension[1)] (other than pre-tensioned members)	400

[1)] Tension members, such as bracings, pre-tensioned to avoid sag, need not satisfy the maximum slenderness ratio limits.

columns and frames may be designed on the assumption that the wind or earthquake load is divided among them in proportion to their relative stiffness. Columns also should be designed to withstand the net uplifting effect caused by excessive wind or earthquake. Additional axial forces arising in adjacent columns due to the vertical component of bracings or due to frame action shall also be accounted for.

9.9.3.2 Earthquake forces are proportional to the seismic mass as defined in **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. Earthquake forces should be applied at the centre of gravity of all such components of mass and their transfer to the foundation should be ensured. Other construction details, stipulated in good practice [6-6(36)] should also be followed.

9.9.3.3 In buildings where high-speed travelling cranes are supported or where a building or structure is otherwise subjected to vibration or sway, triangulated bracing or rigid portal systems shall be provided to reduce the vibration or sway to an acceptable minimum.

9.9.4 *Foundations*

The foundations of a building or other structures shall be designed to provide the rigidity and strength that has been assumed in the analysis and design of the superstructure.

9.9.5 *Eccentrically Placed Loads*

Where a wall, or other gravity load, is placed eccentrically upon the flange of a supporting steel beam, the beam and its connections shall be designed for torsion, unless the beam is restrained laterally in such a way as to prevent the twisting of the beam.

9.10 Expansion Joints

Expansion joints in case of low-rise buildings shall comply with **9.10.1** to **9.10.4**. For requirement of expansion joints in high-rise buildings, specialist literature shall be referred to.

9.10.1 In view of the large number of factors involved in deciding the location, spacing and nature of expansion joints, the decision regarding provision of expansion joints shall be left to the discretion of the designer.

9.10.2 Structures in which marked changes in plan dimensions take place abruptly, shall be provided with expansion joints at the section where such changes occur. Expansion joints shall be so provided that the necessary movement occurs with minimum resistance at the joint. The gap at the expansion joint should be such that,

a) it accommodates the expected expansion/ contraction due to seasonal and diurnal variation of temperature; and

b) it avoids pounding of adjacent units under earthquake. The structure adjacent to the joint should preferably be supported on separate columns but not necessarily on separate foundations.

9.10.3 The details as to the length of a structure where expansion joints have to be provided may be determined after taking into consideration various factors such as temperature, exposure to weather and structural design. The provisions in **9.10.3.1** to **9.10.3.3** are given as general guidance.

9.10.3.1 If one bay of longitudinal bracing is provided at the centre of the building or building section, the length of the building section may be restricted to 180 m in case of covered buildings and 120 m in case of open gantries (*see* Fig. 3).

9.10.3.2 If more than one bay of longitudinal bracing is provided near the centre of the building/section, the maximum centre line distance between the two lines of bracing may be restricted to 50 m for covered buildings (and 30 m for open gantries) and the maximum distance between the centre of the bracing to the nearest expansion joint/end of building or section may be restricted to 90 m (60 m in case of open gantries). The maximum length of the building section thus may be

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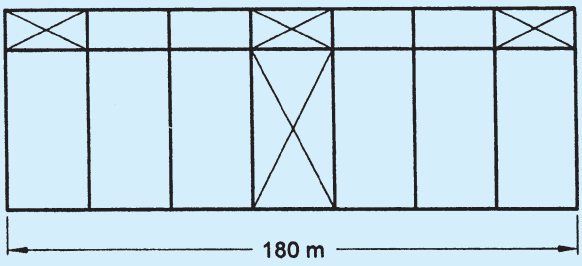


FIG. 3 MAXIMUM LENGTH OF BUILDING WITH ONE BAY OF BRACING

restricted to 230 m for covered buildings (150 m for open gantries). Beyond this, suitable expansion joints shall be provided (*see* Fig. 4).

9.10.3.3 The maximum width of the covered building section should preferably be restricted to 150 m beyond which suitable provisions for the expansion joint may be made.

9.10.4 When the provisions of these sections are met for a building or open structure made only of steel frame with elastic steel claddings, the stress analysis due to temperature is not required. However, for buildings with steel concrete composite construction, specialist literature may be referred to decide on thermal stress design.

SECTION 6(d) METHODS OF STRUCTURAL ANALYSIS

10 METHODS OF STRUCTURAL ANALYSIS

10.1 Methods of Determining Action Effects

10.1.1 *General*

For the purpose of complying with the requirements of the limit states of stability, strength and serviceability specified in Section 6(e), effects of design actions on a structure and its members and connections, shall be determined by structural analysis using the assumptions of **10.2** and **10.3** and one of the following methods of analysis:

a) Elastic analysis in accordance with **10.4**,
b) Plastic analysis in accordance with **10.5**,
c) Advanced analysis in accordance with Annex A, or
d) Dynamic analysis in accordance with **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

The design action effects for design basis earthquake loads shall be obtained only by an elastic analysis. The maximum credible earthquake loads shall be assumed to correspond to the load at which significant plastic hinges are formed in the structure and the corresponding effects shall be obtained by plastic or advanced analysis. More information on analysis and design to resist earthquake is given in Section 6(n) and **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

10.1.2 *Non-Sway and Sway Frames*

For the purpose of analysis and design, the structural frames are classified as non-sway and sway frames as given below:

a) *Non-sway frame* — One in which the transverse displacement of one end of the member relative to the other end is effectively prevented. This applies to triangulated frames and trusses or to frames where in-plane stiffness is provided by bracings, or by shear walls, or by floor slabs and roof decks secured horizontally to walls or to bracing systems parallel to the plane of loading and bending of the frame.
b) *Sway frame* — One in which the transverse displacement of one end of the member relative to the other end is not effectively prevented. Such members and frames occur in structures which depend on flexural action

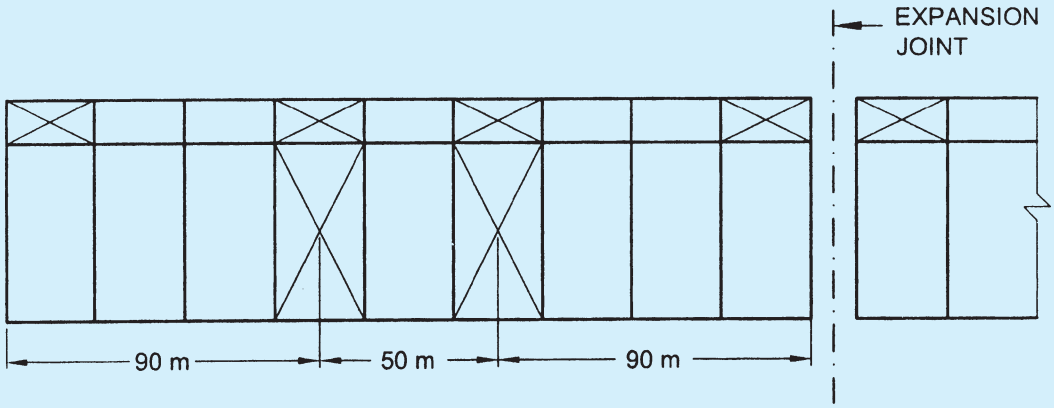


FIG. 4 MAXIMUM LENGTH OF COVERED BUILDING/SECTION WITH TWO BAYS OF BRACINGS

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of members to resist lateral loads and sway, as in moment resisting frames.

c) A rigid jointed multi-storey frame may be considered as a non-sway frame if in every individual storey, the deflection d, over a storey height h_s due to the notional horizontal loading given in **10.3.6** satisfies the following criteria:

1) For clad frames, when the stiffening effect of the cladding is not taken into account in the deflection calculations:

$$\delta \leq \frac{h_s}{2\ 000}$$

2) For unclad frame or clad frames, when the stiffening effect of the cladding is taken into account in the deflection calculations:

$$\delta \leq \frac{h_s}{4\ 000}$$

3) A frame, which when analysed considering all the lateral supporting system does not comply with the above criteria, should be classified as a sway frame, even if it is braced or otherwise laterally stiffened.

10.2 Forms of Construction Assumed for Structural Analysis

10.2.1 The effects of design action in the members and connections of a structure shall be determined by assuming singly or in combination of the following forms of construction (*see* **16.6.1**).

10.2.1.1 *Rigid construction*

In rigid construction, the connections between members (beam and column) at their junction shall be assumed to have sufficient rigidity to hold the original angles between the members connected at a joint unchanged under loading.

10.2.1.2 *Semi-rigid construction*

In semi-rigid construction, the connections between members (beam and column) at their junction may not have sufficient rigidity to hold the original angles between the members at a joint unchanged, but shall be assumed to have the capacity to furnish a dependable and known degree of flexural restraint. The relationship between the degree of flexural restraint and the level of the load effects shall be established by any rational method or based on test results (*see* Annex E).

10.2.1.3 *Simple construction*

In simple construction, the connections between members (beam and column) at their junction will not resist any appreciable moment and shall be assumed to be hinged.

10.2.2 *Design of connections*

The design of all connections shall be consistent with the form of construction, and the behaviour of the connections shall not adversely affect any other part of the structure beyond what is allowed for in design. Connections shall be designed in accordance with Section 6(k).

10.3 Assumptions in Analysis

10.3.1 The structure shall be analysed in its entirety except as follows:

a) Regular building structures, with orthogonal frames in plan, may be analysed as a series of parallel two-dimensional sub-structures (part of a structure), the analysis being carried out in each of the two directions, at right angles to each other, except when there is significant load redistribution between the sub-structures (part of a structure). For earthquake loading three dimensional analysis may be necessary to account for effects of torsion and also for multi-component earthquake forces (*see* **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

b) For vertical loading in a multi-storey building structure, provided with bracing or shear walls to resist all lateral forces, each level thereof, together with the columns immediately above and below, may be considered as a substructure, the columns being assumed fixed at the ends remote from the level under consideration.

c) Where beams at a floor level in a multi-bay building structure are considered as a substructure (part of a structure), the bending moment at the support of the beam due to gravity loads may be determined based on the assumption that the beam is fixed at the far end support, one span away from the span under consideration, provided that the floor beam is continuous beyond that support point.

10.3.2 *Span Length*

The span length of a flexural member in a continuous frame system shall be taken as the centre-to-centre distance between the supports.

10.3.3 *Arrangements of Imposed Loads in Buildings*

For building structures, the various arrangements of imposed loads considered for the analysis, shall include at least the following:

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a) Where the loading pattern is fixed, the arrangement concerned.

b) Where the imposed load is variable and not greater than three-quarters of the dead load, the imposed load may be taken to be acting on all spans.

c) Where the imposed load is variable and exceeds three-quarters of the dead load, arrangements of imposed load acting on the floor under consideration shall include the following cases:

1) Imposed load on alternate spans,
2) Imposed load on two adjacent spans, and
3) Imposed load on all the spans.

10.3.4 *Base Stiffness*

In the analysis of all structures the appropriate base stiffness about the axis under consideration shall be used. In the absence of the knowledge of the pedestal and foundation stiffness, the following may be assumed:

a) When the column is rigidly connected to a suitable foundation, the stiffness of the pedestal shall be taken as the stiffness of the column above base plate. However, in case of very stiff pedestals and foundations the column may be assumed as fixed at base.

b) When the column is nominally connected to the foundation, a pedestal stiffness of 10 percent of the column stiffness may be assumed.

c) When an actual pin or rocker is provided in the connection between the steel column and pedestal, the column is assumed as hinged at base and the pedestal and foundation may be appropriately designed for the reactions from the column.

d) In case of (a) and (b), the bottom of the pedestal shall be assumed to have the following boundary condition in the absence of any detailed procedure based on theory or tests:

1) When the foundation consist of a group of piles with a pile cap, raft foundation or an isolated footing resting on rock or very hard soil, the pedestal shall be assumed to be fixed at the level of the bottom of footing or at the top of pile cap.
2) When the foundation consists of an isolated footing resting on other soils, pedestal shall be assumed to be hinged at the level of the bottom of footing.
3) When the pedestal is supported by a single pile, which is laterally surrounded by soil providing passive resistance, the pile shall be assumed to be fixed at a depth of 5 times the diameter of the pile below the ground level in case of compact ground or the top level of compact soil in case of poor soil overlying compact soil.
4) When the column is founded into rock, it may be assumed to be fixed at the interface of the column and rock.

10.3.5 *Simple Construction*

Bending members may be assumed to have their ends connected for shear only and to be free to rotate. In triangulated structures, axial forces may be determined by assuming that all members are pin connected. The eccentricity for stanchion and column shall be assumed in accordance with **13.3.3**.

10.3.6 *Notional Horizontal Loads*

To analyse a frame subjected to gravity loads, considering the sway stability of the frame, notional horizontal forces should be applied. These notional horizontal forces account for practical imperfections and should be taken at each level as being equal to 0.5 percent of factored dead load plus vertical imposed loads applied at that level. The notional load should not be applied along with other lateral loads such as wind and earthquake loads in the analysis.

10.3.6.1 The notional forces should be applied on the whole structure, in both orthogonal directions, in one direction at a time, at roof and all floor levels or their equivalent. They should be taken as acting simultaneously with factored gravity loads.

10.3.6.2 The notional force should not be,

a) applied when considering overturning or overall instability;
b) combined with other horizontal (lateral) loads;
c) combined with temperature effects, and
d) taken to contribute to the net shear on the foundation.

10.3.6.3 The sway effect using notional load under gantry load case need not be considered if the ratio of height to lateral width of the building is less than unity.

10.4 Elastic Analysis

10.4.1 *Assumptions*

Individual members shall be assumed to remain elastic under the action of the factored design loads for all limit states.

The effect of haunching or any variation of the cross-section along the axis of a member shall be considered, and where significant, shall be taken into account in the determination of the member stiffness.

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10.4.2 *First-Order Elastic Analysis*

10.4.2.1 In a first-order elastic analysis, the equilibrium of the frame in the undeformed geometry is considered, the changes in the geometry of the frame due to the loading are not accounted for, and changes in the effective stiffness of the members due to axial force are neglected. The effects of these on the first-order bending moments shall be allowed for by using one of the methods of moment amplification of **10.4.3.2** or **10.4.3.3** as appropriate. Where the moment amplification factor K_y, K_z, calculated in accordance with **10.4.3.2** or **10.4.3.3** as appropriate, is greater than 1.4, a second-order elastic analysis in accordance with Annex A shall be carried out.

10.4.3 *Second-Order Elastic Analysis*

10.4.3.1 The analysis shall allow for the effects of the design loads acting on the structure and its members in their displaced and deformed configuration. These second-order effects shall be taken into account by using either:

a) A first-order elastic analysis with moment amplification in accordance with **10.4.2**, provided the moment amplification factors, K_y and K_z are not greater than 1.4; or

b) A second-order elastic analysis in accordance with Annex A.

10.4.3.2 *Moment amplification for members in non-sway frames*

For a member with zero axial compression or a member subject to axial tension, the design bending moment is that obtained from the first-order analysis for factored loads, without any amplification.

For a braced member with a design axial compressive force P_d as determined by the first-order analysis, the design bending moment shall be calculated considering moment amplification as in **15.3.2.2**.

10.4.3.3 *Moment amplification for members in sway frames*

The design bending moment shall be calculated as the product of moment amplification factor [*see* **15.3.2.2** (K_y, K_z)] and the moment obtained from the first-order analysis of the sway frame, unless analysis considering second order effects is carried out (*see* **10.4.3**).

10.4.3.4 The calculated bending moments from the first order elastic analysis may be modified by redistribution up to 15 percent of the peak calculated moment of the member under factored load, provided that,

a) the internal forces and moments in the members of the frame are in equilibrium with applied loads.

b) all the members in which the moments are reduced shall belong to plastic or compact section classification (*see* **9.7**).

10.5 Plastic Analysis

10.5.1 *Application*

The effects of design action throughout or on part of a structure may be determined by a plastic analysis, provided that the requirements of **10.5.2** are met. The distribution of design action effects shall satisfy equilibrium and the boundary conditions.

10.5.2 *Requirements*

When a plastic method of analysis is used, all of the following conditions shall be satisfied, unless adequate ductility of the structure and plastic rotation capacity of its members and connections are established for the design loading conditions by other means of evaluation:

a) The yield stress of the grade of the steel used shall not exceed 450 MPa.

b) The stress-strain characteristics of the steel shall not be significantly different from those obtained for steels complying with the accepted standard [6-6(6)] or equivalent and shall be such as to ensure complete plastic moment redistribution. The stress-strain diagram shall have a plateau at the yield stress, extending for at least six times the yield strain. The ratio of the tensile strength to the yield stress specified for the grade of the steel shall not be less than 1.2. The elongation on a gauge length complying with the accepted standard [6-6(6)] shall not be less than 15 percent; and the steel shall exhibit strain-hardening capability. Steels conforming to the accepted standard [6-6(6)] shall be deemed to satisfy the above requirements.

c) The members used shall be hot-rolled or fabricated using hot-rolled plates and sections.

d) The cross-section of members not containing plastic hinges should be at least that of compact section (*see* **9.7.2**), unless the members meet the strength requirements from elastic analysis.

e) Where plastic hinges occur in a member, the proportions of its Cross-section should not exceed the limiting values for plastic section given in **9.7.2**.

f) The cross-section should be symmetrical about its axis perpendicular to the axis of the plastic hinge rotation.

g) The members shall not be subject to impact loading, requiring fracture assessment or

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fluctuating loading, requiring a fatigue assessment [*see* Section 6(p)].

10.5.2.1 *Restraints*

If practicable, torsional restraint (against lateral buckling) should be provided at all plastic hinge locations. Where not feasible, the restraint should be provided within a distance of *D*/2 of the plastic hinge location, where *D* is the total depth of section.

The torsional restraint requirement at a section as above, need not be met at the last plastic hinge to form, provided it can be clearly identified.

Within a member containing a plastic hinge, the maximum distance L_m from the restraint at the plastic hinge to an adjacent restraint should be calculated by any rational method or the conservative method given below, so as to prevent lateral buckling.

Conservatively L_m (in mm) may be taken as:

$$L_m \leq \frac{38\ r_y}{\left[\frac{f_c}{130} + \left(\frac{f_y}{250}\right)^2 \left(\frac{x_t}{40}\right)^2\right]^{1/2}}$$

where

f_c = actual compressive stress on the cross-section due to axial load, in N/mm^2,

f_y = yield stress, in N/mm^2;

r_y = radius of gyration about the minor axis, in mm;

x_t = torsional index, $x_t = 1.132\ (AI_w/I_yI_t)0.5$;

A = area of cross-section; and

I_w, I_y, I_t = warping constant, second moment of the cross-section about the minor axes and St. Venant's torsion constant, respectively.

Where the member has unequal flanges, r_y should be taken as the lesser of the values of the compression flange only or the whole section.

Where the cross-section of the member varies within the length L_m, the maximum value of r_y and the minimum value of x_t should be used.

The spacing of restraints to member lengths not containing a plastic hinge should satisfy the recommendations of section on lateral buckling strength of beams (*see* **14.2.2**). Where the restraints are placed at the limiting distance L_m, no further checks are required.

10.5.2.2 *Stiffeners at plastic hinge locations*

Web stiffeners should be provided where a concentrated load, which exceeds 10 percent of the shear capacity of the member, is applied within *D/2* of a plastic hinge location, (*see* **14.2.1.2**). The stiffener should be provided within a distance of half the depth of the member on either side of the hinge location and be designed to carry the applied load in accordance with **14.7.4**. If the stiffeners are flat plates, the outstand width to the thickness ratio, *b/t*, should not exceed the values given in the plastic section (*see* **9.7** and Table 2). Where other sections are used, the ratio $\left(\frac{I_{so}}{I_t}\right)^{1/2}$, should not exceed the values given for plastic section (for simple outstand, as in **9.7**);

where

I_{so} = second moment of area of the stiffener about the face of the element perpendicular to the web; and

I_t = St. Venant's torsion constant of the stiffener.

10.5.2.3 The frame shall be adequately supported against sway and out-of-plane buckling, by bracings, moment resisting frame or an independent system such as shear wall.

10.5.2.4 *Fabrication restriction*

Within a length equal to the member depth, on either side of a plastic hinge location, the following restrictions should be applied to the tension flange and noted in the design drawings. Holes, if required, should be drilled or else punched 2 mm undersize and reamed. All sheared or hand flame cut edges should be finished smooth by grinding, chipping or planning.

10.5.3 *Assumptions in Analysis*

The design action effects shall be determined using a rigid-plastic analysis.

It shall be permissible to assume full strength or partial strength connections, provided the capacities of these are used in the analysis, and provided that,

a) In a full strength connection, the moment capacity of the connection shall be not less than that of the member being connected;

b) In a partial strength connection, the moment capacity of the connection may be less than that of the member being connected; and

c) In both cases the behavior of the connection shall be such as to allow all plastic hinges necessary for the collapse mechanism to develop, and shall be such that the required plastic hinge rotation does not exceed the rotation capacity at any of the plastic hinges in the collapse mechanism.

In the case of building structures, it is not normally necessary to consider the effect of alternating plasticity.

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10.5.4 *Second-Order Elastic Analysis*

Any second-order effects of the loads acting on the structure in its deformed configuration may be neglected, provided the following are satisfied:

a) For clad frames, provided the stiffening effects of masonry infill wall panels or diaphragms of profiled wall panel is not taken into account, and where elastic buckling load factor, λ_{cr} (*see* **10.6**) satisfies $\lambda_{cr}/\lambda_p \geq 10$.

   If $10 > \lambda_{cr}/\lambda_p \geq 4.6$ the second-order effects may be considered by amplifying the design load effects obtained from plastic analysis by a factor $\delta_p = \{0.9\ \lambda_{cr} /(\lambda_{cr}–1)\}$.

   If $\lambda_{cr}/\lambda_p < 4.6$, second-order elasto-plastic analysis or second order elastic analysis (*see* **10.4.3**) is to be carried out.

b) for unclad frames or for clad frames where the stiffening effects of masonry infill or diaphragms of profiled wall panel is taken into account, where elastic buckling load factor, λ_{cr} (*see* **10.6**) satisfies $\lambda_{cr}/\lambda_p \geq 20$.

   If $20 > \lambda_{cr}/\lambda_p \geq 5.75$ the second-order effects may be considered by amplifying the design load effects obtained from plastic analysis by a factor $\delta_p = \{0.9\ \lambda_{cr} /(\lambda_{cr}–1)\}$.

   If $\lambda_{cr}/\lambda_p < 5.75$, second-order elasto-plastic analysis or second-order elastic analysis (*see* **10.4.3**) shall be carried out.

10.6 Frame Buckling Analysis

10.6.1 The elastic buckling load factor (λ_{cr}) shall be the ratio of the elastic buckling load set of the frame to the design load set for the frame, and shall be determined in accordance with **10.6.2**.

NOTE — The value of λ_{cr} depends on the load set and has to be evaluated for each possible set of load combination.

10.6.2 *In-Plane frame buckling*

The elastic buckling load factor (λ_{cr}) of a rigid-jointed frame shall be determined by using:

a) One of the approximate methods of **10.6.2.1** and **10.6.2.2**, or

b) A rational elastic buckling analysis of the whole frame.

10.6.2.1 *Regular non-sway frames* (*see* **10.1.2**)

In a rectangular non-sway frame with regular loading and negligible axial forces in the beams, the Euler buckling stress $f_{cc,}$ for each column shall be determined in accordance with **13.1.2.1**. The elastic buckling load factor (λ_{cr}) for the whole frame shall be taken as the lowest of the ratio of (f_{cc}/f_{cd}) for all the columns, where f_{cd} is the axial compressive stress in the column from the factored load analysis.

10.6.2.2 *Regular sway frames*

In a rectangular sway frame with regular loading and negligible axial forces in the beams, the buckling load, $P_{cc,}$ for each column shall be determined as $P_{cc} = A f_{cc}$ where f_{cc} is the elastic buckling stress of the column in the plane of frame, obtained in accordance with **13.1.2.1**. The elastic buckling load factor $\lambda_{cr,}$ for the whole frame shall be taken as the lowest of all the ratios, $\lambda_{scr,}$ calculated for each storey of the building, as given below:

$$\lambda_{scr} = \frac{\sum(P_{cc}/L)}{\sum(P/L)}$$

where

P = member axial force from the factored load analysis, with tension taken as negative, and

L = column length and the summation includes all columns in the plane frame within a storey.

SECTION 6(e) LIMIT STATE DESIGN

11 LIMIT STATE DESIGN

11.1 Basis for Design

11.1.1 In the limit state design method, the structure shall be designed to withstand safely all loads likely to act on it throughout its life. It shall not suffer total collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent beyond the local damages. The objective of the design is to achieve a structure that will remain fit for use during its life with acceptable target reliability. In other words, the probability of a limit state being reached during its lifetime should be very low. The acceptable limit for the safety and serviceability requirements before failure occurs is called a limit state. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

11.1.2 Steel structures are to be designed and constructed to satisfy the design requirements with regard to stability, strength, serviceability, brittle fracture, fatigue, fire, and durability such that they meet the following:

a) Remain fit with adequate reliability and be able to sustain all actions (loads) and other influences experienced during construction and use;

b) Have adequate durability under normal maintenance;

c) Do not suffer overall damage or collapse disproportionately under accidental events

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like explosions, vehicle impact or due to consequences of human error to an extent beyond local damage. The potential for catastrophic damage shall be limited or avoided by appropriate choice of one or more of the following:

1) Avoiding, eliminating or reducing exposure to hazards, which the structure is likely to sustain.
2) Choosing structural forms, layouts and details and designing such that,
   i) the structure has low sensitivity to hazardous conditions; and
   ii) the structure survives with only local damage even after serious damage to any one individual element by the hazard;
3) Choosing suitable material, design and detailing procedure, construction specifications, and control procedures for shop fabrication and field construction as relevant to the particular structure.

The following conditions may be satisfied to avoid a disproportionate collapse:

a) The building should be effectively tied together at each principal floor level and each column should be effectively held in position by means of continuous ties (beams) nearly orthogonal, except where the steel work supports only cladding weighing not more than 0.7 kN/m^2 along with imposed and wind loads. These ties shall be steel members such as beams, which may be designed for other purposes, steel bar reinforcement anchoring the steel frame to concrete floor or steel mesh reinforcement in composite slab with steel profiled sheeting directly connected to beam with shear connectors. These steel ties and their end connections should be capable of resisting factored tensile force not less than the factored dead and imposed loads acting on the floor area tributary to the tie nor less than 75 kN. Such connection of ties to edge column should also be capable of resisting 1 percent of the maximum axial compression in the column at the level due to factored dead and imposed loads. All column splices should be capable of resisting a tensile force equal to the largest of a factored dead and imposed load reaction from a single floor level located between that column splice and the next column splice below that splice. Lateral load system to resist notional horizontal loads prescribed in **10.3.6** should be distributed throughout the building in nearly orthogonal directions so that no substantial portions is connected at only one point to such a system. Precast concrete or other heavy floor or roof units should be effectively anchored in the direction of their span either to each other over the support or directly to the support.

b) Where the above conditions to tie the columns to the floor adequately are not satisfied each storey of the building should be checked to ensure that disproportionate collapse would not precipitate by the notional removal, one at a time, of each column.

c) Where each floor is not laterally supported by more than one system, check should be made at each storey by removing one such lateral support system at a time to ensure that disproportionate collapse would not occur. The collapse is considered disproportionate, if more than 15 percent of the floor or roof area of 70 m^2 collapse at that level and at one adjoining level either above or below it, under a load equal to 1.05 or 0.9 times the dead load, 0.33 times temporary or full imposed load of permanent nature (as in storage buildings) and 0.33 times wind load acting together.

11.1.3 Structures designed for unusual or special functions shall comply with any other relevant additional limit state considered appropriate to that structure.

11.1.4 Generally structures and elements shall be designed by limit state method. Where limit state method cannot be conveniently adopted, working stress design [*see* Section 6(m)] may be used.

11.2 Limit State Design

11.2.1 For achieving the design objectives, the design shall be based on characteristic values for material strengths and applied loads (actions), which take into account the probability of variations in the material strengths and in the loads to be supported. The characteristic values shall be based on statistical data, if available. Where such data is not available, these shall be based on experience. The design values are derived from the characteristic values through the use of partial safety factors, both for material strengths and for loads. In the absence of special considerations, these factors shall have the values given in this Section according to the material, the type of load and the limit state being considered. The reliability of design is ensured by satisfying the requirement:

$$\text{Design action} \leq \text{Design strength}$$

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11.2.2 Limit states are the states beyond which the structure no longer satisfies the performance requirements specified. The limit states are classified as:

a) Limit state of strength; and

b) Limit state of serviceability.

11.2.2.1 The limit states of strength are those associated with failures (or imminent failure), under the action of probable and most unfavourable combination of loads on the structure using the appropriate partial safety factors, which may endanger the safety of life and property. The limit state of strength includes,

a) loss of equilibrium of the structure as a whole or any of its parts or components.

b) loss of stability of the structure (including the effect of sway where appropriate and overturning) or any of its parts including supports and foundations.

c) failure by excessive deformation, rupture of the structure or any of its parts or components.

d) fracture due to fatigue.

e) brittle fracture.

11.2.2.2 The limit state of serviceability includes,

a) deformation and deflections, which may adversely affect the appearance or effective use of the structure or may cause improper functioning of equipment or services or may cause damages to finishes and non-structural members.

b) vibrations in the structure or any of its components causing discomfort to people, damages to the structure, its contents or which may limit its functional effectiveness. Special consideration shall be given to systems susceptible to vibration, such as large open floor areas free of partitions to ensure that such vibrations are acceptable for the intended use and occupancy (*see* Annex B).

c) repairable damage or crack due to fatigue.

d) corrosion, durability, and

e) fire.

11.3 Actions

The actions (loads) to be considered in design include direct actions (loads) experienced by the structure due to self weight, external actions, etc, and imposed deformations such as that due to temperature and settlements.

11.3.1 *Classification of Actions*

Actions are classified by their variation with time as given below:

a) *Permanent actions* (Q_p) — Actions due to self-weight of structural and non-structural components, fittings, ancillaries, and fixed equipment, etc.

b) *Variable actions* (Q_v) — Actions due to construction and service stage loads such as imposed (live) loads (crane loads, snow loads, etc.), wind loads, and earthquake loads, etc.

c) *Accidental actions* (Q_a) — Actions expected due to explosions, and impact of vehicles, etc.

11.3.2 *Characteristic Actions* (*Loads*)

11.3.2.1 The characteristic actions, $Q_{c,}$ are the values of the different actions that are not expected to be exceeded with more than 5 percent probability, during the life of the structure and they are taken as,

a) the self-weight, in most cases calculated on the basis of nominal dimensions and unit weights (*see* **2** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

b) the variable loads, values of which are specified in relevant standard (*see* Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

c) the upper limit with a specified probability (usually 5 percent) not exceeding during some reference period (design life).

d) specified by client, or by designer in consultation with client, provided they satisfy the minimum provisions of the relevant loading standard.

11.3.2.2 The characteristic values of accidental loads generally correspond to the value specified by relevant code, standard or client. The design for accidental load is generally not required in building unless it is required by client or approving authority in which case, generally recommendation in **11.1.2** (c) or specialist literature shall be followed.

11.3.3 *Design Actions*

The design action, $Q_{d,}$ is expressed as $Q_d = \sum_k \gamma_{fk} Q_{ck}$

where

λ_{fk} = partial safety factor for different loads k, given in Table 4 to account for,

a) possibility of unfavourable deviation of the load from the characteristic value,

b) possibility of inaccurate assessment of the load,

c) uncertainty in the assessment of effects of the load, and

d) uncertainty in the assessment of the limit states being considered.

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Table 4 Partial Safety Factors for Loads, γ_f, for Limit States

(*Clauses* 9.5.1 *and* 11.3.3)

Sl No.	Combination	Limit State of Strength					Limit State of Serviceability			
		DL	IL [1]		WL/ EL	AL	DL	IL [1]		WL/ EL
			Leading	Accompanying				Leading	Accompanying	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	DL+IL+CL	1.5	1.5	1.05	—	—	1.0	1.0	1.0	—
ii)	DL+IL+CL+	1.2	1.2	1.05	0.6	—	1.0	0.8	0.8	0.8
	WL/EL	1.2	1.2	0.53	1.2					
iii)	DL+WL/EL	1.5 (0.9) [2]	—	—	1.5	—	1.0	—	—	1.0
iv)	DL+ER	1.2 (0.9) [2]	1.2	—	—	—	—	—	—	—
v)	DL+IL+AL	1.0	0.35	0.35	—	1.0	—	—	—	—

[1] When action of different imposed loads is simultaneously considered, the leading imposed load shall be considered to be the one causing the higher load effects in the member/section.

[2] This value is to be considered when the dead load contributes to stability against overturning is critical or the dead load causes reduction in stress due to other loads.

Abbreviations:

DL = Dead load, IL = Imposed load (Live load), WL = Wind load, CL = Crane load (Vertical/Horizontal), AL = Accidental load, ER = Erection load, EL = Earthquake load.

NOTE — The effects of actions (loads) in terms of stresses or stress resultants may be obtained from an appropriate method of analysis as in **10**.

The loads or load effects shall be multiplied by the relevant γ_f factors, given in Table 4, to get the design loads or design load effects.

11.4 Strength

The ultimate strength calculation may require consideration of the following:

a) Loss of equilibrium of the structure or any part of it, considered as a rigid body, and

b) Failure by excessive deformation, rupture or loss of stability of the structure or any part of it including support and foundation.

11.4.1 *Design Strength*

The design strength, S_d, is obtained as given below from ultimate strength, S_u and partial safety factors for materials, γ_m given in Table 5.

$$S_d = S_u / \gamma_m$$

where partial safety factor for materials, γ_m account for,

a) possibility of unfavourable deviation of material strength from the characteristic value;

b) possibility of unfavourable variation of member sizes;

c) possibility of unfavourable reduction in member strength due to fabrication and tolerances; and

d) uncertainty in the calculation of strength of the members.

Table 5 Partial Safety Factor for Materials, γ_m

(*Clause* 11.4.1)

Sl No.	Definition	Partial Safety Factor	
(1)	(2)	(3)	
i)	Resistance, governed by yielding, γ_{m0}	1.10	
ii)	Resistance of member to buckling, γ_{m0}	1.10	
iii)	Resistance, governed by ultimate stress, γ_{m1}	1.25	
iv)	Resistance of connection:	*Shop Fabrications*	*Field Fabrications*
	a) Bolts-Friction Type, γ_{mf}	1.25	1.25
	b) Bolts-Bearing Type, γ_{mb}	1.25	1.25
	c) Rivets, γ_{mr}	1.25	1.25
	d) Welds, γ_{mw}	1.25	1.50

11.5 Factors Governing the Ultimate Strength

11.5.1 *Stability*

Stability shall be ensured for the structure as a whole and for each of its elements. This should include, overall frame stability against overturning and sway, as given in **11.5.1.1** and **11.5.1.2**.

11.5.1.1 *Stability against overturning*

The structure as a whole or any part of it shall be designed to prevent instability due to overturning, uplift or sliding under factored load as given below:

a) The actions shall be divided into components aiding instability and components resisting instability.

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b) The permanent and variable actions and their effects causing instability shall be combined using appropriate partial safety factors for loads as per the limit state requirements, to obtain maximum destabilizing effect.

c) The permanent actions (loads) and effects contributing to resistance shall be multiplied with a partial safety factor 0.9 and added together with design resistance (after multiplying with appropriate partial safety factor). Variable actions and their effects contributing to resistance shall be disregarded.

d) The resistance effect shall be greater than or equal to the destabilizing effect. Combination of imposed and dead loads should be such as to cause most severe effect on overall stability.

11.5.1.2 *Sway stability*

The whole structure, including portions between expansion joints, shall be adequately stiff against sway. To ensure this, in addition to designing for applied horizontal loads, a separate check should be carried out for notional horizontal loads such as given in **10.3.6** to evaluate the sway under gravity loads.

11.5.2 *Fatigue*

Generally fatigue need not be considered unless a structure or element is subjected to numerous significant fluctuations of stress. Stress changes due to fluctuations in wind loading normally need not be considered. Fatigue design shall be in accordance with Section 6(p). When designing for fatigue, the partial safety factor for load, $\gamma_{f,}$ equal to unity shall be used for the load causing stress fluctuation and stress range.

11.5.3 *Plastic Collapse*

Plastic analysis and design may be used, if the requirement specified under the plastic method of analysis (*see* **10.5**) are satisfied.

11.6 Limit State of Serviceability

Serviceability limit state is related to the criteria governing normal use. Serviceability limit state is limit state beyond which the service criteria specified below, are no longer met:

a) Deflection limit,
b) Vibration limit,
c) Durability consideration, and
d) Fire resistance.

Unless specified otherwise (*see* Table 4), partial safety factor for loads, $\gamma_{f,}$ of value equal to unity shall be used for all loads leading to serviceability limit states to check the adequacy of the structure under serviceability limit states.

11.6.1 *Deflection*

The deflection under serviceability loads of a building or a building component should not impair the strength of the structure or components or cause damage to finishing. Deflections are to be checked for the most adverse but realistic combination of service loads and their arrangement, by elastic analysis, using partial safety factors in Table 4 for loads, as required, in Table 6. Table 6 gives recommended limits of deflections for certain structural members and systems. In Table 6, imposed load should include all post construction loads including superimposed dead loads. Circumstances may arise where greater or lesser values would be more appropriate, depending upon the nature of material in element to be supported (vulnerable to cracking or not) and intended use of the structure, as required by client.

11.6.1.1 Where the deflection due to the combination of dead load and imposed load is likely to be excessive, consideration should be given to pre-camber the beams, trusses and girders. The value of desired camber shall be specified in design drawing. Generally, for spans greater than 25 m, a camber approximately equal to the deflection due to dead loads plus half the imposed load may be used. The deflection of a member shall be calculated without considering the impact factor or dynamic effect of the loads on deflection. Roofs, which are very flexible, shall be designed to withstand any additional load that is likely to occur as a result of ponding of water or accumulation of snow or ice.

11.6.2 *Vibration*

Suitable provisions in the design shall be made for the dynamic effects of imposed loads, impact loads and vibration due to machinery operating loads. In severe cases possibility of resonance, fatigue or unacceptable vibrations shall be investigated. Unusually flexible structures (generally the height to effective width of lateral load resistance system exceeding 5:1) shall be investigated for lateral vibration under dynamic wind loads. Structures subjected to large number of cycles of loading shall be designed against fatigue failure, as specified in Section 6(p). Floor vibration effect shall be considered using specialist literature (*see* Annex B).

11.6.3 *Durability*

Factors that affect the durability of the buildings, under conditions relevant to their intended life, are listed below:

a) Environment,
b) Degree of exposure,
c) Shape of the member and the structural detail,
d) Protective measure, and
e) Ease of maintenance.

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Table 6 Deflection Limits

(*Clause* 11.6.1)

Type of Building (1)	Deflection (2)	Design Load (3)	Member (4)	Supporting (5)	Maximum Deflection (6)
Industrial buildings	Vertical	Imposed load and wind load	Purlins and Girts	Elastic cladding	Span / 150
				Brittle cladding	Span / 180
		Imposed load	Simple span	Elastic cladding	Span / 240
				Brittle cladding	Span / 300
		Imposed load	Cantilever span	Elastic cladding	Span / 120
				Brittle cladding	Span / 150
		Imposed load, wind load and crane load	Rafter supporting	Profiled metal sheeting	Span / 180
				Plastered sheeting	Span / 240
		Crane load (Manual operation)	Gantry	Wheels of crane	Span / 500
		Crane load (Electric operation up to 50 t)	Gantry	Wheels of crane	Span / 750
		Crane load (Electric operation over 50 t)	Gantry	Wheels of crane	Span / 1 000
	Lateral	No cranes (due to wind)	Column	Elastic cladding	Height / 150
				Masonry/Brittle cladding	Height / 240
		Crane load and wind load	Gantry (lateral)	Crane (absolute)	Span / 400
				Relative displacement between rails supporting wheels of crane	10 mm
Other buildings		Crane load and wind load	Column/frame	Gantry (Elastic cladding)	Height / 200
				Gantry (Brittle cladding; cab operated)	Height / 400
	Vertical	Imposed load	Floor and roof	Elements not susceptible to cracking	Span / 300
				Elements susceptible to cracking	Span / 360
		Imposed load	Cantilever	Elements not susceptible to cracking	Span / 150
				Elements susceptible to cracking	Span / 180
	Lateral	Wind load	Building	Elastic cladding	Height / 300
				Battle cladding	Height / 500
		Wind load	Inter-storey drift	—	Storey height/300

11.6.3.1 The durability of steel structures shall be ensured by following recommendations in Section 6(r). Specialist literature may be referred to for more detailed and additional information in design for durability.

11.6.4 *Fire Resistance*

Fire resistance of a steel member is a function of its mass, its geometry, and the actions to which it is subjected, its structural support condition, fire protection measures adopted and the fire to which it is exposed. Design provisions to resist fire are briefly discussed in Section 6(s). Specialist literature may be referred to for more detailed information in design of fire resistance of steel structures.

SECTION 6(f) DESIGN OF TENSION MEMBERS

12 DESIGN OF TENSION MEMBERS

12.1 Tension Members

Tension members are linear members in which axial forces act to cause elongation (stretch). Such members can sustain loads up to the ultimate load, at which stage they may fail by rupture at a critical section. However, if the gross area of the member yields over a major portion of its length before the rupture load is reached, the member may become non-functional due to excessive elongation. Plates and other rolled sections in tension may also fail by block shear of end bolted regions (*see* **12.4.1**).

The factored design tension T, in the members shall satisfy the following requirement:

$$T < T_d$$

where

T_d = design strength of the member.

The design strength of a member under axial tension, $T_{d,}$ is the lowest of the design strength due to yielding of gross section, $T_{dg;}$ rupture strength of critical section, $T_{dn;}$ and block shear $T_{db,}$ given in **12.2**, **12.3** and **12.4**, respectively.

12.2 Design Strength Due to Yielding of Gross Section

The design strength of members under axial tension, $T_{dg,}$ as governed by yielding of gross section, is given by:

$$T_{dg} = A_g f_y / \gamma_{m0}$$

where

f_y = yield stress of the material,

A_g = gross area of Cross-section, and

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γ_{m0} = partial safety factor for failure in tension by yielding (*see* Table 5).

12.3 Design Strength Due to Rupture of Critical Section

12.3.1 *Plates*

The design strength in tension of a plate, $T_{dn,}$ as governed by rupture of net cross-sectional area, $A_{n,}$ at the holes is given by:

$$T_{dn} = 0.9\, A_n f_u / \gamma_{m1}$$

where

γ_{m1} = partial safety factor for failure at ultimate stress (*see* Table 5),

f_u = ultimate stress of the material, and

A_n = net effective area of the member given by.

$$A_n = \left[b - nd_h + \sum \frac{p_{si}^2}{4g_i} \right] t$$

where

b, t = width and thickness of the plate, respectively,

d_h = diameter of the bolt hole (2 mm in addition to the diameter of the hole, in case of directly punched holes),

g = gauge length between the bolt holes, as shown in Fig. 5,

p_s = staggered pitch length between line of bolt holes, as shown in Fig. 5,

n = number of bolt holes in the critical section, and

i = subscript for summation of all the inclined legs.

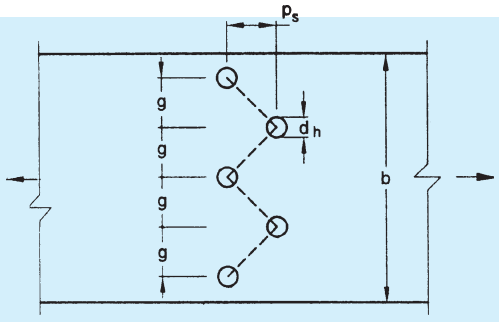


FIG. 5 PLATES WITH BOLTS HOLES IN TENSION

12.3.2 *Threaded Rods*

The design strength of threaded rods in tension, T_{dn}, as governed by rupture is given by:

$$T_{dn} = 0.9\, A_n f_u / \gamma_{m1}$$

where

A_n = net root area at the threaded section.

12.3.3 *Single Angles*

The rupture strength of an angle connected through one leg is affected by shear lag. The design strength, $T_{dn,}$ as governed by rupture at net section is given by:

$$T_{dn} = 0.9\, A_{nc} f_u / \gamma_{m1} + \beta\, A_{go} f_y / \gamma_{m0}$$

where

$$\beta = 1.4 - 0.076\,(w/t)\,(f_y/f_u)\,(b_s/L_c) \le (0.9 f_u \gamma_{m0}/f_y \gamma_{m1}) \ge 0.7$$

where

w = outstand leg width,

b_s = shear lag width, as shown in Fig. 6, and

L_c = length of the end connection, that is the distance between the outermost bolts in the end joint measured along the load direction or length of the weld along the load direction.

For preliminary sizing, the rupture strength of net section may be approximately taken as:

$$T_{dn} = \alpha\, A_n f_u / \gamma_{m1}$$

where

α = 0.6 for one or two bolts, 0.7 for three bolts and 0.8 for four or more bolts along the length in the end connection or equivalent weld length,

A_n = net area of the total cross-section,

A_{nc} = net area of the connected leg,

A_{go} = gross area of the outstanding leg, and

t = thickness of the leg.

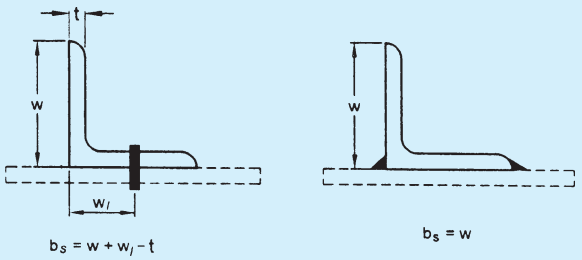


FIG. 6 ANGLES WITH SINGLE LEG CONNECTIONS

12.3.4 *Other Section*

The rupture strength, $T_{dn,}$ of the double angles, channels, I-sections and other rolled steel sections, connected by one or more elements to an end gusset is also governed by shear lag effects. The design tensile strength of such sections as governed by tearing of net section may also be calculated using equation in **12.3.3**, where b is calculated based on the shear lag distance, $b_{s,}$ taken

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from the farthest edge of the outstanding leg to the nearest bolt/weld line in the connected leg of the cross-section.

12.4 Design Strength Due to Block Shear

The strength as governed by block shear at an end connection of plates and angles is calculated as given in **12.4.1**.

12.4.1 *Bolted Connections*

The block shear strength, T_{db} of connection shall be taken as the smaller of,

$$T_{db} = [\, A_{vg} f_y / (\sqrt{3}\, \gamma_{m0}) + 0.9 A_{tn} f_u / \gamma_{m1} \,]$$

or

$$T_{db} = [0.9 A_{vn} f_u / (\sqrt{3}\, \gamma_{m1}) + A_{tg} f_y / \gamma_{m0}]$$

where

A_{vg}, A_{vn} = minimum gross and net area in shear along bolt line parallel to external force, respectively (1-2 and 3-4 as shown in Fig. 7A and 1-2 as shown in Fig. 7B),

A_{tg}, A_{tn} = minimum gross and net area in tension from the bolt hole to the toe of the angle, end bolt line, perpendicular to the line of force, respectively (2-3 as shown in Fig. 7B), and

f_u, f_y = ultimate and yield stress of the material, respectively.

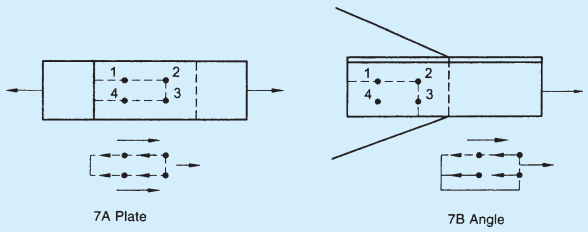


FIG. 7 BLOCK SHEAR FAILURE

12.4.2 *Welded Connection*

The block shear strength, T_{db} shall be checked for welded end connections by taking an appropriate section in the member around the end weld, which can shear off as a block.

SECTION 6(g) DESIGN OF COMPRESSION MEMBERS

13 DESIGN OF COMPRESSION MEMBERS

13.1 Design Strength

13.1.1 Common hot rolled and built-up steel members used for carrying axial compression, usually fail by flexural buckling. The buckling strength of these members is affected by residual stresses, initial bow and accidental eccentricities of load. To account for all these factors, the strength of members subjected to axial compression is defined by buckling class a, b, c, or d as given Table 7.

13.1.2 The factored design compression, P in members shall satisfy the following requirement:

$$P < P_d$$

where

$P_d = A_e f_{cd}$

where

A_e = effective sectional area as defined in **13.3.2**, and

f_{cd} = design compressive stress, obtained as per **13.1.2.1**.

13.1.2.1 The design compressive strength, f_{cd}, of axially loaded compression members shall be calculated using the following equation:

$$f_{cd} = \frac{f_y / \gamma_{m0}}{\phi + \left[\phi^2 - \lambda^2\right]^{0.5}} = \chi\, f_y / \gamma_{m0} \leq f_y / \gamma_{m0}$$

where

$\phi = 0.5[1 + \alpha\,(\lambda - 0.2) + \lambda^2]$

λ = non-dimensional effective slenderness ratio

$$= \sqrt{f_y / f_{cc}} = \sqrt{f_y \left(KL/r\right)^2 / \pi^2 E}$$

f_{cc} = Euler buckling stress $= \dfrac{\pi^2 E}{(KL/r)^2}$

where

KL/r = effective slenderness ratio or ratio of effective length, KL to appropriate radius of gyration, r;

α = imperfection factor given in Table 7;

χ = stress reduction factor (*see* Table 8) for different buckling class, slenderness ratio and yield stress

$$= \frac{1}{\left[\phi + \left(\phi^2 - \lambda^2\right)^{0.5}\right]}$$

γ_{m0} = partial safety factor for material strength.

NOTE — Calculated values of design compressive stress, f_{cd} for different buckling classes are given in Table 9.

13.1.2.2 The classification of different sections under different buckling class a, b, c or d, is given in Table 10.

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The stress reduction factor χ, and the design compressive stress f_{cd}, for different buckling class, yield stress, and effective slenderness ratio is given in Table 8 for convenience. The curves corresponding to different buckling class are presented in non-dimensional form, in Fig. 8.

Table 7 Imperfection Factor, α

(*Clauses* 13.1.1 *and* 13.1.2.1)

Buckling Class	a	b	c	d
(1)	(2)	(3)	(4)	(5)
α	0.21	0.34	0.49	0.76

13.2 Effective Length of Compression Members

13.2.1 The effective length *KL,* is calculated from the actual length *L*, of the member, considering the rotational and relative translational boundary conditions at the ends. The actual length shall be taken as the length from centre-to-centre of its intersections with the supporting members in the plane of the buckling deformation. In the case of a member with a free end, the free standing length from the centre of the intersecting member at the supported end, shall be taken as the actual length.

13.2.2 *Effective Length*

Where the boundary conditions in the plane of buckling can be assessed, the effective length, *KL* can be calculated on the basis of Table 11. Where frame analysis does not consider the equilibrium of a framed structure in the deformed shape (second-order analysis or advanced analysis), the effective length of compression members in such cases can be calculated using the procedure given in **C-1**. The effective length of stepped column in single storey buildings can be calculated using the procedure given in **C-2**.

13.2.3 *Eccentric Beam Connection*

In cases where the beam connections are eccentric in plan with respect to the axes of the column, the same conditions of restraint as in concentric connection shall be deemed to apply, provided the connections are carried across the flange or web of the columns as the case may be, and the web of the beam lies within, or in direct contact with the column section. Where practical difficulties prevent this, the effective length shall be taken as equal to the distance between points of restraint, in non-sway frames.

13.2.4 *Compression Members in Trusses*

In the case of bolted, riveted or welded trusses and braced frames, the effective length, *KL*, of the compression members shall be taken as 0.7 to 1.0 times the distance between centres of connections, depending on the degree of end restraint provided. In the case of members of trusses, buckling in the plane perpendicular to the plane of the truss, the effective length, *KL* shall be taken as the distance between the centers of intersection. The design of angle struts shall be as specified in **13.5**.

13.3 Design Details

13.3.1 *Thickness of Plate Elements*

Classification of members on the basis of thickness of

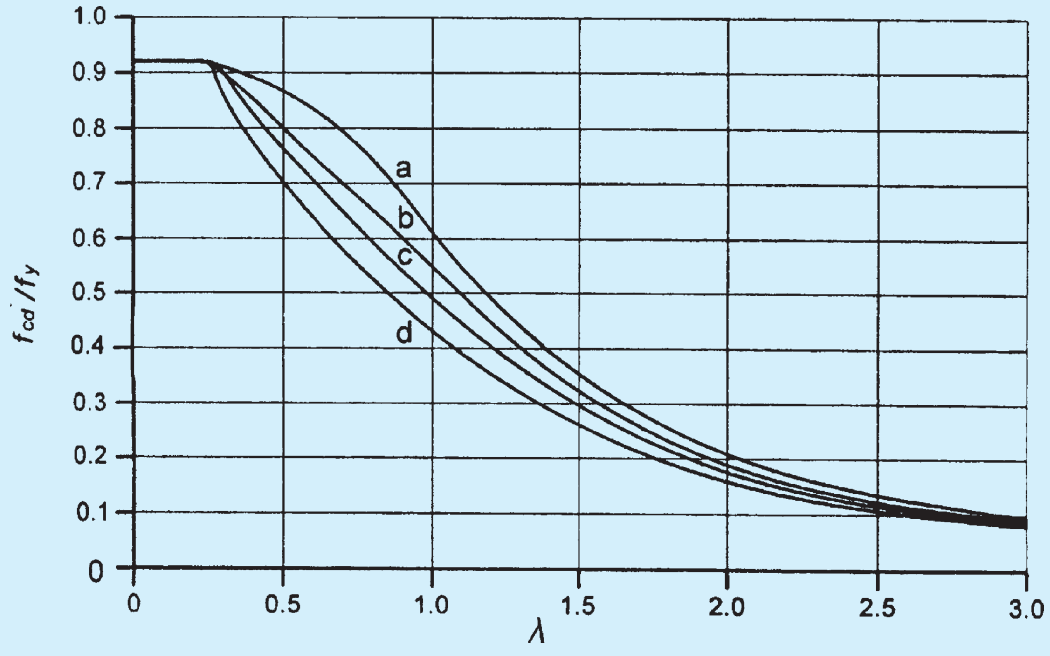


FIG. 8 COLUMN BUCKLING CURVES

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Table 8 (a) Stress Reduction Factor, χ for Column Buckling Class a

(*Clauses* 13.1.2.1 *and* 13.1.2.2)

KL/*r*	Yield Stress, f_y (MPa)																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	1.000	0.999	0.998	0.997	0.995	0.994	0.993	0.993	0.990	0.988	0.986	0.984	0.983	0.981	0.979	0.977	0.975	0.972	0.970
30	0.977	0.975	0.974	0.972	0.970	0.969	0.967	0.965	0.961	0.957	0.954	0.951	0.948	0.946	0.943	0.938	0.934	0.930	0.925
40	0.952	0.949	0.947	0.944	0.942	0.939	0.937	0.934	0.926	0.921	0.916	0.911	0.906	0.901	0.896	0.888	0.881	0.873	0.865
50	0.923	0.919	0.915	0.911	0.908	0.904	0.900	0.896	0.884	0.876	0.867	0.859	0.851	0.842	0.834	0.820	0.807	0.794	0.780
60	0.888	0.883	0.877	0.871	0.865	0.859	0.853	0.847	0.828	0.816	0.803	0.790	0.777	0.763	0.750	0.730	0.710	0.690	0.671
70	0.846	0.837	0.829	0.820	0.811	0.803	0.794	0.785	0.758	0.740	0.722	0.703	0.686	0.668	0.651	0.626	0.602	0.579	0.557
80	0.793	0.781	0.769	0.757	0.746	0.734	0.722	0.710	0.675	0.653	0.631	0.610	0.589	0.570	0.551	0.525	0.501	0.478	0.458
90	0.730	0.715	0.700	0.685	0.671	0.657	0.643	0.628	0.590	0.565	0.542	0.520	0.500	0.481	0.463	0.439	0.416	0.396	0.377
100	0.661	0.644	0.627	0.610	0.594	0.579	0.564	0.549	0.510	0.486	0.463	0.443	0.424	0.407	0.390	0.368	0.348	0.331	0.314
110	0.591	0.573	0.555	0.538	0.522	0.507	0.492	0.478	0.440	0.418	0.397	0.379	0.362	0.346	0.332	0.312	0.295	0.279	0.265
120	0.525	0.507	0.489	0.473	0.458	0.443	0.429	0.416	0.381	0.361	0.343	0.326	0.311	0.297	0.284	0.267	0.252	0.238	0.226
130	0.466	0.448	0.432	0.416	0.402	0.388	0.376	0.364	0.332	0.314	0.298	0.283	0.269	0.257	0.246	0.231	0.217	0.206	0.195
140	0.413	0.397	0.382	0.368	0.355	0.342	0.331	0.320	0.291	0.275	0.260	0.247	0.235	0.224	0.214	0.201	0.189	0.179	0.170
150	0.368	0.353	0.339	0.326	0.314	0.303	0.293	0.283	0.257	0.243	0.229	0.218	0.207	0.197	0.189	0.177	0.166	0.157	0.149
160	0.329	0.316	0.303	0.291	0.280	0.270	0.261	0.252	0.229	0.215	0.204	0.193	0.184	0.175	0.167	0.157	0.147	0.139	0.132
170	0.296	0.283	0.272	0.261	0.251	0.242	0.233	0.225	0.204	0.192	0.182	0.172	0.164	0.156	0.149	0.140	0.131	0.124	0.117
180	0.267	0.255	0.245	0.235	0.226	0.218	0.210	0.203	0.184	0.173	0.163	0.155	0.147	0.140	0.134	0.125	0.118	0.111	0.105
190	0.242	0.231	0.222	0.213	0.205	0.197	0.190	0.183	0.166	0.156	0.147	0.140	0.133	0.126	0.121	0.113	0.106	0.100	0.095
200	0.220	0.210	0.202	0.193	0.186	0.179	0.172	0.166	0.151	0.142	0.134	0.127	0.120	0.115	0.109	0.102	0.096	0.091	0.086
210	0.201	0.192	0.184	0.177	0.170	0.163	0.157	0.152	0.137	0.129	0.122	0.115	0.110	0.104	0.099	0.093	0.087	0.083	0.078
220	0.184	0.176	0.169	0.162	0.155	0.149	0.144	0.139	0.126	0.118	0.111	0.106	0.100	0.095	0.091	0.085	0.080	0.075	0.071
230	0.170	0.162	0.155	0.149	0.143	0.137	0.132	0.128	0.115	0.108	0.102	0.097	0.092	0.088	0.083	0.078	0.073	0.069	0.065
240	0.157	0.149	0.143	0.137	0.132	0.127	0.122	0.118	0.106	0.100	0.094	0.089	0.085	0.081	0.077	0.072	0.068	0.064	0.060
250	0.145	0.138	0.132	0.127	0.122	0.117	0.113	0.109	0.098	0.092	0.087	0.082	0.078	0.074	0.071	0.066	0.062	0.059	0.056

Table 8 (b) Stress Reduction Factor, χ for Column Buckling Class b

(*Clauses* 13.1.2.1 *and* 13.1.2.2)

KL/*r*	Yield Stress, f_y (MPa)																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	1.000	0.998	0.996	0.994	0.993	0.991	0.990	0.986	0.983	0.981	0.978	0.975	0.972	0.970	0.967	0.963	0.960	0.956	0.953
30	0.963	0.961	0.958	0.955	0.953	0.950	0.948	0.943	0.938	0.933	0.929	0.924	0.920	0.915	0.911	0.904	0.898	0.892	0.886
40	0.925	0.921	0.917	0.913	0.909	0.906	0.902	0.895	0.887	0.880	0.873	0.866	0.859	0.852	0.845	0.835	0.825	0.815	0.805
50	0.883	0.877	0.872	0.866	0.861	0.855	0.850	0.839	0.829	0.818	0.808	0.798	0.787	0.777	0.767	0.752	0.737	0.722	0.708
60	0.835	0.827	0.820	0.812	0.805	0.798	0.790	0.775	0.761	0.746	0.732	0.718	0.704	0.691	0.677	0.657	0.638	0.620	0.602
70	0.781	0.771	0.761	0.751	0.742	0.732	0.722	0.703	0.685	0.667	0.649	0.632	0.615	0.599	0.584	0.561	0.540	0.520	0.502
80	0.721	0.709	0.697	0.685	0.673	0.661	0.650	0.627	0.606	0.585	0.566	0.547	0.529	0.512	0.496	0.474	0.453	0.434	0.416
90	0.657	0.643	0.629	0.615	0.602	0.589	0.576	0.552	0.530	0.508	0.488	0.470	0.452	0.436	0.421	0.400	0.380	0.363	0.346
100	0.593	0.577	0.562	0.548	0.534	0.520	0.507	0.483	0.461	0.440	0.421	0.403	0.387	0.372	0.358	0.339	0.321	0.306	0.291
110	0.531	0.515	0.500	0.485	0.471	0.458	0.445	0.422	0.401	0.381	0.364	0.348	0.333	0.319	0.306	0.289	0.274	0.260	0.247
120	0.474	0.458	0.443	0.429	0.416	0.403	0.391	0.370	0.350	0.332	0.316	0.301	0.288	0.276	0.265	0.249	0.236	0.223	0.212
130	0.423	0.408	0.394	0.380	0.368	0.356	0.345	0.325	0.307	0.291	0.276	0.263	0.251	0.240	0.230	0.217	0.204	0.194	0.184
140	0.378	0.364	0.350	0.338	0.327	0.316	0.306	0.287	0.271	0.256	0.243	0.231	0.221	0.211	0.202	0.190	0.179	0.169	0.161
150	0.339	0.325	0.313	0.302	0.291	0.281	0.272	0.255	0.241	0.227	0.215	0.205	0.195	0.186	0.178	0.167	0.158	0.149	0.142
160	0.305	0.292	0.281	0.271	0.261	0.252	0.243	0.228	0.215	0.203	0.192	0.182	0.174	0.166	0.158	0.149	0.140	0.133	0.126
170	0.275	0.264	0.253	0.244	0.235	0.227	0.219	0.205	0.193	0.182	0.172	0.163	0.155	0.148	0.142	0.133	0.125	0.118	0.112
180	0.249	0.239	0.229	0.220	0.212	0.205	0.198	0.185	0.174	0.164	0.155	0.147	0.140	0.133	0.128	0.120	0.113	0.106	0.101
190	0.227	0.217	0.208	0.200	0.193	0.186	0.179	0.168	0.157	0.148	0.140	0.133	0.127	0.121	0.115	0.108	0.102	0.096	0.091
200	0.207	0.198	0.190	0.183	0.176	0.169	0.163	0.153	0.143	0.135	0.128	0.121	0.115	0.110	0.105	0.098	0.092	0.087	0.083
210	0.190	0.182	0.174	0.167	0.161	0.155	0.149	0.140	0.131	0.123	0.117	0.110	0.105	0.100	0.096	0.090	0.084	0.080	0.075
220	0.174	0.167	0.160	0.154	0.148	0.142	0.137	0.128	0.120	0.113	0.107	0.101	0.096	0.092	0.088	0.082	0.077	0.073	0.069
230	0.161	0.154	0.147	0.141	0.136	0.131	0.126	0.118	0.111	0.104	0.098	0.093	0.088	0.084	0.080	0.075	0.071	0.067	0.063
240	0.149	0.142	0.136	0.131	0.126	0.121	0.117	0.109	0.102	0.096	0.091	0.086	0.082	0.078	0.074	0.070	0.065	0.062	0.058
250	0.138	0.132	0.126	0.121	0.117	0.112	0.108	0.101	0.095	0.089	0.084	0.080	0.076	0.072	0.069	0.064	0.060	0.057	0.054

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Table 8 (c) Stress Reduction Factor, χ for Column Buckling Class c

(*Clauses* 13.1.2.1 *and* 13.1.2.2)

***KL*/r**	**Yield Stress, f_y (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	0.999	0.997	0.994	0.992	0.990	0.987	0.985	0.981	0.976	0.972	0.968	0.964	0.961	0.957	0.953	0.948	0.943	0.938	0.933
30	0.948	0.944	0.941	0.937	0.933	0.930	0.926	0.920	0.913	0.907	0.901	0.895	0.889	0.883	0.877	0.869	0.861	0.853	0.845
40	0.896	0.891	0.885	0.880	0.875	0.870	0.866	0.856	0.847	0.838	0.829	0.820	0.812	0.803	0.795	0.783	0.771	0.760	0.748
50	0.841	0.834	0.827	0.821	0.814	0.807	0.801	0.788	0.776	0.763	0.752	0.740	0.729	0.717	0.706	0.690	0.675	0.660	0.645
60	0.783	0.774	0.765	0.757	0.748	0.740	0.732	0.716	0.700	0.685	0.670	0.656	0.642	0.628	0.615	0.596	0.578	0.561	0.544
70	0.722	0.711	0.700	0.690	0.680	0.670	0.660	0.641	0.623	0.605	0.588	0.572	0.557	0.542	0.528	0.508	0.489	0.471	0.454
80	0.659	0.646	0.634	0.622	0.611	0.600	0.589	0.568	0.548	0.529	0.512	0.495	0.479	0.464	0.450	0.430	0.412	0.395	0.379
90	0.596	0.583	0.569	0.557	0.544	0.533	0.521	0.499	0.479	0.460	0.443	0.426	0.411	0.397	0.383	0.365	0.348	0.332	0.318
100	0.536	0.522	0.508	0.495	0.483	0.471	0.459	0.438	0.418	0.400	0.384	0.368	0.354	0.341	0.328	0.311	0.296	0.282	0.269
110	0.480	0.466	0.453	0.440	0.428	0.416	0.405	0.385	0.366	0.349	0.333	0.319	0.306	0.294	0.283	0.268	0.254	0.242	0.230
120	0.430	0.416	0.403	0.391	0.379	0.368	0.358	0.339	0.321	0.306	0.291	0.278	0.267	0.256	0.246	0.232	0.220	0.209	0.199
130	0.385	0.372	0.360	0.348	0.337	0.327	0.317	0.299	0.283	0.269	0.256	0.244	0.234	0.224	0.215	0.203	0.192	0.182	0.173
140	0.346	0.333	0.322	0.311	0.301	0.291	0.282	0.266	0.251	0.238	0.227	0.216	0.206	0.197	0.189	0.178	0.168	0.160	0.152
150	0.311	0.300	0.289	0.279	0.269	0.261	0.252	0.237	0.224	0.212	0.202	0.192	0.183	0.175	0.168	0.158	0.149	0.141	0.134
160	0.281	0.270	0.260	0.251	0.242	0.234	0.227	0.213	0.201	0.190	0.180	0.172	0.164	0.156	0.150	0.141	0.133	0.126	0.120
170	0.255	0.245	0.236	0.227	0.219	0.212	0.205	0.192	0.181	0.171	0.162	0.154	0.147	0.140	0.134	0.126	0.119	0.113	0.107
180	0.232	0.223	0.214	0.206	0.199	0.192	0.186	0.174	0.164	0.155	0.147	0.139	0.133	0.127	0.121	0.114	0.107	0.102	0.096
190	0.212	0.203	0.195	0.188	0.181	0.175	0.169	0.158	0.149	0.140	0.133	0.126	0.120	0.115	0.110	0.103	0.097	0.092	0.087
200	0.194	0.186	0.179	0.172	0.166	0.160	0.154	0.144	0.136	0.128	0.121	0.115	0.110	0.105	0.100	0.094	0.089	0.084	0.079
210	0.178	0.171	0.164	0.158	0.152	0.146	0.141	0.132	0.124	0.117	0.111	0.105	0.100	0.096	0.092	0.086	0.081	0.076	0.072
220	0.164	0.157	0.151	0.145	0.140	0.135	0.130	0.122	0.114	0.108	0.102	0.097	0.092	0.088	0.084	0.079	0.074	0.070	0.066
230	0.152	0.145	0.140	0.134	0.129	0.124	0.120	0.112	0.105	0.099	0.094	0.089	0.085	0.081	0.077	0.073	0.068	0.065	0.061
240	0.141	0.135	0.129	0.124	0.120	0.115	0.111	0.104	0.098	0.092	0.087	0.082	0.078	0.075	0.071	0.067	0.063	0.060	0.056
250	0.131	0.125	0.120	0.115	0.111	0.107	0.103	0.096	0.090	0.085	0.081	0.076	0.073	0.069	0.066	0.062	0.058	0.055	0.052

Table 8 (d) Stress Reduction Factor, χ for Column Buckling Class d

(*Clauses* 13.1.2.1 *and* 13.1.2.2)

***KL*/r**	**Yield Stress, f_y (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
20	0.999	0.995	0.991	0.988	0.984	0.980	0.977	0.970	0.964	0.958	0.952	0.946	0.940	0.935	0.930	0.922	0.915	0.908	0.901
30	0.922	0.916	0.911	0.906	0.901	0.896	0.891	0.881	0.872	0.863	0.855	0.847	0.839	0.831	0.823	0.813	0.802	0.792	0.782
40	0.848	0.841	0.834	0.828	0.821	0.815	0.808	0.796	0.784	0.773	0.762	0.751	0.741	0.731	0.721	0.707	0.694	0.681	0.668
50	0.777	0.768	0.760	0.752	0.744	0.736	0.728	0.713	0.699	0.685	0.672	0.659	0.647	0.635	0.624	0.608	0.592	0.577	0.563
60	0.707	0.697	0.687	0.678	0.668	0.659	0.651	0.634	0.617	0.602	0.587	0.573	0.560	0.547	0.535	0.517	0.501	0.486	0.471
70	0.640	0.629	0.618	0.607	0.597	0.587	0.578	0.559	0.542	0.526	0.510	0.496	0.482	0.469	0.456	0.439	0.423	0.408	0.394
80	0.576	0.564	0.553	0.542	0.531	0.521	0.511	0.492	0.474	0.458	0.442	0.428	0.414	0.402	0.390	0.373	0.358	0.344	0.330
90	0.517	0.505	0.493	0.482	0.471	0.461	0.451	0.432	0.415	0.399	0.384	0.370	0.357	0.345	0.334	0.319	0.304	0.292	0.280
100	0.464	0.451	0.440	0.428	0.418	0.408	0.398	0.380	0.363	0.348	0.334	0.321	0.309	0.298	0.288	0.274	0.261	0.249	0.239
110	0.416	0.404	0.392	0.381	0.371	0.361	0.352	0.335	0.319	0.305	0.292	0.281	0.270	0.259	0.250	0.237	0.226	0.215	0.206
120	0.373	0.361	0.350	0.340	0.330	0.321	0.313	0.297	0.282	0.269	0.257	0.246	0.236	0.227	0.219	0.207	0.197	0.187	0.179
130	0.336	0.325	0.314	0.305	0.295	0.287	0.279	0.264	0.251	0.239	0.228	0.218	0.209	0.200	0.193	0.182	0.173	0.164	0.157
140	0.303	0.292	0.283	0.274	0.265	0.257	0.250	0.236	0.224	0.213	0.203	0.194	0.185	0.178	0.171	0.161	0.153	0.145	0.138
150	0.274	0.264	0.255	0.247	0.239	0.231	0.224	0.212	0.201	0.190	0.181	0.173	0.165	0.159	0.152	0.144	0.136	0.129	0.123
160	0.249	0.240	0.231	0.223	0.216	0.209	0.203	0.191	0.181	0.171	0.163	0.155	0.149	0.142	0.137	0.129	0.122	0.116	0.110
170	0.227	0.218	0.210	0.203	0.196	0.190	0.184	0.173	0.164	0.155	0.147	0.140	0.134	0.128	0.123	0.116	0.110	0.104	0.099
180	0.207	0.199	0.192	0.185	0.179	0.173	0.167	0.157	0.149	0.141	0.134	0.127	0.122	0.116	0.111	0.105	0.099	0.094	0.089
190	0.190	0.183	0.176	0.169	0.164	0.158	0.153	0.144	0.136	0.128	0.122	0.116	0.111	0.106	0.101	0.095	0.090	0.085	0.081
200	0.175	0.168	0.162	0.156	0.150	0.145	0.140	0.132	0.124	0.118	0.112	0.106	0.101	0.097	0.093	0.087	0.082	0.078	0.074
210	0.161	0.155	0.149	0.143	0.138	0.134	0.129	0.121	0.114	0.108	0.102	0.097	0.093	0.089	0.085	0.080	0.075	0.071	0.068
220	0.149	0.143	0.138	0.133	0.128	0.123	0.119	0.112	0.105	0.100	0.094	0.090	0.086	0.082	0.078	0.074	0.069	0.066	0.062
230	0.138	0.133	0.128	0.123	0.118	0.114	0.110	0.104	0.097	0.092	0.087	0.083	0.079	0.075	0.072	0.068	0.064	0.061	0.058
240	0.129	0.123	0.119	0.114	0.110	0.106	0.103	0.096	0.090	0.085	0.081	0.077	0.073	0.070	0.067	0.063	0.059	0.056	0.053
250	0.120	0.115	0.110	0.106	0.102	0.099	0.095	0.089	0.084	0.079	0.075	0.071	0.068	0.065	0.062	0.058	0.055	0.052	0.049

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Table 9 (a) Design Compressive Stress, f_{cd} (MPa) For Column Buckling Class a

(*Clause* 13.1.2.1)

***KL*/r**	**Yield Stress, f_y (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	182	191	200	213	218	227	236	255	273	291	309	327	345	364	382	409	436	464	491
20	182	191	200	208	217	226	235	252	270	287	305	322	339	357	374	400	425	451	476
30	178	186	195	203	212	220	229	245	262	279	295	311	328	344	360	384	408	431	454
40	173	181	189	197	205	213	221	237	253	268	283	298	313	328	342	363	384	405	425
50	168	176	183	191	198	205	213	227	241	255	268	281	294	306	318	336	352	368	383
60	162	169	175	182	189	195	202	214	226	237	248	258	268	278	286	299	310	320	329
70	154	160	166	171	177	182	188	197	207	215	223	230	237	243	249	256	263	268	274
80	144	149	154	158	163	167	171	178	184	190	195	199	204	207	210	215	219	222	225
90	133	137	140	143	146	149	152	157	161	164	168	170	173	175	177	179	182	184	185
100	120	123	125	128	130	132	133	136	139	141	143	145	146	148	149	151	152	153	154
110	107	109	111	112	114	115	116	118	120	121	123	124	125	126	127	128	129	129	130
120	95.5	96.7	97.9	98.9	100	101	101	103	104	105	106	107	107	108	109	109	110	110	111
130	84.6	85.5	86.3	87	87.7	88.3	88.8	89.8	90.6	91.3	92.0	92.5	93.0	93.5	93.9	94.4	94.9	95.3	95.7
140	75.2	75.8	76.4	76.9	77.4	77.8	78.2	78.9	79.5	80.0	80.5	80.9	81.3	81.6	81.9	82.3	82.6	83.0	83.2
150	67.0	67.4	67.9	68.2	68.6	68.9	69.2	69.7	70.2	70.6	70.9	71.2	71.5	71.8	72.0	72.3	72.6	72.9	73.1
160	59.9	60.3	60.6	60.9	61.1	61.4	61.6	62.0	62.4	62.7	62.9	63.2	63.4	63.6	63.8	64.0	64.3	64.5	64.6
170	53.8	54.1	54.3	54.6	54.8	55.0	55.1	55.5	55.7	56.0	56.2	56.4	56.6	56.7	56.9	57.1	57.3	57.4	57.6
180	48.6	48.8	49.0	49.2	49.3	49.5	49.6	49.9	50.1	50.3	50.5	50.6	50.8	50.9	51.0	51.2	51.3	51.5	51.6
190	44.0	44.2	44.3	44.5	44.6	44.7	44.9	45.1	45.3	45.4	45.6	45.7	45.8	45.9	46.0	46.2	46.3	46.4	46.5
200	40.0	40.2	40.3	40.4	40.5	40.7	40.7	40.9	41.1	41.2	41.3	41.4	41.5	41.6	41.7	41.8	41.9	42.0	42.1
210	36.6	36.7	36.8	36.9	37.0	37.1	37.2	37.3	37.4	37.6	37.7	37.8	37.8	37.9	38.0	38.1	38.2	38.3	38.3
220	33.5	33.6	33.7	33.8	33.9	34.0	34.0	34.2	34.3	34.4	34.5	34.5	34.6	34.7	34.7	34.8	34.9	35.0	35.0
230	30.8	30.9	31.0	31.1	31.2	31.2	31.3	31.4	31.5	31.6	31.6	31.7	31.8	31.8	31.9	31.9	32.0	32.1	32.1
240	28.5	28.5	28.6	28.7	28.7	28.8	28.8	28.9	29.0	29.1	29.1	29.2	29.3	29.3	29.4	29.4	29.5	29.5	29.6
250	26.3	26.4	26.5	26.5	26.6	26.6	26.7	26.7	26.8	26.9	26.9	27.0	27.0	27.1	27.1	27.2	27.2	27.3	27.3

Table 9 (b) Design Compressive Stress, f_{cd} (MPa) for Column Buckling Class b

(*Clause* 13.1.2.1)

***KL*/r**	**Yield Stress, f_y (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	182	191	200	209	218	227	236	255	273	291	309	327	345	364	382	409	436	464	491
20	182	190	199	208	217	225	234	251	268	285	302	319	336	353	369	394	419	443	468
30	175	183	192	200	208	216	224	240	256	271	287	302	318	333	348	370	392	414	435
40	168	176	183	191	198	206	213	228	242	256	270	283	297	310	323	342	360	378	395
50	161	167	174	181	188	194	201	214	226	238	250	261	272	283	293	308	322	335	347
60	152	158	164	170	176	181	187	197	207	217	226	235	243	251	259	269	279	287	295
70	142	147	152	157	162	166	171	179	187	194	201	207	213	218	223	230	236	241	246
80	131	135	139	143	147	150	154	160	165	170	175	179	183	186	190	194	198	201	204
90	120	123	126	129	131	134	136	141	144	148	151	154	156	159	161	163	166	168	170
100	108	110	112	114	116	118	120	123	126	128	130	132	134	135	137	139	140	142	143
110	96.5	98.3	100	101	103	104	105	107	109	111	112	114	115	116	117	118	119	121	121
120	86.2	87.5	88.6	89.7	90.7	91.7	92.5	94.1	95.4	96.6	97.7	98.6	100	100	101	102	103	104	104
130	76.9	77.8	78.7	79.5	80.3	81.0	81.6	82.7	83.7	84.6	85.4	86.1	86.8	87.3	87.9	88.6	89.2	89.8	90.3
140	68.7	69.4	70.1	70.7	71.3	71.8	72.3	73.1	73.9	74.6	75.2	75.7	76.2	76.6	77.1	77.6	78.1	78.5	78.9
150	61.6	62.1	62.6	63.1	63.6	64.0	64.3	65.0	65.6	66.1	66.6	67.0	67.4	67.7	68.1	68.5	68.9	69.2	69.5
160	55.4	55.8	56.2	56.6	56.9	57.3	57.5	58.1	58.5	59.0	59.3	59.7	60.0	60.3	60.5	60.9	61.2	61.5	61.7
170	50.0	50.3	50.7	51.0	51.2	51.5	51.7	52.2	52.5	52.9	53.2	53.5	53.7	53.9	54.1	54.4	54.7	54.9	55.1
180	45.3	45.6	45.9	46.1	46.3	46.5	46.7	47.1	47.4	47.7	47.9	48.1	48.3	48.5	48.7	48.9	49.2	49.3	49.5
190	41.2	41.5	41.7	41.9	42.1	42.2	42.4	42.7	42.9	43.2	43.4	43.6	43.7	43.9	44.0	44.2	44.4	44.6	44.7
200	37.6	37.8	38.0	38.2	38.3	38.5	38.6	38.9	39.1	39.3	39.5	39.6	39.8	39.9	40.0	40.2	40.3	40.5	40.6
210	34.5	34.7	34.8	35.0	35.1	35.2	35.3	35.5	35.7	35.9	36.0	36.2	36.3	36.4	36.5	36.6	36.8	36.9	37.0
220	31.7	31.9	32.0	32.1	32.2	32.3	32.4	32.6	32.8	32.9	33.0	33.1	33.2	33.3	33.4	33.6	33.7	33.8	33.9
230	29.2	29.4	29.5	29.6	29.7	29.8	29.9	30.0	30.1	30.3	30.4	30.5	30.6	30.7	30.7	30.8	30.9	31.0	31.1
240	27.1	27.2	27.3	27.3	27.4	27.5	27.6	27.7	27.8	27.9	28.0	28.1	28.2	28.3	28.3	28.4	28.5	28.6	28.7
250	25.1	25.2	25.3	25.3	25.4	25.5	25.6	25.7	25.8	25.9	26.0	26.0	26.1	26.2	26.2	26.3	26.4	26.5	26.5

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Table 9 (c) Design Compressive Stress, f_{cd} (MPa) for Column Buckling Class c

(*Clause* 13.1.2.1)

***KL*/r**	**Yield Stress, f_y, (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	182	191	200	209	218	227	236	255	273	291	309	327	345	364	382	409	436	464	491
20	182	190	199	207	216	224	233	250	266	283	299	316	332	348	364	388	412	435	458
30	172	180	188	196	204	211	219	234	249	264	278	293	307	321	335	355	376	395	415
40	163	170	177	184	191	198	205	218	231	244	256	268	280	292	304	320	337	352	367
50	153	159	165	172	178	183	189	201	212	222	232	242	252	261	270	282	295	306	317
60	142	148	153	158	163	168	173	182	191	199	207	215	222	228	235	244	252	260	267
70	131	136	140	144	148	152	156	163	170	176	182	187	192	197	202	208	213	218	223
80	120	123	127	130	133	136	139	145	149	154	158	162	165	169	172	176	180	183	186
90	108	111	114	116	119	121	123	127	131	134	137	140	142	144	146	149	152	154	156
100	97.5	100	102	104	105	107	109	112	114	116	119	120	122	124	125	127	129	131	132
110	87.3	89.0	90.5	92.0	93.3	94.6	95.7	97.9	100	102	103	104	106	107	108	110	111	112	113
120	78.2	79.4	80.6	81.7	82.7	83.7	84.6	86.2	87.6	88.9	90.1	91.1	92.1	93.0	93.8	94.9	95.9	96.8	97.6
130	70.0	71.0	71.9	72.8	73.5	74.3	75.0	76.2	77.3	78.3	79.2	80.0	80.7	81.4	82.0	82.9	83.6	84.3	84.9
140	62.9	63.6	64.4	65.0	65.6	66.2	66.7	67.7	68.6	69.3	70.0	70.7	71.2	71.8	72.3	72.9	73.5	74.1	74.6
150	56.6	57.2	57.8	58.3	58.8	59.2	59.7	60.4	61.1	61.7	62.3	62.8	63.3	63.7	64.1	64.6	65.1	65.5	65.9
160	51.1	51.6	52.1	52.5	52.9	53.3	53.6	54.2	54.8	55.3	55.7	56.1	56.5	56.9	57.2	57.6	58.0	58.4	58.7
170	46.4	46.8	47.1	47.5	47.8	48.1	48.4	48.9	49.3	49.8	50.1	50.5	50.8	51.1	51.3	51.7	52.0	52.3	52.6
180	42.2	42.5	42.8	43.1	43.4	43.6	43.9	44.3	44.7	45.0	45.3	45.6	45.8	46.1	46.3	46.6	46.9	47.1	47.3
190	38.5	38.8	39.0	39.3	39.5	39.7	39.9	40.3	40.6	40.9	41.1	41.4	41.6	41.8	42.0	42.2	42.5	42.7	42.9
200	35.3	35.5	35.7	35.9	36.1	36.3	36.5	36.8	37.0	37.3	37.5	37.7	37.9	38.1	38.2	38.4	38.6	38.8	39.0
210	32.4	32.6	32.8	33.0	33.1	33.3	33.4	33.7	33.9	34.1	34.3	34.5	34.7	34.8	34.9	35.1	35.3	35.4	35.6
220	29.9	30.1	30.2	30.4	30.5	30.6	30.8	31.0	31.2	31.4	31.5	31.7	31.8	31.9	32.1	32.2	32.4	32.5	32.6
230	27.6	27.8	27.9	28.0	28.2	28.3	28.4	28.6	28.8	28.9	29.1	29.2	29.3	29.4	29.5	29.7	29.8	29.9	30.0
240	25.6	25.7	25.9	26.0	26.1	26.2	26.3	26.4	26.6	26.7	26.9	27.0	27.1	27.2	27.3	27.4	27.5	27.6	27.7
250	23.8	23.9	24.0	24.1	24.2	24.3	24.4	24.5	24.7	24.8	24.9	25.0	25.1	25.2	25.3	25.4	25.5	25.6	25.7

Table 9 (d) Design Compressive Stress, f_{cd} (MPa) for Column Buckling Class d

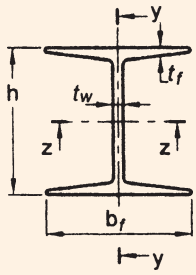
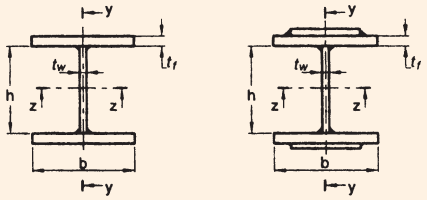
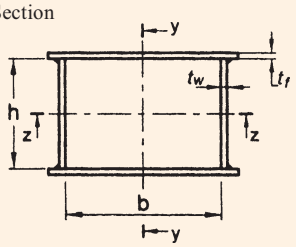
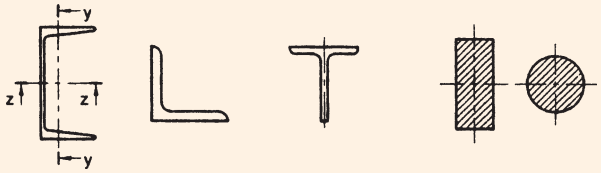
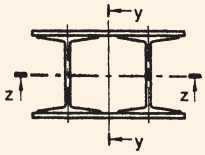
(*Clause* 13.1.2.1)

***KL*/r**	**Yield Stress, f_y (MPa)**																		
↓	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10	182	191	200	209	218	227	236	255	273	291	309	327	345	364	382	409	436	464	491
20	182	190	198	206	215	223	231	247	263	279	294	310	325	340	355	377	399	421	442
30	168	175	182	189	197	204	211	224	238	251	264	277	290	302	314	332	350	367	384
40	154	161	167	173	179	185	191	203	214	225	235	246	256	266	275	289	303	316	328
50	141	147	152	157	162	167	172	182	191	199	208	216	224	231	238	249	258	268	277
60	129	133	137	142	146	150	154	161	168	175	182	188	193	199	204	212	219	225	231
70	116	120	124	127	130	133	137	142	148	153	158	162	167	171	174	180	184	189	193
80	105	108	111	113	116	118	121	125	129	133	137	140	143	146	149	153	156	159	162
90	94.1	96.4	98.6	101	103	105	107	110	113	116	119	121	123	126	128	130	133	135	137
100	84.3	86.2	87.9	89.6	91.1	92.6	94.0	96.7	99.1	101	103	105	107	108	110	112	114	116	117
110	75.6	77.0	78.4	79.7	81.0	82.1	83.2	85.3	87.1	88.8	90.4	91.8	93.1	94.4	95.5	97.1	98.5	100	101
120	67.8	69.0	70.1	71.1	72.1	73.0	73.9	75.5	77.0	78.3	79.5	80.6	81.7	82.6	83.5	84.7	85.8	86.9	87.8
130	61.0	62.0	62.8	63.7	64.5	65.2	65.9	67.2	68.3	69.4	70.4	71.2	72.1	72.8	73.5	74.5	75.4	76.2	76.9
140	55.0	55.8	56.5	57.2	57.8	58.4	59.0	60.0	61.0	61.8	62.6	63.3	64.0	64.6	65.2	66.0	66.7	67.3	67.9
150	49.8	50.4	51.0	51.6	52.1	52.6	53.1	53.9	54.7	55.4	56.0	56.6	57.2	57.7	58.1	58.8	59.3	59.9	60.4
160	45.2	45.7	46.2	46.7	47.1	47.5	47.9	48.6	49.3	49.9	50.4	50.9	51.3	51.7	52.1	52.7	53.1	53.6	54.0
170	41.2	41.6	42.1	42.4	42.8	43.1	43.5	44.1	44.6	45.1	45.5	45.9	46.3	46.7	47.0	47.4	47.8	48.2	48.6
180	37.7	38.0	38.4	38.7	39.0	39.3	39.6	40.1	40.5	41.0	41.3	41.7	42.0	42.3	42.6	43.0	43.3	43.6	43.9
190	34.5	34.9	35.2	35.4	35.7	35.9	36.2	36.6	37.0	37.4	37.7	38.0	38.2	38.5	38.7	39.1	39.4	39.6	39.9
200	31.8	32.0	32.3	32.5	32.8	33.0	33.2	33.6	33.9	34.2	34.5	34.7	35.0	35.2	35.4	35.7	35.9	36.2	36.4
210	29.3	29.6	29.8	30.0	30.2	30.4	30.5	30.9	31.2	31.4	31.7	31.9	32.1	32.3	32.5	32.7	32.9	33.1	33.3
220	27.1	27.3	27.5	27.7	27.9	28.0	28.2	28.5	28.7	29.0	29.2	29.4	29.6	29.7	29.9	30.1	30.3	30.5	30.6
230	25.2	25.3	25.5	25.7	25.8	26.0	26.1	26.4	26.6	26.8	27.0	27.1	27.3	27.5	27.6	27.8	27.9	28.1	28.2
240	23.4	23.6	23.7	23.9	24.0	24.1	24.2	24.5	24.7	24.8	25.0	25.2	25.3	25.4	25.5	25.7	25.9	26.0	26.1
250	21.8	22.0	22.1	22.2	22.3	22.5	22.6	22.8	22.9	23.1	23.2	23.4	23.5	23.6	23.7	23.9	24.0	24.1	24.2

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Table 10 Buckling Class of Cross-Sections

(*Clause* 13.1.2.2)

Cross-Section (1)	Limits (2)	Buckling About Axis (3)	Buckling Class (4)
Rolled I-Sections 	$h/b_f > 1.2$:		
	$t_f \leq 40$ mm	*z-z*	a
		y-y	b
	40 mm < $t_f \leq 100$ mm	*z-z*	b
		y-y	c
	$h/b_f \leq 1.2$:		
	$t_f \leq 100$ mm	*z-z*	b
		y-y	c
	$t_f > 100$ mm	*z-z*	d
		y-y	d
Welded I-Section 	$t_f \leq 40$ mm	*z-z*	b
		y-y	c
	$t_f > 40$ mm	*z-z*	c
		y-y	d
Hollow Section 	Hot rolled	Any	a
	Cold formed	Any	b
Welded Box Section 	Generally (except as below)	Any	b
	Thick welds and		
	$b/t_f < 30$	*z-z*	c
	$h/t_w < 30$	*y-y*	c
Channel, Angle, T and Solid Sections 		Any	b
Built-up Member 		Any	c

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Table 11 Effective Length of Prismatic Compression Members

(*Clause* 13.2.2)

Boundary Conditions				Schematic Representation	Effective Length
At One End		At the Other End			
Translation (1)	Rotation (2)	Translation (3)	Rotation (4)	(5)	(6)
Restrained	Restrained	Free	Free		2.0*L*
Restrained	Free	Free	Restrained		
Restrained	Free	Restrained	Free		1.0*L*
Restrained	Restrained	Free	Restrained		1.2*L*
Restrained	Restrained	Restrained	Free		0.8*L*
Restrained	Restrained	Restrained	Restrained		0.65*L*

NOTE — *L* is the unsupported length of the compression member (*see* **13.2.1**).

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constituent plate elements shall satisfy the width-thickness ratio requirements specified in Table 2.

13.3.2 *Effective Sectional Area, A_e*

Except as modified in **9.7.2** (Class 4), the gross sectional area shall be taken as the effective sectional area for all compression members fabricated by welding, bolting and riveting so long as the section is semi-compact or better. Holes not fitted with rivets, bolts or pins shall be deducted from gross area to calculate effective sectional area.

13.3.3 *Eccentricity for Stanchions and Columns*

13.3.3.1 For the purpose of determining the stress in a stanchion or column section, the beam reactions or similar loads shall be assumed to be applied at an eccentricity of 100 mm from the face of the section or at the center of bearing whichever dimension gives the greater eccentricity, and with the exception of the following two cases:

a) In the case of cap connection, the load shall be assumed to be applied at the face of the column or stanchion section or at the edge of packing, if used towards the span of the beam.

b) In the case of a roof truss bearing on a cap, no eccentricity be taken for simple bearings without connections capable of developing any appreciable moment. In case of web member connection with face, actual eccentricity is to be considered.

13.3.3.2 In continuous columns, the bending moments due to eccentricities of loading on the columns at any floor may be divided equally between the columns above and below that floor level, provided that the moment of inertia of one column section, divided by its effective length does not exceed 1.5 times the corresponding value of the other column. Where this ratio is exceeded, the bending moment shall be divided in proportion to the moment of inertia of the column sections divided by their respective effective lengths.

13.3.4 *Splices*

13.3.4.1 Where the ends of compression members are prepared for bearing over the whole area, they shall be spliced to hold the connected members accurately in position, and to resist bending or tension, if present. Such splices should maintain the intended member stiffness about each axis. Splices should be located as close to the point of inflection as possible. Otherwise their capacity should be adequate to carry magnified moment (*see* **15.3.2.2**). The ends of compression members faced for bearing shall invariably be machined to ensure perfect contact of surfaces in bearing.

13.3.4.2 Where such members are not faced for complete bearing, the splices shall be designed to transmit all the forces to which the members are subjected.

13.3.4.3 Wherever possible, splices shall be proportioned and arranged so that the centroidal axis of the splice coincides as nearly as possible with the centroidal axes of the members being jointed, in order to avoid eccentricity; but where eccentricity is present in the joint, the resulting stress shall be accounted for.

13.4 Column Bases

13.4.1 *General*

Column bases should have sufficient stiffness and strength to transmit axial force, bending moments and shear forces at the base of the columns to their foundation without exceeding the load carrying capacity of the supports. Anchor bolts and shear keys should be provided wherever necessary. Shear resistance at the proper contact surface between steel base and concrete/grout may be calculated using a friction coefficient of 0.45.

The nominal bearing pressure between the base plate and the support below may be determined on the basis of linearly varying distribution of pressure. The maximum bearing pressure on concrete under the limit states design load should not exceed the bearing strength equal to $0.45 f_{ck} \left[\sqrt{(A_1 / A_2)}\right]$ and $0.9 f_{ck}$, whichever is smaller, where f_{ck} is the smaller of characteristic cube strength of concrete or bedding material, A_1 is the area of concrete pedestal on which the base plate is sitting, and A_2 is the surface area of the steel base plate transferring the load to the concrete pedestal.

13.4.1.1 If the size of the base plate is larger than that required to limit the bearing pressure on the base support, an equal projection c of the base plate beyond the face of the column and gusset may be taken as effective in transferring the column load as given in Fig. 9, such that bearing pressure on the effective area does not exceed bearing capacity of concrete base.

13.4.2 *Gusseted Bases*

For stanchion with gusseted bases, the gusset plates, angle cleats, stiffeners, fastenings, etc, in combination with the bearing area of the shaft, shall be sufficient to take the loads, bending moments and reactions to the base plate without exceeding specified strength. All the bearing surfaces shall be machined to ensure perfect contact.

13.4.2.1 Where the ends of the column shaft and the gusset plates are not faced for complete bearing, the welds, fastenings connecting them to the base plate shall be sufficient to transmit all the forces to which the base is subjected.

13.4.2.2 *Column and base plate connections*

Where the end of the column is connected directly to the base plate by means of full penetration butt welds, the connection shall be deemed to transmit to the base all the forces and moments to which the column is subjected.

13.4.3 *Slab Bases*

Columns with slab bases need not be provided with gussets, but sufficient fastenings shall be provided to retain the parts securely in place and to resist all moments and forces, other than direct compression, including those arising during transit, unloading and erection.

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13.4.3.1 The minimum thickness, t_s, of rectangular slab bases, supporting columns under axial compression shall be:

$$t_s = \sqrt{2.5w(a^2 - 0.3b^2)\gamma_{m0} / f_y} > t_f$$

where

w = uniform pressure from below on the slab base under the factored load axial compression;

a, b = larger and smaller projection, respectively of the slab base beyond the rectangle circumscribing the column; and

t_f = flange thickness of compression member.

When only the effective area of the base plate is used as in **13.4.1.1**, c^2 may be used in the above equation (*see* Fig. 9) instead of $(a^2 - 0.3b^2)$.

13.4.3.2 When the slab does not distribute the column load uniformly, due to eccentricity of the load etc, special calculation shall be made to show that the base is adequate to resist the moment due to the non-uniform pressure from below.

13.4.3.3 Bases for bearing upon concrete or masonry need not be machined on the underside.

13.4.3.4 In cases where the cap or base is fillet welded directly to the end of the column without boring and shouldering, the contact surfaces shall be machined to give a perfect bearing and the welding shall be sufficient to transmit the forces as required in **13.4.3**. Where full strength butt welds are provided, machining of contact surfaces is not required.

13.5 Angle Struts

13.5.1 *Single Angle Struts*

The compression in single angles may be transferred either concentrically to its centroid through the end connections or eccentrically by connecting one of its legs to a gusset or adjacent member.

13.5.1.1 *Concentric loading*

When a single angle is concentrically loaded in compression, the design strength may be evaluated using **13.1.2**, by calculating the non-dimensional slenderness ratio, λ_{vv}, for buckling about the minor axis, *v-v*, as given by:

$$\lambda_{vv} = \frac{\left(\frac{l_{vv}}{r_{vv}}\right)}{\varepsilon\sqrt{\frac{\pi^2 E}{250}}}$$

l_{vv} = Laterally unsupported length preventing translation normal to the minor axis

r_{vv} = radius of gyration of the angle section about the minor axis

13.5.1.2 *Loaded through one leg*

The design strength of single angle members loaded in compression through one of its legs is affected by flexural torsional buckling and bending. The design compressive strength of such eccentrically loaded angle members, *in lieu of* a more exact second order design under combined bending axial compression, may be evaluated approximately as given below.

The design compressive strength, of single angles loaded through gusset connection to one leg parallel to the *a-a* axis (*a-a* axis being either the *z-z* or the *y-y* axis, depending on which leg is connected to the gusset) of the member may be calculated as:

$$f_{cde} = K_f \chi_{aa} f_y / \gamma_{m0}$$

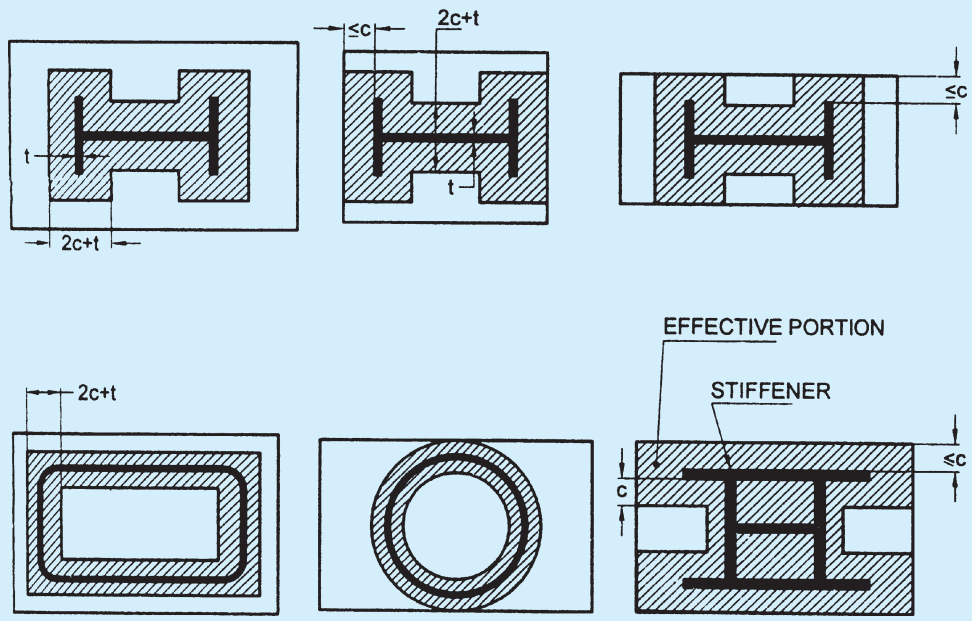


FIG. 9 EFFECTIVE AREA OF BASE PLATE

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where

χ_{aa} = Stress reduction factor (*see* Table 8) for buckling class 'b', calculated as per **13.1.12.1,** using the non-dimensional slenderness ratio, λ_{aa}.

$$K_f = k_1 + k_2\lambda_{aa} + k_3\lambda_f,$$

where

K_f = modification factor to account for eccentric end connection

k_1, k_2, k_3 = constants depending upon the end condition, as given in Table 12,

$$\lambda_{aa} = \frac{\left(\frac{l_{aa}}{r_{aa}}\right)}{\varepsilon\sqrt{\frac{\pi^2 E}{250}}}$$

$$\lambda_{\varphi} = \frac{(b_1 + b_2)/2t}{\varepsilon\sqrt{\frac{\pi^2 E}{250}}}$$

l_{aa} = centre-to-centre length of the lateral support preventing translation of the member perpendicular to *a-a* axis (*a-a* axis being either the *z-z* or the *y-y* axis, depending on which leg is connected to the gusset),

r_{aa} = radius of gyration of the angle member about the *a-a* axis (*a-a* axis being either the *z-z* or the *y-y* axis, depending on which leg is connected to the gusset), parallel to the plane of the end gusset plates,

b_1, b_2 = width of the connected and outstanding legs of the angle, respectively.

t = thickness of the leg, and

ε = yield stress ratio, $\sqrt{\frac{250}{f_y}}$, f_y being in MPa

Table 12 Constants k_1, k_2, and k_3

(*Clause* 13.5.1.2)

Sl No.	End Connection	Gusset/ Connecting Member Fixity[1)]	k_1	k_2	k_3
(1)	(2)	(3)	(4)	(5)	(6)
i)	Fully welded or connected with two or more bolts	Fixed	0.798	0.563	-2.072
		Hinged	0.401	0.420	-1.040
ii)	Single bolt	Fixed	0.418	0.547	-1.400
		Hinged	0.374	0.415	-2.072

[1)] In-plane rotational restraint provided to the gusset by the supporting member. For partial restraint, k_f can be interpolated between the results for fixed and hinged cases.

13.5.2 *Double Angle Struts*

13.5.2.1 For double angle discontinuous struts, connected back to back, on opposite sides of the gusset or a section, by not less than two bolts or rivets in line along the angles at each end, or by the equivalent in welding, the load may be regarded as applied axially. The effective length, *KL*, in the plane of end gusset shall be taken as between 0.7 and 0.85 times the distance between intersections, depending on the degree of the restraint provided. The effective length, *KL,* in the plane perpendicular to that of the end gusset, shall be taken as equal to the distance between centers of intersections. The calculated average compressive stress shall not exceed the values based on **13.1.2**. The angles shall be connected together over their lengths so as to satisfy the requirements of **13.8** and **16.2.5**.

13.5.2.2 Double angle discontinuous struts connected back-to-back, to one side of a gusset or section by one or more bolts or rivets in each angle, or by the equivalent in welding, shall be designed in accordance with **13.5.1** and the angles shall be connected together over their lengths so as to satisfy the requirements of **13.8** and **16.2.5**.

13.5.3 *Continuous Members*

Double angle continuous struts such as those forming the flanges, chords or ties of trusses or trussed girders, or the legs of towers shall be designed as axially loaded compression members, and the effective length shall be taken in accordance with **13.2.4**.

13.5.4 *Combined Stresses*

In addition to axial loads, if the struts carry loads which cause transverse bending, the combined bending and axial stresses shall be checked in accordance with **14.3**. For determining the permissible axial and bending stresses, the effective length shall be taken in accordance with the **13.2** and **14.3**.

13.6 Laced Columns

13.6.1 *General*

13.6.1.1 Members comprising two main components laced and tied, should where practicable, have a radius of gyration about the axis perpendicular to the plane of lacing not less than the radius of gyration about the axis parallel to the plane of lacing [*see* Fig.10A and Fig. 10B].

13.6.1.2 As far as practicable, the lacing system shall be uniform throughout the length of the column.

13.6.1.3 Except for tie plates as specified in **13.7**, double laced systems [*see* Fig. 10B] and single laced systems [*see* Fig. 10A] on opposite sides of the main components shall not be combined with cross members (ties) perpendicular to the longitudinal axis of the strut [*see* Fig. 10C], unless all forces resulting from deformation of the strut members are calculated and provided for in the design of lacing and its fastenings.

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13.6.1.4 Single laced systems, on opposite faces of the components being laced together shall preferably be in the same direction so that one is the shadow of the other, instead of being mutually opposed in direction.

13.6.1.5 The effective slenderness ratio, $(KL/r)_e$, of laced columns shall be taken as 1.05 times the $(KL/r)_0$, the actual maximum slenderness ratio, in order to account for shear deformation effects.

13.6.2 *Width of Lacing Bars*

In bolted/riveted construction, the minimum width of lacing bars shall be three times the nominal diameter of the end bolt/rivet.

13.6.3 *Thickness of Lacing Bars*

The thickness of flat lacing bars shall not be less than one-fortieth of its effective length for single lacings and one-sixtieth of the effective length for double lacings.

13.6.3.1 Rolled sections or tubes of equivalent strength may be permitted instead of flats, for lacings.

13.6.4 *Angle of Inclination*

Lacing bars, whether in double or single systems, shall be inclined at an angle not less than 40° nor more than 70° to the axis of the built-up member.

13.6.5 *Spacing*

13.6.5.1 The maximum spacing of lacing bars, whether connected by bolting, riveting or welding, shall also be such that the maximum slenderness ratio of the components of the main member (a_1/r_1), between consecutive lacing connections is not greater than 50 or 0.7 times the most unfavourable slenderness ratio of the member as a whole, whichever is less, where a_1 is the unsupported length of the individual member between lacing points, and r_1 is the minimum radius of gyration of the individual member being laced together.

13.6.5.2 Where lacing bars are not lapped to form the connection to the components of the members, they shall be so connected that there is no appreciable interruption in the triangulation of the system.

13.6.6 *Design of Lacings*

13.6.6.1 The lacing shall be proportioned to resist a total transverse shear, V_t, at any point in the member, equal to at least 2.5 percent of the axial force in the member and shall be divided equally among all transverse-lacing systems in parallel planes.

13.6.6.2 For members carrying calculated bending stress due to eccentricity of loading, applied end moments and/or lateral loading, the lacing shall be proportioned to resist the actual shear due to bending, in addition to that specified in **13.6.6.1**.

13.6.6.3 The slenderness ratio, *KL/r*, of the lacing bars shall not exceed 145. In bolted/riveted construction, the effective length of lacing bars for the determination of the design strength shall be taken as the length between the inner end fastener of the bars for single lacing, and as 0.7 of this length for double lacings effectively connected at intersections. In welded construction, the effective lengths shall be taken as 0.7 times the distance between the inner ends of welds connecting the single lacing bars to the members.

NOTE — The required section for lacing bars as compression/tension members shall be determined by using the appropriate design stresses, f_{cd} subject to the requirements in **13.6.3** to **13.6.6** and T_d in **12.1**.

13.6.7 *Attachment to Main Members*

The bolting, riveting or welding of lacing bars to the main members shall be sufficient to transmit the force calculated in the bars. Where welded lacing bars overlap the main members, the amount of lap measured along either edge of the lacing bar shall be not less than four times the thickness of the bar or the thickness of the element of the members to which it is connected,

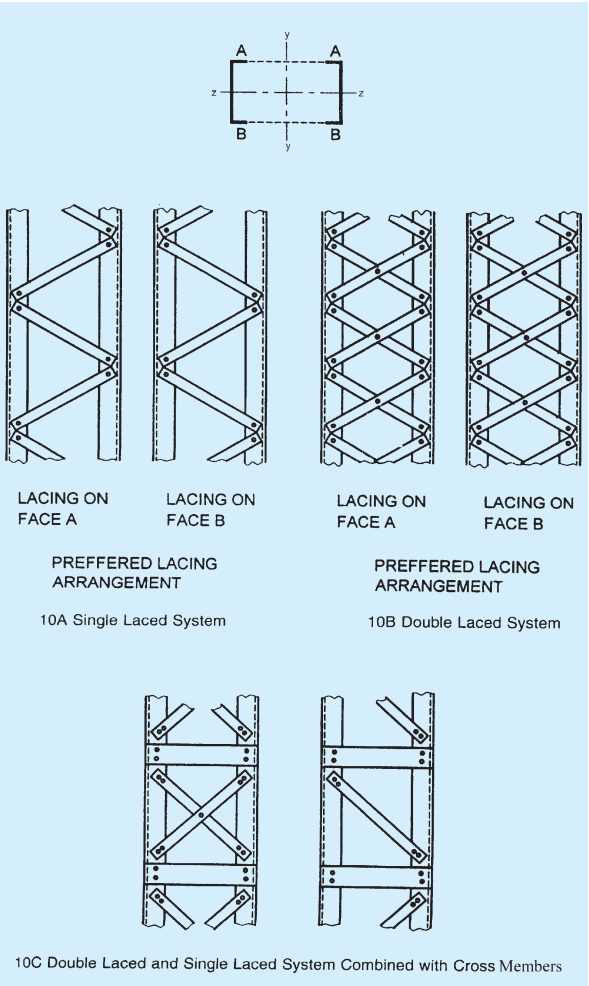


FIG. 10 TOP RESTRAINT CONDITIONS

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whichever is less. The welding should be sufficient to transmit the load in the bar and shall, in any case, be provided along each side of the bar for the full length of lap.

13.6.8 *End Tie Plates*

Laced compression members shall be provided with tie plates as per **13.7** at the ends of lacing systems and at intersection with other members/stays and at points where the lacing systems are interrupted.

13.7 Battened Columns

13.7.1 *General*

13.7.1.1 Compression members composed of two main components battened should preferably have the individual members of the same cross-section and symmetrically disposed about their major axis. Where practicable, the compression members should have a radius of gyration about the axis perpendicular to the plane of the batten not less than the radius of gyration about the axis parallel to the plane of the batten (*see* Fig. 11).

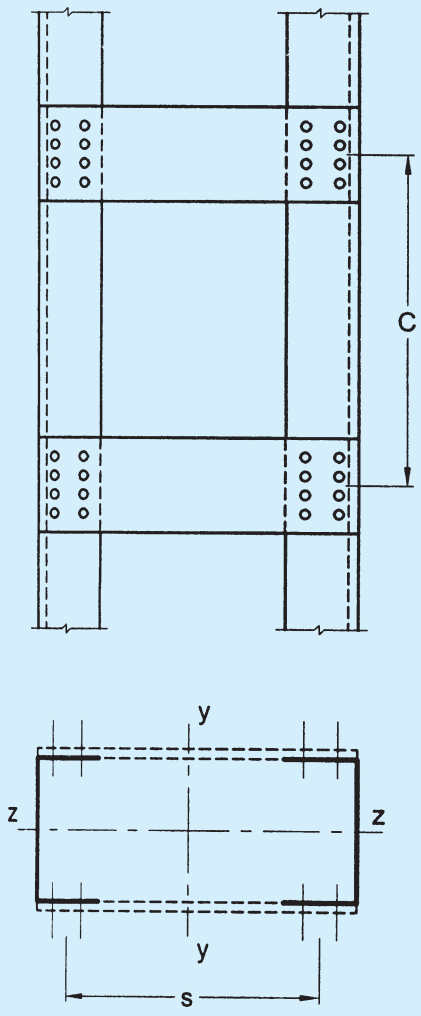


FIG. 11 BATTEN COLUMN SECTION

13.7.1.2 Battened compression members, not complying with the requirements specified in this Section or those subjected to eccentricity of loading, applied moments or lateral forces in the plane of the battens (*see* Fig. 11), shall be designed according to the exact theory of elastic stability or empirically, based on verification by tests.

NOTE — If the column section is subjected to eccentricity or other moments about an axis perpendicular to battens, the battens and the column section should be specially designed for such moments and shears.

13.7.1.3 The battens shall be placed opposite to each other at each end of the member and at points where the member is stayed in its length and as far as practicable, be spaced and proportioned uniformly throughout. The number of battens shall be such that the member is divided into not less than three bays within its actual length from centre-to-centre of end connections.

13.7.1.4 The effective slenderness ratio $(KL/r)_e$ of battened columns, shall be taken as 1.1 times the $(KL/r)_0$, the maximum actual slenderness ratio of the column, to account for shear deformation effects.

13.7.2 *Design of Battens*

13.7.2.1 *Battens*

Battens shall be designed to carry the bending moments and shear forces arising from transverse shear force V_t equal to 2.5 percent of the total axial force on the whole compression member, at any point in the length of the member, divided equally between parallel planes of battens. Battened member carrying calculated bending moment due to eccentricity of axial loading, calculated end moments or lateral loads parallel to the plane of battens, shall be designed to carry actual shear in addition to the above shear. The main members shall also be checked for the same shear force and bending moments as for the battens.

Battens shall be of plates, angles, channels, or I-sections and at their ends shall be riveted, bolted or welded to the main components so as to resist simultaneously a shear $V_b = V_t C/NS$ along the column axis and a moment $M = V_t C/2N$ at each connection,

where

V_t = transverse shear force as defined above;

C = distance between centre-to-centre of battens, longitudinally;

N = number of parallel planes of battens; and

S = minimum transverse distance between the centroid of the rivet/bolt group/welding connecting the batten to the main member.

13.7.2.2 *Tie plates*

Tie plates are members provided at the ends of battened

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and laced members, and shall be designed by the same method as battens. In no case shall a tie plate and its fastenings be incapable of carrying the forces for which the lacing or batten has been designed.

13.7.2.3 *Size*

When plates are used for battens, the end battens and those at points where the member is stayed in its length shall have an effective depth, longitudinally, not less than the perpendicular distance between the centroids of the main members. The intermediate battens shall have an effective depth of not less than three quarters of this distance, but in no case shall the effective depth of any batten be less than twice the width of one member, in the plane of the battens. The effective depth of a batten shall be taken as the longitudinal distance between outermost bolts, rivets or welds at the ends. The thickness of batten or the tie plates shall be not less than one fiftieth of the distance between the innermost connecting lines of rivets, bolts or welds, perpendicular to the main member.

13.7.2.4 The requirement of bolt size and thickness of batten specified above does not apply when angles, channels or I-sections are used for battens with their legs or flanges perpendicular to the main member. However, it should be ensured that the ends of the compression members are tied to achieve adequate rigidity.

13.7.3 *Spacing of Battens*

13.7.3.1 In battened compression members where the individual members are not specifically checked for shear stress and bending moments, the spacing of battens, centre-to-centre of its end fastenings, shall be such that the slenderness ratio (KL/r) of any component over that distance shall be not greater than 50 nor greater than 0.7 times the slenderness ratio of the member as a whole about its z-z axis (parallel to the battens).

13.7.4 *Attachment to Main Members*

13.7.4.1 *Welded connections*

Where tie or batten plates overlap the main members, the amount of lap shall be not less than four times the thickness of the plate. The length of weld connecting each edge of the batten plate to the member shall, in aggregate, be not less than half the depth of the batten plate. At least one-third of the weld shall be placed at each end of this edge. The length of weld and depth of batten plate shall be measured along the longitudinal axis of the main member.

In addition, the welding shall be returned along the other two edges of the plates transversely to the axis of the main member for a length not less than the minimum lap specified above.

13.8 Compression Members Composed of Two Components Back-to-Back

13.8.1 Compression members composed of two angles, channels, or tees back-to-back in contact or separated by a small distance, shall be connected together by riveting, bolting or welding so that the ratio of most unfavorable slenderness of each member between the intermediate connections is not greater than 40 or 0.6 times the most unfavourable ratio of slenderness of the strut as a whole, whichever is less [*see* Section 6(k)].

13.8.2 In no case shall the ends of the strut be connected together with less than two rivets or bolts or their equivalent in welding, and there shall be not less than two additional connections in between, spaced equidistant along the length of the strut. Where the members are separated back-to-back, the rivets or bolts through these connections shall pass through solid washers or packing in between. Where the legs of the connected angles or the connected tees are 125 mm wide or more, or where webs of channels are 150 mm wide or over, not less than two rivets or bolts shall be used in each connection, one on line of each gauge mark.

13.8.3 Where these connections are made by welding, solid packing shall be used to effect the jointing unless the members are sufficiently close together to permit direct welding, and the members shall be connected by welding along both pairs of edges of the main components.

13.8.4 The rivets, bolts or welds in these connections shall be sufficient to carry the shear force and moments, if any, specified for battened struts (*see* **13.7.3**), and in no case shall the rivets or bolts be less than 16 mm diameter for members up to and including 10 mm thick; 20 mm diameter for members up to and including 16 mm thick; and 22 mm diameter for members over 16 mm thick.

13.8.4.1 Compression members connected by such riveting, bolting or welding shall not be subjected to transverse loading in a plane perpendicular to the riveted, bolted or welded surfaces.

13.8.5 Where the components are in contact back-to-back, the spacing of the rivets, bolts or intermittent welds shall not exceed the maximum spacing for compression members as given in Section 6(m).

SECTION 6(h) DESIGN OF MEMBERS SUBJECTED TO BENDING

14 DESIGN OF MEMBERS SUBJECTED TO BENDING

14.1 General

Members subjected to predominant bending shall have adequate design strength to resist bending moment, shear force, and concentrated forces imposed upon and their combinations. Further, the members shall satisfy

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the deflection limitation presented in Section 6(e), as serviceability criteria. Member subjected to other forces in addition to bending or biaxial bending shall be designed in accordance with Section 6(j).

14.1.1 *Effective Span of Beams*

The effective span of a beam shall be taken as the distance between the centres of the supports, except where the point of application of the reaction is taken as eccentric at the support, when it shall be permissible to take the effective span as the length between the assumed lines of the reactions.

14.2 Design Strength in Bending (Flexure)

The design bending strength of beam, adequately supported against lateral torsional buckling (laterally supported beam) is governed by the yield stress (*see* **14.2.1**). When a beam is not adequately supported against lateral buckling (laterally un-supported beams) the design bending strength may be governed by lateral torsional buckling strength (*see* **14.2.2**).

The factored design moment, M at any section, in a beam due to external actions, shall satisfy

$$M \leq M_d$$

where

M_d = design bending strength of the section, calculated as given in **14.2.1.2**.

14.2.1 *Laterally Supported Beam*

A beam may be assumed to be adequately supported at the supports, provided the compression flange has full lateral restraint and nominal torsional restraint at supports supplied by web cleats, partial depth end plates, fin plates or continuity with the adjacent span. Full lateral restraint to compression flange may be assumed to exist if the frictional or other positive restraint of a floor connection to the compression flange of the member is capable of resisting a lateral force not less than 2.5 percent of the maximum force in the compression flange of the member. This may be considered to be uniformly distributed along the flange, provided gravity loads constitute the dominant loading on the member and the floor construction is capable of resisting this lateral force.

The design bending strength of a section which are not susceptible to web buckling under shear before yielding (where $d/t_w \leq 67e$) shall be determined according to **14.2.1.2**.

14.2.1.1 *Section with webs susceptible to shear buckling before yielding*

When the flanges are plastic, compact or semi-compact but the web is susceptible to shear buckling before yielding (*see* **14.4.2.1**), the design bending strength shall be calculated using one of the following methods:

a) The bending moment and axial force acting on the section may be assumed to be resisted by flanges only and the web is designed only to resist shear (*see* **14.4**).

b) The bending moment and axial force acting on the section may be assumed to be resisted by the whole section. In such a case, the web shall be designed for combined shear and normal stresses using simple elastic theory in case of semi-compact webs and simple plastic theory in the case of compact and plastic webs.

14.2.1.2 When the factored design shear force does not exceed 0.6 V_d, where V_d is the design shear strength of the cross-section (*see* **14.4**), the design bending strength, M_d shall be taken as:

$$M_d = \beta_b Z_p f_y / \gamma_{m0}$$

To avoid irreversible deformation under serviceability loads, M_d shall be less than 1.2 $Z_e f_y / \gamma_{m0}$ in case of simply supported and 1.5 $Z_e f_y / \gamma_{m0}$ in case of cantilever beams;

where

β_b = 1.0 for plastic and compact sections;
= Z_e / Z_p for semi-compact sections;

Z_p, Z_e = plastic and elastic section moduli of the cross-section, respectively;

f_y = yield stress of the material; and

γ_{m0} = partial safety factor (*see* **11.4.1**).

14.2.1.3 When the design shear force (factored), V exceeds 0.6V_d, where V_d is the design shear strength of the cross-section (*see* **14.4**) the design bending strength, M_d shall be taken as:

$$M_d = M_{dv}$$

where

M_{dv} = design bending strength under high shear as defined in **15.2**.

14.2.1.4 *Holes in the tension zone*

a) The effect of holes in the tension flange, on the design bending strength need not be considered if

$$(A_{nf} / A_{gf}) \geq (f_y / f_u)\,(\gamma_{m1} / \gamma_{m0})/0.9$$

where

A_{nf}/A_{gf} = ratio of net to gross area of the flange in tension;

f_y/f_u = ratio of yield and ultimate stress of the material; and

γ_{m1}/γ_{m0} = ratio of partial safety factors

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against ultimate to yield stress (*see* **11.4.1**).

When the A_{nf}/A_{gf} does not satisfy the above requirement, the reduced effective flange area, A_{ef} satisfying the above equation may be taken as the effective flange area in tension, instead of A_{gf}.

b) The effect of holes in the tension region of the web on the design flexural strength need not be considered, if the limit given in **14.2.1.4**(a) above is satisfied for the complete tension zone of the cross-section, comprising the tension flange and tension region of the web.

c) Fastener holes in the compression zone of the cross-section need not be considered in design bending strength calculation, except for oversize and slotted holes or holes without any fastener.

14.2.1.5 *Shear lag effects*

The shear lag effects in flanges may be disregarded provided:

a) For outstand elements (supported along one edge), $b_o \le L_o/20$; and

b) For internal elements (supported along two edges), $b_i \le L_o/10$.

where

L_o = length between points of zero moment (inflection) in the span,

b_o = width of the flange with outstand, and

b_i = width of the flange as an internal element

Where these limits are exceeded, the effective width of flange for design strength may be calculated using specialist literature, or conservatively taken as the value satisfying the limit given above.

14.2.2 *Laterally Unsupported Beams*

Resistance to lateral torsional buckling need not be checked separately (member may be treated as laterally supported, *see* **14.2.1**) in the following cases:

a) Bending is about the minor axis of the section,

b) Section is hollow (rectangular/ tubular) or solid bars, and

c) In case of major axis bending, λ_{LT} (as defined herein) is less than 0.4.

The design bending strength of laterally unsupported beam as governed by lateral torsional buckling is given by:

$$M_d = \beta_b Z_p f_{bd}$$

where

β_b = 1.0 for plastic and compact sections;

= Z_e/Z_p for semi-compact sections;

Z_p, Z_e = plastic section modulus and elastic section modulus with respect to extreme compression fibre;

f_{bd} = design bending compressive stress, obtained as given below [*see* Tables 13(a) and 13(b)];

f_{bd} = $c_{LT} f_y/\gamma_{m0;}$ and

χ_{LT} = bending stress reduction factor to account for lateral torsional buckling, given by:

$$\chi_{LT} = \frac{1}{\left\{\phi_{LT} + \left[\phi_{LT}^2 - \lambda_{LT}^2\right]^{0.5}\right\}} \le 1.0$$

$$\phi_{LT} = 0.5\left[1 + \alpha_{LT}\left(\lambda_{LT} - 0.2\right) + \lambda_{LT}{}^2\right]$$

α_{LT}, the imperfection parameter is given by:

α_{LT} = 0.21 for rolled steel section

α_{LT} = 0.49 for welded steel section

The non-dimensional slenderness ratio, l_{LT}, is given by:

$$\lambda_{LT} = \sqrt{\beta_b Z_p f_y / M_{cr}} \le \sqrt{1.2 Z_e f_y / M_{cr}}$$

$$= \sqrt{f_y / f_{cr,b}}$$

where

M_{cr} = elastic critical moment calculated in accordance with **14.2.2.1**, and

$f_{cr,b}$ = extreme fibre bending compressive stress corresponding to elastic lateral buckling moment (*see* **14.2.2.1** and Table 14).

14.2.2.1 *Elastic lateral torsional buckling moment*

In case of simply supported, prismatic members with symmetric cross-section, the elastic lateral buckling moment, $M_{cr,}$ can be determined from:

$$M_{cr} = \sqrt{\left\{\left(\frac{\pi^2 EI_y}{(L_{LT})^2}\right)\left[GI_t + \frac{\pi^2 EI_w}{(L_{LT})^2}\right]\right\}} = \beta_b Z_p f_{cr,b}$$

$f_{cr,b}$ of non-slender rolled steel sections in the above equation may be approximately calculated from the values given in the Table 14, which has been prepared using the following equation:

$$f_{cr,b} = \frac{1.1\pi^2 E}{(L_{LT}/r_y)^2}\left[1 + \frac{1}{20}\left(\frac{L_{LT}/r_y}{h_f/t_f}\right)^2\right]^{0.5}$$

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Table 13(a) Design Bending Compressive Stress Corresponding to Lateral Buckling, f_{bd}, α_{LT} = 0.21)

(*Clause* 14.2.2)

$f_{cr,b}$	f_y																		
	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10 000	181.8	190.9	200	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
8 000	181.8	190.9	200	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
6 000	181.8	190.9	200	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
4 000	181.8	190.9	200	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
2 000	181.8	190.9	200	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
1 000	169.1	179.5	186	196.5	202.9	209.1	219.8	229.1	245.5	261.8	275.1	291.3	300.5	323.6	332.2	355.9	370.9	384.8	412.4
900	169.1	179.5	186	194.5	200.7	204.5	215.1	231.6	242.7	258.9	272	291.3	300.5	316.4	328.4	339.5	366.5	380.2	392.7
800	167.3	177.5	184	190.3	196.4	206.8	212.7	224	240	258.9	268.9	284.7	293.6	301.8	324.5	335.5	349.1	370.9	387.8
700	163.6	171.8	182	188.2	192	202.3	208	226.5	237.3	250.2	259.6	278.2	286.7	294.5	305.5	327.3	340.4	352.4	363.3
600	161.8	168	176	181.9	194.2	197.7	203.3	218.9	226.4	244.4	253.5	261.8	276.4	287.3	294	306.8	322.9	333.8	343.6
500	161.8	166.1	172	179.8	185.5	188.6	200.9	208.7	218.2	232.7	244.2	248.7	259.1	269.1	274.9	286.4	296.7	301.4	314.2
450	158.2	164.2	168	173.5	183.3	186.4	191.5	206.2	215.5	224	231.8	242.2	248.7	258.2	263.5	274.1	279.3	292.1	294.5
400	150.9	162.3	166	169.4	174.5	184.1	186.7	196	204.5	215.3	222.5	229.1	238.4	243.6	248.2	257.7	261.8	264.3	274.9
350	147.3	152.7	162	165.2	170.2	172.7	179.6	188.4	193.6	200.7	210.2	212.7	221.1	225.5	229.1	233.2	240	241.1	245.5
300	143.6	147	152	154.7	161.5	163.6	167.8	175.6	182.7	186.2	194.7	196.4	196.9	203.6	206.2	212.7	213.8	217.9	220.9
250	134.5	137.5	142	144.3	148.4	152.3	153.6	160.4	163.6	165.8	170	173.5	179.6	178.2	179.5	184.1	183.3	185.5	191.5
200	121.8	124.1	126	129.6	130.9	134.1	134.7	137.5	141.8	142.5	145.3	147.3	148.5	149.1	152.7	151.4	152.7	153	157.1
150	101.8	103.1	104	104.5	106.9	106.8	108.7	109.5	111.8	113.5	114.4	114.5	117.5	116.4	118.4	118.6	117.8	120.5	122.7
100	74.5	76.4	76	77.4	76.4	77.3	78	78.9	79.1	78.5	80.4	81.8	79.5	80	80.2	81.8	82.9	83.5	83.5
90	67.3	68.7	70	69	69.8	70.5	70.9	71.3	70.9	72.7	74.2	72	72.5	72.7	72.5	73.6	74.2	74.2	73.6
80	61.8	63	62	62.7	63.3	63.6	63.8	63.6	65.5	64	64.9	65.5	65.6	65.5	64.9	65.5	65.5	64.9	68.7
70	54.5	55.4	56	56.5	56.7	56.8	56.7	56	57.3	58.2	58.7	58.9	58.7	58.2	57.3	57.3	56.7	60.3	58.9
60	47.3	47.7	48	48.1	48	50	49.6	48.4	49.1	49.5	49.5	49.1	48.4	50.9	49.6	49.1	52.4	51	49.1
50	40	40.1	40	41.8	41.5	40.9	40.2	40.7	40.9	40.7	43.3	42.5	41.5	43.6	42	40.9	43.6	41.7	44.2
40	32.7	32.5	32	33.5	32.7	34.1	33.1	33.1	32.7	34.9	34	32.7	34.5	32.7	34.4	32.7	34.9	32.5	34.4
30	25.5	24.8	26	25.1	26.2	25	26	25.5	24.5	26.2	24.7	26.2	24.2	25.5	26.7	24.5	26.2	27.8	24.5
20	16.4	17.2	18	16.7	17.5	18.2	16.5	17.8	16.4	17.5	18.5	16.4	17.3	18.2	19.1	16.4	17.5	18.5	19.6
10	9.1	9.5	8	8.4	8.7	9.1	9.5	7.6	8.2	8.7	9.3	9.8	10.4	7.3	7.6	8.2	8.7	9.3	9.8

Table 13(b) Design Bending Compressive Stress Corresponding to Lateral Buckling, f_{bd}, α_{LT} = 0.49)

(*Clause* 14.2.2)

$f_{cr,b}$	f_y																		
	200	210	220	230	240	250	260	280	300	320	340	360	380	400	420	450	480	510	540
10 000	181.8	190.9	200.0	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
8 000	181.8	190.9	200.0	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
6 000	181.8	190.9	200.0	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
4 000	181.8	190.9	200.0	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
2 000	181.8	190.9	200.0	209.1	218.2	227.3	236.4	254.5	272.7	290.9	309.1	327.3	345.5	363.6	381.8	409.1	436.4	463.6	490.9
1 000	160.0	164.2	170.0	179.8	185.5	190.9	196.2	211.3	220.9	235.6	247.3	255.3	266.0	280	290.2	302.7	318.5	329.2	343.6
900	154.5	164.2	170.0	173.5	183.3	188.6	193.8	203.6	218.2	226.9	238.0	252.0	262.5	269.1	282.5	290.5	305.5	319.9	333.8
800	152.7	158.5	168.0	171.5	176.7	181.8	191.5	201.1	210.0	224.0	234.9	242.2	252.2	258.2	271.1	282.3	296.7	306	319.1
700	150.9	154.6	160.0	169.4	172.4	177.3	182.0	196	207.3	215.3	222.5	232.4	238.4	247.3	259.6	270	279.3	292.1	304.4
600	145.5	150.8	154.0	161.0	168.0	172.7	177.3	188.4	193.6	203.6	213.3	222.5	228	236.4	244.4	253.6	261.8	273.5	274.9
500	140.0	145.1	150.0	154.7	159.3	161.4	167.8	175.6	185.5	192	200.9	206.2	214.2	218.2	225.3	229.1	240	245.7	250.4
450	134.5	141.3	144.0	148.5	152.7	156.8	160.7	168	177.3	186.2	191.6	196.4	203.8	210.9	213.8	220.9	231.3	236.5	235.6
400	129.1	135.5	138.0	142.2	148.4	150	153.6	162.9	169.1	174.5	182.4	183.3	193.5	196.4	202.4	208.6	209.5	217.9	220.9
350	123.6	129.8	132.0	135.9	139.6	143.2	148.9	152.7	158.2	162.9	170	173.5	176.2	181.8	183.3	192.3	196.4	199.4	206.2
300	118.2	122.2	126.0	129.6	130.9	134.1	137.1	142.5	147.3	154.2	157.6	157.1	162.4	167.3	168	175.9	178.9	180.8	181.6
250	109.1	112.6	116.0	117.1	120.0	122.7	125.3	129.8	130.9	136.7	139.1	140.7	145.1	149.1	148.9	151.4	152.7	157.6	157.1
200	98.2	101.2	102.0	104.5	104.7	109.1	108.7	112	117.3	119.3	120.5	121.1	124.4	127.3	126	130.9	130.9	129.8	132.5
150	83.6	84.0	86.0	87.8	89.5	88.6	89.8	91.6	95.5	96.0	95.8	98.2	100.2	101.8	103.1	102.3	104.7	106.6	103.1
100	63.6	63.0	64.0	64.8	65.5	65.9	66.2	68.7	68.2	69.8	71.1	68.7	69.1	72.7	72.5	73.6	74.2	74.2	73.6
90	58.2	57.3	60.0	58.5	61.1	61.4	61.5	61.1	62.7	64.0	64.9	65.5	65.6	65.5	64.9	65.5	65.5	64.9	68.7
80	52.7	53.5	54.0	54.4	54.5	54.5	54.4	56	57.3	58.2	58.7	58.9	58.7	58.2	61.1	61.4	61.1	60.3	58.9
70	47.3	47.7	48.0	48.1	48.0	50.0	49.6	50.9	49.1	49.5	52.5	52.4	51.8	50.9	53.5	53.2	52.4	55.6	54.0
60	41.8	42.0	42.0	41.8	43.6	43.2	42.5	43.3	43.6	43.6	43.3	45.8	44.9	47.3	45.8	45.0	48.0	46.4	49.1
50	36.4	36.3	36.0	35.5	37.1	36.4	37.8	38.2	38.2	37.8	37.1	39.3	38.0	40.0	38.2	40.9	39.3	37.1	39.3
40	29.1	30.5	30.0	29.3	30.5	29.5	30.7	30.5	30.0	32.0	30.9	32.7	31.1	32.7	30.5	32.7	30.5	32.5	34.4
30	23.6	22.9	22.0	23.0	24.0	22.7	23.6	22.9	24.5	23.3	24.7	22.9	24.2	25.5	22.9	24.5	26.2	23.2	24.5
20	16.4	15.3	16.0	16.7	15.3	15.9	16.5	15.3	16.4	17.5	15.5	16.4	17.3	18.2	15.3	16.4	17.5	18.5	14.7
10	9.1	7.6	8.0	8.4	8.7	9.1	9.5	7.6	8.2	8.7	9.3	9.8	6.9	7.3	7.6	8.2	8.7	9.3	9.8

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Table 14 Critical Stress, $f_{cr,b}$

(*Clause* 14.2.2.1)

L_{LT}/r_y	h_i/t_f														
	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100
10	22551.2	22255.1	22092.6	21994.1	21929.8	21885.7	21854.0	21805.4	21779.0	21763.1	21752.7	21740.5	21733.8	21727.2	21724.2
20	6220.5	5947.9	5794.5	5700.0	5637.8	5594.7	5563.8	5515.8	5489.7	5473.8	5463.5	5451.4	5444.8	5438.2	5435.1
30	3149.3	2905.9	2764.6	2676.0	2616.7	2575.3	2545.3	2498.5	2472.8	2457.1	2447.0	2434.9	2428.3	2421.7	2418.6
40	2036.1	1821.2	1693.0	1610.8	1555.1	1515.8	1487.0	1441.7	1416.5	1401.1	1391.0	1379.0	1372.5	1365.9	1362.8
50	1492.9	1303.2	1187.3	1111.8	1059.9	1022.7	995.3	951.7	927.1	912.0	902.0	890.2	883.7	877.1	874.2
60	1178.0	1009.5	905.0	835.6	787.4	752.4	726.4	684.6	660.9	646.1	636.4	624.7	618.2	611.7	608.7
70	973.9	823.2	728.5	664.8	620.1	587.4	562.9	522.9	500.0	485.5	476.0	464.4	458.0	451.7	448.7
80	831.3	695.4	609.2	550.7	509.1	478.4	455.3	417.2	395.1	381.2	371.8	360.5	354.1	347.7	344.7
90	725.9	602.6	523.6	469.5	430.9	402.2	380.4	344.2	322.9	309.3	300.2	289.1	282.8	276.5	273.5
100	644.7	532.0	459.3	409.3	373.2	346.4	325.8	291.4	270.9	257.7	248.8	237.9	231.8	225.5	222.5
110	580.4	476.6	409.3	362.9	329.2	303.9	284.5	251.8	232.1	219.3	210.8	200.1	194.0	187.8	184.8
120	527.9	431.9	369.5	326.0	294.5	270.7	252.3	221.2	202.4	190.1	181.6	171.2	165.2	159.1	156.2
130	484.3	395.0	336.8	296.1	266.5	244.1	226.7	197.1	179.0	167.1	158.8	148.6	142.8	136.7	133.9
140	447.6	364.2	309.5	271.5	243.4	222.3	205.8	177.5	160.2	148.7	140.7	130.8	125.0	119.0	116.2
150	416.0	337.8	286.6	250.6	224.2	204.2	188.4	161.5	144.8	133.7	126.0	116.3	110.6	104.7	101.9
160	388.7	315.2	266.8	232.8	207.8	188.8	173.9	148.2	132.0	121.3	113.9	104.3	98.8	93.0	90.1
170	364.9	295.4	249.6	217.5	193.7	175.6	161.4	136.7	121.3	111.0	103.6	94.4	89.0	83.2	80.4
180	343.9	278.0	234.6	204.1	181.5	164.2	150.6	127.1	112.2	102.2	95.2	86.0	80.7	75.0	72.3
190	325.2	262.6	221.3	192.3	170.7	154.2	141.2	118.6	104.3	94.6	87.8	79.0	73.7	68.1	65.3
200	308.3	248.8	209.6	181.7	161.2	145.4	133.0	111.3	97.5	88.1	81.4	72.8	67.8	62.2	59.5
210	293.3	236.5	198.9	172.4	152.7	137.6	125.7	104.8	91.5	82.4	75.9	67.5	62.6	57.1	54.5
220	279.5	225.3	189.3	163.9	145.1	130.6	119.1	99.0	86.2	77.4	71.2	62.9	58.1	52.7	50.1
230	267.1	215.2	180.7	156.3	138.2	124.3	113.3	93.9	81.5	72.9	66.9	58.9	54.1	48.8	46.2
240	255.8	205.8	172.8	149.4	132.0	118.6	108.0	89.3	77.2	69.0	63.1	55.3	50.6	45.4	42.8
250	245.3	197.3	165.6	143.0	126.3	113.4	103.2	85.1	73.5	65.5	59.7	52.1	47.5	42.4	39.8
260	235.7	189.5	159.0	137.3	121.1	108.7	98.8	81.3	70.1	62.3	56.7	49.3	44.8	39.7	37.2
270	226.8	182.3	152.8	131.9	116.3	104.3	94.7	77.9	67.0	59.4	53.9	46.8	42.2	37.3	34.8
280	218.6	175.7	147.2	126.9	111.9	100.2	91.1	74.7	64.1	56.8	51.5	44.4	40.0	35.2	32.7
290	210.9	169.4	141.9	122.3	107.8	96.6	87.7	71.8	61.5	54.3	49.2	42.2	38.1	33.2	30.8
300	203.8	163.7	137.1	118.1	104.1	93.2	84.5	69.1	59.1	52.1	47.1	40.4	36.2	31.5	29.0

The following simplified equation may be used in the case of prismatic members made of standard rolled I-sections and welded doubly symmetric I-sections, for calculating the elastic lateral buckling moment, M_{cr} (*see* Table 14).

$$M_{cr} = \frac{\pi^2 E I_y h_f}{2L_{LT}^2}\left[1+\frac{1}{20}\left(\frac{L_{LT}/r_y}{h_f/t_f}\right)^2\right]^{0.5}$$

where

I_t = torsional constant $\sum b_i t_i^3/3$ for open section;

I_w = warping constant;

$I_{y,}, r_y$ = moment of inertia and radius of gyration, respectively about the weaker axis;

L_{LT} = effective length for lateral torsional buckling (*see* **14.3**);

h_f = centre-to-centre distance between flanges; and

t_f = thickness of the flange.

M_{cr} for different beam sections, considering loading, support condition, and asymmetric section, shall be more accurately calculated using the method given in Annex D. The above equations for calculating M_{cr} may be conservatively used for channel sections.

14.3 Effective Length for Lateral Torsional Buckling

14.3.1 For simply supported beams and girders of span length, *L,* where no lateral restraint to the compression flanges is provided, but where each end of the beam is restrained against torsion, the effective length L_{LT} of the lateral buckling to be used in **14.2.2.1** shall be taken as in Table 15.

In simply supported beams with intermediate lateral restraints against lateral torsional buckling, the effective length for lateral torsional buckling, L_{LT} to be used in **14.2.2.1**, shall be taken as the length of the relevant segment in between the lateral restraints. In the case of intermediate partial lateral restraints, the effective length, L_{LT} shall be taken as equal to 1.2 times the length of the relevant segment in between the partial lateral restraints.

Restraint against torsional rotation at supports in these beams may be provided by,

a) web or flange cleats, or

b) bearing stiffeners acting in conjunction with the bearing of the beam, or

c) lateral end frames or external supports providing lateral restraint to the compression flanges at the ends, or

d) their being built into walls.

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Table 15 Effective Length for Simply Supported Beams, L_{LT}

(*Clause* 14.3.1)

Sl No.	Conditions of Restraint at Supports		Loading Condition	
	Torsional restraint	Warping Restraint	Normal	Destabilizing
(1)	(2)	(3)	(4)	(5)
i)	Fully restrained	Both flanges fully restrained	0.70 *L*	0.85 *L*
ii)	Fully restrained	Only compression flange fully restrained	0.75 *L*	0.90 *L*
iii)	Fully restrained	Both flanges partially restrained	0.80 *L*	0.95 L
iv)	Fully restrained	Only compression flange partially restrained	0.85 *L*	1.00 *L*
v)	Fully restrained	No restraint in both flanges	1.00 *L*	1.20 *L*
vi)	Partially restrained by bottom flange support connection	No restraint in both flanges	1.0 *L*+ 2*D*	1.2 *L*+2*D*
vii)	Partially restrained by bottom flange bearing support	No restraint in both flanges	1.2 *L*+ 2*D*	1.4 *L*+2*D*

NOTES

1 Torsional restraint prevents rotation about the longitudinal axis.

2 Warping restraint prevents rotation of the flange in its plane.

3 *D* is the overall depth of the beam.

4 In case of continuous beams, *L* shall be taken as the distance between points of inflection, and the restraint conditions at the points of inflection should be considered.

14.3.2 For beams, which are provided with members giving effective lateral restraint to the compression flange at intervals along the span, in addition to the end torsional restraint required in **14.3.1**, the effective length for lateral torsional buckling shall be taken as the distance, centre-to-centre of the restraint members in the relevant segment under normal loading condition and 1.2 times this distance, where the load is not acting on the beam at or above the shear centre and towards the shear centre, so as to have destabilizing effect during lateral torsional buckling deformation.

14.3.3 For cantilever beams of projecting length *L*, the effective length L_{LT} to be used in **14.2.2.1** shall be taken as in Table 16 for different support conditions.

14.3.4 Where a member is provided intermediate lateral supports to improve the lateral buckling strength, these restraints should have sufficient strength and stiffness to prevent lateral movement of the compression flange at that point, relative to the end supports. The intermediate lateral restraints should be either connected to an appropriate bracing system capable of transferring the restraint force to the effective lateral support at the ends of the member, or should be connected to an independent robust part of the structure capable of transferring the restraint force. Two or more parallel member requiring such lateral restraint shall not be simply connected together assuming mutual dependence for the lateral restraint.

The intermediate lateral restraints should be connected to the member as close to the compression flange as practicable. Such restraints should be closer to the shear centre of the compression flange than to the shear centre of the section. However, if torsional restraint preventing relative rotation between the two flanges is provided, the intermediate lateral restraint may be connected at any appropriate level.

For beams which are provided with members giving effective lateral restraint at intervals along the span, the effective lateral restraint shall be capable of resisting a force of 2.5 percent of the maximum force in the compression flange taken as divided equally between the points at which the restraint members are provided. Further, each restraint point should be capable of resisting 1 percent of the maximum force in the compression flange.

14.3.4.1 In a series of such beams, with solid webs, which are connected together by the same system of restraint members, the sum of the restraining forces required shall be taken as 2.5 percent of the maximum flange force in one beam only.

14.3.4.2 In the case of a series of latticed beams, girders or roof trusses which are connected together by the same system of restraint members, the sum of the restraining forces required shall be taken as 2.5 percent of the maximum force in the compression flange plus 1.25 percent of this force for every member of the series other than the first, up to a maximum total of 7.5 percent.

14.3.5 Purlins adequately restrained by sheeting need not be normally checked for the restraining forces required by rafters, roof trusses or portal frames that carry predominately roof loads provided there is bracing of adequate stiffness in the plane of rafters or roof sheeting which is capable of acting as a stressed skin diaphragm.

14.3.6 In case of beams with double curvature bending, adequate direct lateral support to the compression flange in the hogging moment region may be provided as given above for simply supported beam. The effect of support to the tension (top) flange in the hogging moment region on lateral restraint to the compression flange may be considered as per specialist literature.

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14.4 Shear

The factored design shear force, V, in a beam due to external actions shall satisfy

$$V \le V_d$$

where

V_d = design strength
$= V_n/\gamma_{m0}$

where

γ_{m0} = partial safety factor against shear failure (*see* **11.4.1**).

The nominal shear strength of a cross-section, V_n, may be governed by plastic shear resistance (*see* **14.4.1**) or strength of the web as governed by shear buckling (*see* **14.4.2**).

14.4.1 The nominal plastic shear resistance under pure shear is given by:

$$V_n = V_p$$

where

$$V_p = \frac{A_v f_{yw}}{\sqrt{3}}$$

A_v = shear area; and
f_{yw} = yield strength of the web.

14.4.1.1 The shear area may be calculated as given below:

a) I-and channel sections:
Major Axis Bending:
Hot-rolled : $h\ t_w$
Welded : $d\ t_w$
Minor Axis Bending:
Hot-rolled or welded : $2b\ t_f$

b) Rectangular hollow sections of uniform thickness:
Loaded parallel to depth (h) : $A\ h/(b+h)$
Loaded parallel to width (b) : $A\ b/(b+h)$

c) Circular hollow tubes of uniform thickness : $2A/\pi$

d) Plates and solid bars : A

where

A = cross-section area,
b = overall breadth of tubular section, breadth of I-section flanges,
d = clear depth of the web between flanges,
h = overall depth of the section,
t_f = thickness of the flange, and
t_w = thickness of the web.

NOTE — Fastener holes need not be accounted for in plastic design shear strength calculation provided that:

$$A_{vn} \ge (f_y/f_u)(\gamma_{m1}/\gamma_{m0})\ A_v/0.9$$

If A_{vn} does not satisfy the above condition, the effective shear area may be taken as that satisfying the above limit. Block shear failure criteria may be verified at the end connections. Section 6(j) may be referred to for design strength under combined high shear and bending.

14.4.2 *Resistance to Shear Buckling*

14.4.2.1 Resistance to shear buckling shall be verified as specified, when

$d/t_w > 67\varepsilon_w$ for a web without stiffeners, and

$> 67\varepsilon_w\sqrt{\frac{K_v}{5.35}}$ for a web with stiffeners

where

K_v = shear buckling coefficient (*see* **14.4.2.2**), and

$\varepsilon_w = \sqrt{250/f_{yw}}$

14.4.2.2 *Shear buckling design methods*

The nominal shear strength, V_n, of webs with or without intermediate stiffeners as governed by buckling may be evaluated using one of the following methods:

a) *Simple post-critical method* — The simple post critical method, based on the shear buckling strength can be used for webs of I-section girders, with or without intermediate transverse stiffener, provided that the web has transverse stiffeners at the supports. The nominal shear strength is given by:

$$V_n = V_{cr}$$

where

V_{cr} = shear force corresponding to web buckling
$= A_v\tau_b$

where

τ_b = shear stress corresponding to web buckling, determined as follows:

1) when $\lambda_w \le 0.8$, $\tau_b = f_{yw}/\sqrt{3}$

2) when $0.8 < \lambda_w < 1.2$,
$\tau_b = \left[1-0.8\left(\lambda_w - 0.8\right)\right]\left(f_{yw}/\sqrt{3}\right)$

3) when $\lambda_w \ge 1.2$, $\tau_b = f_{yw}/\left(\sqrt{3}\ \lambda_w^{\ 2}\right)$

where

λ_w = Non-dimensional web slenderness ratio for shear buckling stress, given by:

$$\lambda_w = \sqrt{f_{yw}/(\sqrt{3}\ \tau_{cr,e})}$$

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$t_{cr,e}$ = elastic critical shear stress of the web

$$= \frac{K_v \pi^2 E}{12\left(1-\mu^2\right)\left[d/t_w\right]^2}$$

where

μ = Poisson's ratio, and

K_v = 5.35 when transverse stiffeners are provided only at supports

= $4.0 + 5.35/(c/d)^2$ for $c/d < 1.0$

= $5.35 + 4.0/(c/d)^2$ for $c/d \geq 1.0$

where c, d are the spacing of transverse stiffeners and depth of the web, respectively.

b) *Tension field method* — The tension field method, based on the post-shear buckling strength, may be used for webs with intermediate transverse stiffeners, in addition to the transverse stiffeners at supports, provided the panels adjacent to the panel under tension field action, or the end posts provide anchorage for the tension fields and if $c/d \geq 1.0$, where c, d are the spacing of transverse stiffeners and depth of the web, respectively.

In the tension field method, the nominal shear resistance, V_n, is given by:

$$V_n = V_{tf}$$

where

$$V_{tf} = \left[A_v \tau_b + 0.9 w_{tf} t_w f_v \sin\phi\right] \leq V_p$$

where

τ_b = shear stress corresponding to buckling of web **14.4.2.2**(a);

f_v = yield strength of the tension field obtained from $\left[f_{yw}^2 - 3\tau_b^2 + \psi^2\right]^{0.5} - \psi$;

ψ = $1.5\ \tau_b \sin 2\phi$;

ϕ = inclination of the tension field nearly

$$= \tan^{-1}\frac{\left(\frac{d}{c}\right)}{1.5};$$

w_{tf} = width of the tension field, given by:

= $d \cos\phi - (c - s_c - s_t)\sin\phi$;

f_{yw} = yield stress of the web;

d = depth of the web;

c = spacing of transverse stiffeners in the web; and

s_c, s_t = anchorage lengths of tension field along the compression and tension flange, respectively, obtained from:

$$s = \frac{2}{\sin\phi}\left[\frac{M_{fr}}{f_{yw} t_w}\right]^{0.5} \leq c$$

where

M_{fr} = reduced plastic moment capacity of the respective flange plate (disregarding any edge stiffener) after accounting for the axial force, N_f in the flange, due to overall bending and any external axial force in the cross-section, and is calculated as :

$$M_{fr} = 0.25 b_f t_f^2 f_{yf}\left[1 - \left\{N_f/\left(b_f t_f f_{yf}/\gamma_{m0}\right)\right\}^2\right]$$

where

b_f, t_f = width and thickness of the relevant flange, respectively; and

f_{yf} = yield stress of the flange.

14.5 Stiffened Web Panels

14.5.1 *End Panels Design* (*see Fig.12*)

The girders in which the interior panel (panel A) is designed using tension field action, the end panels shall be designed using only simple post critical method, according to **14.4.2.2**(a).

Additionally, the end panel along with the stiffeners should be checked as a beam spanning between the flanges to resist a shear force, $R_{tf,}$ and a moment, $M_{tf,}$ due to tension field forces as given in **14.5.3**. Further, end stiffener should be capable of resisting the reaction plus a compressive force due to the moment, equal to M_{tf} [*see* Fig. (12)].

14.5.2 *End Panels Designed Using Tension Field Action* (*see Fig. 13 and Fig. 14*)

The end panel (Panel A) shall be designed according to **14.4.2.2**(b).

Additionally it should be provided with an end post consisting of a single or double stiffener (*see* Fig. 13 and Fig. 14), satisfying the following.

a) *Single stiffener* (*see Fig. 13*) — The top of the end post should be rigidly connected to the flange using full strength welds.

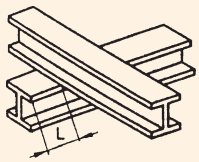
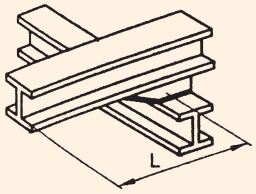
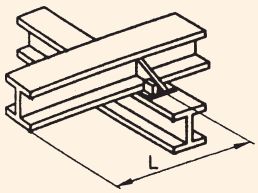
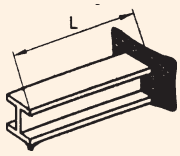
The end post should be capable of resisting the reaction plus a moment from the anchor forces equal to 2/3 M_{tf} due to tension field forces, where M_{tf} is obtained from **14.5.3**. The width and thickness of the end post are not to exceed the width and thickness of the flange.

b) *Double stiffener* (*see Fig. 14*) — The end post should be checked as a beam spanning between the flanges of the girder and capable

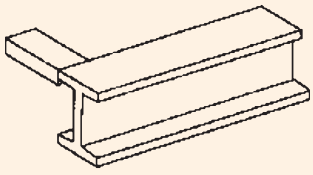
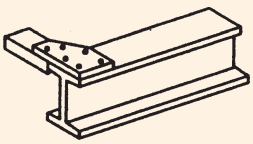
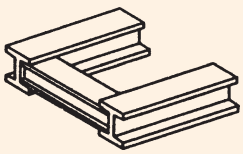
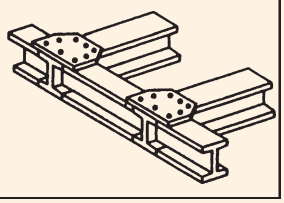
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Table 16 Effective Length, L_{LT} for Cantilever of Length, L

(*Clause* 14.3.3)

Restraint Condition		Loading Conditions	
At Support	At top	Normal	Destabilizing
(2)	(3)	(4)	(5)
a) Continuous, with lateral restraint to top flange 	i) Free	3.0L	7.5L
	ii) Lateral restraint to top flange	2.7L	7.5L
	iii) Torsional restraint	2.4L	4.5L
	iv) Lateral and torsional restraint	2.1L	3.6L
b) Continuous, with partial torsional restraint 	i) Free	2.0L	5.0L
	ii) Lateral restraint to top flange	1.8L	5.0L
	iii) Torsional restraint	1.6L	3.0L
	iv) Lateral and torsional restraint	1.4L	2.4L
c) Continuous, with lateral and torsional restraint 	i) Free	1.0L	2.5L
	ii) Lateral restraint to top flange	0.9L	2.5L
	iii) Torsional restraint	0.8L	1.5L
	iv) Lateral and torsional restraint	0.7L	1.2L
d) Restrained laterally, torsionally and against rotation on plan 	i) Free	0.8L	1.4L
	ii) Lateral restraint to top flange	0.7L	1.4L
	iii) Torsional restraint	0.6L	0.6L
	iv) Lateral and torsional restraint	0.5L	0.5L

Top restraint conditions

i) Free	ii) Lateral restraint to top flange	iii) Torsional restraint	iv) Lateral and torsional restraint
			

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of resisting a shear force R_{tf} and a moment, M_{tf} due to the tension field forces as given in **14.5.3**.

14.5.3 *Anchor Forces*

The resultant longitudinal shear, R_{tf}, and a moment M_{tf} from the anchor of tension field forces are evaluated as given below:

$$R_{tf} = \frac{H_q}{2} \text{ and } M_{tf} = \frac{H_q d}{10}$$

where

$$H_q = 1.25 V_p \left(1 - \frac{V_{cr}}{V_p}\right)^{1/2}$$

$$V_p = \frac{dtf_y}{\sqrt{3}}$$

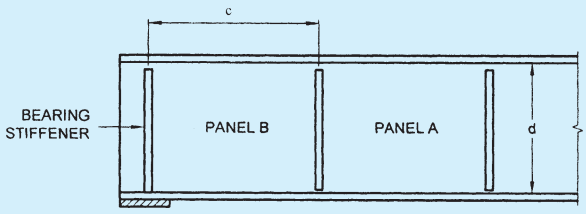
d = web depth,

If the actual factored shear force, V in the panel designed using tension field approach is less than the shear strength, V_{tf} as given in **14.4.2.2**(b), then the values of H_q may be reduced by the ratio $\frac{V - V_{cr}}{V_{tf} - V_{cr}}$

where

V_{tf} = basic shear strength for the panel utilizing tension field action as given in **14.4.2.2**(b), and

V_{cr} = critical shear strength for the panel designed utilizing tension field action as given in **14.4.2.2**(a).



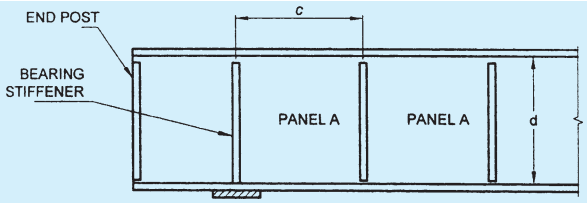
NOTES

1 Panel A is designed utilizing tension field action as given in **14.4.2.2**(b).

2 Panel B is designed using simple post critical method as given in **14.4.2.2**(a).

3 Bearing stiffener is designed for the compressive force due to bearing plus compressive force due to the moment M_{tf} as given in **14.5.3**.

FIG. 12 END PANEL DESIGNED NOT USING TENSION FIELD ACTION

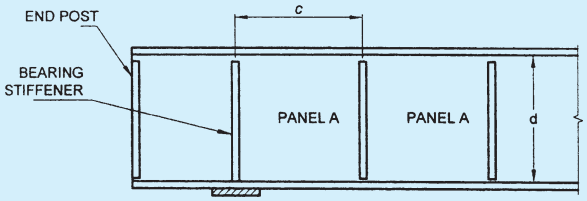


NOTES

1 Panel A is designed utilizing tension field action as given in **14.4.2.2**(b).

2 Bearing stiffener and end post is designed for combination of compressive loads due to bearing and a moment equal to 2/3 M_{tf} as given in **14.5.3**.

FIG. 13 END PANEL DESIGNED USING TENSION FIELD ACTION (SINGLE STIFFENER)



NOTES

1 Panel A is designed utilizing tension field action as given in **14.4.2.2**(b).

2 Bearing stiffener is designed for compressive force due to bearing as given in **14.4.2.2**(a).

3 End post is designed for horizontal shear R_{tf} and moment M_{tf} as given in **14.5.3.**

FIG. 14 END PANEL DESIGNED USING TENSION FIELD ACTION (DOUBLE STIFFENER)

14.5.4 *Panels with Openings*

Panels with opening of dimension greater than 10 percent of the minimum panel dimension should be designed without using tension field action as given in **14.4.2.2**(b). The adjacent panels should be designed as an end panel as given in **14.5.1** or **14.5.2**, as appropriate.

14.6 Design of Beams and Plate Girders with Solid Webs

14.6.1 *Minimum Web Thickness*

The thickness of the web in a section shall satisfy the following requirements:

14.6.1.1 *Serviceability requirement*

a) when transverse stiffeners are not provided,

1) $\frac{d}{t_w} \le 200\,\varepsilon_w$ (web connected to flanges along both longitudinal edges)

2) $\frac{d}{t_w} \le 90\varepsilon_w$ (web connected to flanges along one longitudinal edge only),

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b) when only transverse stiffeners are provided (in webs connected to flanges along both longitudinal edges),

1) when $3d \geq c \geq d$

$$\frac{d}{t_w} \leq 200\varepsilon_w$$

2) when $0.74\,d \geq c < d$

$$\frac{c}{t_w} \leq 200\varepsilon_w$$

3) when $c < 0.74d$

$$\frac{d}{t_w} \leq 270\varepsilon_w$$

4) when $c > 3d$, the web shall be considered as unstiffened,

c) when transverse stiffeners and longitudinal stiffeners at one level only are provided (0.2 d from compression flange) according to **14.7.13**(a),

1) when $2.4d \geq c \geq d$

$$\frac{d}{t_w} \leq 250\varepsilon_w$$

2) when $0.74\,d \leq c \leq d$

$$\frac{c}{t_w} \leq 250\varepsilon_w$$

3) when $c < 0.74\,d$

$$\frac{d}{t_w} \leq 340\varepsilon_w$$

d) when a second longitudinal stiffener (located at neutral axis is provided)

$$\frac{d}{t_w} \leq 400\varepsilon_w$$

where

d = depth of the web,

t_w = thickness of the web,

c = spacing of transverse stiffener (*see* Fig. 12 and Fig. 13),

ε_w = yield stress ratio of web = $\sqrt{250/f_{yw}}$, and

f_{yw} = yield stress of the web.

14.6.1.2 *Compression flange buckling requirement*

In order to avoid buckling of the compression flange into the web, the web thickness shall satisfy the following:

a) When transverse stiffeners are not provided,

$$\frac{d}{t_w} \leq 345\,\varepsilon_f^2$$

b) When transverse stiffeners are provided, and

i) when $c \geq 1.5\,d$

$$\frac{d}{t_w} \leq 345\,\varepsilon_f^2$$

ii) when $c < 1.5d$

$$\frac{d}{t_w} \leq 345\varepsilon_f$$

where

d = depth of the web,

t_w = thickness of the web,

c = spacing of transverse stiffener (*see* Fig. 12 and Fig. 13),

ε_f = yield stress ratio of flange = $\sqrt{250/f_{yf}}$, and

f_{yf} = yield stress of compression flange.

14.6.2 *Sectional Properties*

14.6.2.1 The effective sectional area of compression flanges shall be the gross area with deductions for excessive width of plates as specified for compression members [*see* Section 6(g)] and for open holes occurring in a plane perpendicular to the direction of stress at the section being considered (*see* **14.2.1.4**).

The effective sectional area of tension flanges shall be the gross sectional area with deductions for holes as specified in **14.2.1.4**.

The effective sectional area for parts in shear shall be taken as specified in **14.4.1.1**.

14.6.3 *Flanges*

14.6.3.1 In riveted or bolted construction, flange angles shall form as large a part of the area of the flange as practicable (preferably not less than one-third) and the number of flange plates shall be kept to a minimum.

In exposed situations, where flange angles are used, at least one plate of the top flange shall extend over the full length of the girder, unless the top edge of the web is machined flush with the flange angles. Where two or more flange plates are used, tacking rivets shall be provided, if necessary to comply with the requirements of Section 6(k).

Each flange plate shall extend beyond its theoretical cut-off point, and the extension shall contain sufficient rivets, bolts or welds to develop in the plate, the load calculated for the bending moment on the girder section

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(taken to include the curtailed plate) at the theoretical cut-off point.

The outstand of flange plates, that is the projection beyond the outer line of connections to flange angles, channel or joist flanges or in the case of welded constructions their projection beyond the face of the web or tongue plate, shall not exceed the values given in **9.7.2** (*see* Table 2).

In the case of box girders, the thickness of any plate, or the aggregate thickness of two or more plates, when these plates are tacked together to form the flange, shall satisfy the requirements given in **9.7.2** (*see* Table 2).

14.6.3.2 *Flange splices*

Flange splices should preferably, not be located at points of maximum stress. Where splice plates are used, their area shall be not less than 5 percent in excess of the area of the flange element spliced; their centre of gravity shall coincide, as nearly as possible, with that of the element spliced. There shall be enough bolts, rivets or welds on each side of the splice to develop the load in the element spliced plus 5 percent but in no case should the strength developed be less than 50 percent of the effective strength of the material spliced. In welded construction, flange plates shall be joined by complete penetration butt welds, wherever possible. These butt welds shall develop the full strength of the plates.

14.6.3.3 *Connection of flanges to web*

The flanges of plate girders shall be connected to the web by sufficient rivets, bolts or welds to transmit the maximum horizontal shear force resulting from the bending moment gradient in the girder, combined with any vertical loads which are directly applied to the flange. If the web is designed using tension field method as given in **14.4.2.2** b), the weld should be able to transfer the tension field stress, f_{yw} acting on the web.

14.6.3.4 *Bolted/Riveted construction*

For girders in exposed situations and which do not have flange plates for their entire length, the top edge of the web plate shall be flush with or above the angles, and the bottom edge of the web plate shall be flush with or set back from the angles.

14.6.3.5 *Welded construction*

The gap between the web plates and flange plates shall be kept to a minimum and for fillet welds shall not exceed 1 mm at any point before welding.

14.6.4 *Webs*

14.6.4.1 *Effective sectional area of web of plate girder*

The effective cross-sectional area shall be taken as the full depth of the web plate multiplied by the thickness.

NOTE — Where webs are varied in thickness in the depth of the section by the use of tongue plates or the like, or where the proportion of the web included in the flange area is 25 percent or more of the overall depth, the above approximation is not permissible and the maximum shear stress shall be computed on theory.

14.6.4.2 *Splices in webs*

Splices and cutouts for service ducts in the webs should preferably not be located at points of maximum shear force and heavy concentrated loads.

Splices in the webs of the plate girders and rolled sections shall be designed to resist the shears and moments at the spliced section (*see* Annex E).

In riveted or bolted construction, splice plates shall be provided on each side of the web. In welded construction, web splices shall preferably be made with complete penetration butt welds.

14.6.4.3 Where additional plates are required to augment the strength of the web, they shall be placed on each side of the web and shall be equal in thickness. The proportion of shear force assumed to be resisted by these plates shall be limited by the amount of horizontal shear which they can transmit to the flanges through their fastenings, and such reinforcing plates and their fastenings shall be carried up to the points at which the flange without the additional plates is adequate.

14.7 Stiffener Design

14.7.1 *General*

14.7.1.1 When the web of a member acting alone (that is, without stiffeners) proves inadequate, stiffeners for meeting the following requirements should be provided:

a) *Intermediate transverse web stiffener* — To improve the buckling strength of a slender web due to shear (*see* **14.7.2**).
b) *Load carrying stiffener* — To prevent local buckling of the web due to concentrated loading (*see* **14.7.3** and **14.7.5**).
c) *Bearing stiffener* — To prevent local crushing of the web due to concentrated loading (*see* **14.7.4** and **14.7.6**).
d) *Torsion stiffener* — To provide torsional restraint to beams and girders at supports (*see* **14.7.9**).
e) *Diagonal stiffener* — To provide local reinforcement to a web under shear and bearing (*see* **14.7.7**).
f) *Tension stiffener* — To transmit tensile forces applied to a web through a flange (*see* **14.7.8**).

The same stiffeners may perform more than one function and their design should comply with the requirements of all the functions for which designed.

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14.7.1.2 *Outstand of web stiffeners*

Unless the outer edge is continuously stiffened, the outstand from the face of the web should not exceed $20t_q\varepsilon$.

When the outstand of web stiffener is between $14t_q\varepsilon$ and $20t_q\varepsilon$, then the stiffener design should be on the basis of a core section with an outstand of only $14t_q\varepsilon$, where t_q is the thickness of the stiffener.

14.7.1.3 *Stiff bearing length*

The stiff bearing length of any element, b_1, is that length which cannot deform appreciably in bending. To determine b_1, the dispersion of load through a steel bearing element should be taken as 45° through solid material, such as bearing plates, flange plates, etc (*see* Fig.15).

14.7.1.4 *Eccentricity*

Where a load or reaction is applied eccentric to the centerline of the web or where the centroid of the stiffener does not lie on the centerline of the web, the resulting eccentricity of loading should be accounted for in the design of the stiffener.

14.7.1.5 *Buckling resistance of stiffeners*

The buckling resistance F_{qd} should be based on the design compressive stress f_{cd} (*see* **13.1.2.1**) of a strut (curve c), the radius of gyration being taken about the axis parallel to the web. The effective section is the full area or core area of the stiffener (*see* **14.7.1.2**) together with an effective length of web on each side of the centerline of the stiffeners, limited to 20 times the web thickness. The design strength used should be the minimum value obtained for buckling about the web or the stiffener.

The effective length for intermediate transverse stiffeners used in calculating the buckling resistance, F_{qd}, should be taken as 0.7 times the length, L of the stiffener.

The effective length for load carrying web stiffeners used in calculating the buckling resistance, F_{xd}, assumes that the flange through which the load or reaction is applied is effectively restrained against lateral movement relative to the other flange, the effective length should be taken as:

a) $KL = 0.7L$, when flange is restrained against rotation in the plane of the stiffener (by other structural elements), and

b) $KL = L$, when flange is not so restrained

where

L = length of the stiffener.

If the load or reaction is applied to the flange by a compression member, then unless effective lateral restraint is provided at that point, the stiffener should be designed as part of the compression member applying the load, and the connection between the column and beam flange shall be checked for the effects of the strut action.

14.7.2 *Design of Intermediate Transverse Web Stiffeners*

14.7.2.1 *General*

Intermediate transverse stiffeners may be provided on one or both sides of the web.

14.7.2.2 *Spacing*

Spacing of intermediate stiffeners, where provided, shall comply with **14.6.1** depending on the thickness of the web.

14.7.2.3 *Outstand of stiffeners*

The outstand of the stiffeners should comply with **14.7.1.2**.

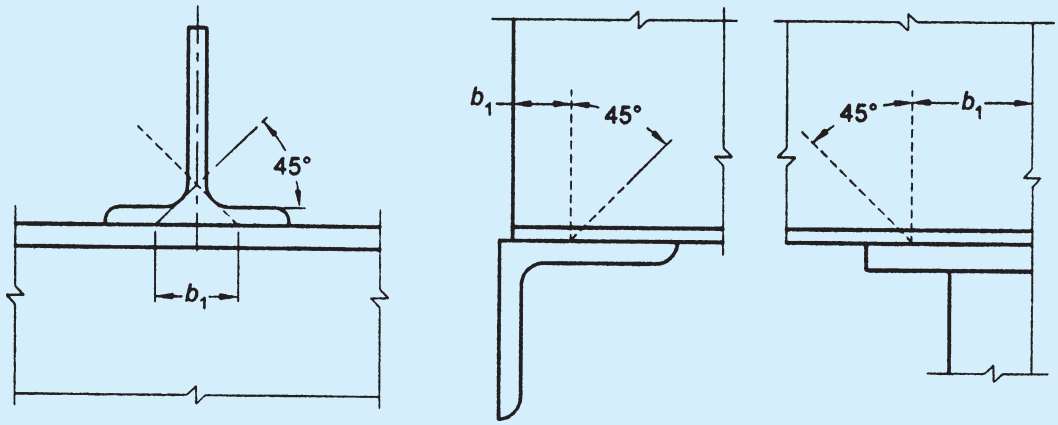


FIG. 15 STIFF BEARING LENGTH, b_1

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14.7.2.4 *Minimum stiffeners*

Transverse web stiffeners not subject to external loads or moments should have a second moment of area, I_s about the centreline of the web, if stiffeners are on both sides of the web and about the face of the web , if single stiffener on only one side of the web is used such that:

$$\text{if } c/d \geq \sqrt{2}\ ,\ I_s \geq 0.75\, d t_w^3\ , \text{ and}$$

$$\text{if } c/d < \sqrt{2}\ ,\ I_s \geq \frac{1.5\, d^3 t_w^3}{c^2}$$

where

d = depth of the web;

t_w = minimum required web thickness for spacing using tension field action, as given in **14.4.2.1**; and

c = actual stiffener spacing.

14.7.2.5 *Buckling check on intermediate transverse web stiffeners*

Stiffeners not subjected to external loads or moments should be checked for a stiffener force:

$$F_q = V - V_{cr} / \gamma_{m0} \leq F_{qd}$$

where

F_{qd} = design resistance of the intermediate stiffeners;

V = factored shear force adjacent to the stiffener; and

V_{cr} = shear buckling resistance of the web panel designed without using tension field action as given in **14.4.2.2** a).

Stiffeners subject to external loads and moments should meet the conditions for load carrying web stiffeners in **14.7.3**. In addition they should satisfy the following interaction expression:

$$\frac{F_q - F_x}{F_{qd}} + \frac{F_x}{F_{xd}} + \frac{M_q}{M_{yq}} \leq 1$$

where

F_q = stiffener force given above;

F_{qd} = design resistance of an intermediate web stiffener corresponding to buckling about an axis parallel to the web (*see* **14.7.1.5**);

F_x = external load or reaction at the stiffener;

F_{xd} = design resistance of a load carrying stiffener corresponding to buckling about axis parallel to the web (*see* **14.7.1.5**);

M_q = moment on the stiffener due to eccentrically applied load and transverse load, if any; and

M_{yq} = yield moment capacity of the stiffener based on its elastic modulus about its centroidal axis parallel to the web.

If $F_q < F_x$, then $(F_q - F_x)$ should be taken as zero;

14.7.2.6 *Connection of intermediate stiffeners to web*

Intermediate transverse stiffeners not subject to external loading should be connected to the web so as to withstand a shear between each component of the stiffener and the web (in kN/mm) of not less than:

$$t_w^2 / (5 b_s)$$

where

t_w = web thickness, in mm; and

b_s = outstand width of the stiffener, in mm.

For stiffeners subject to external loading, the shear between the web and the stiffener due to such loading has to be added to the above value.

Stiffeners not subject to external loads or moments may terminate clear of the tension flange and in such a situation the distance cut short from the line of the weld should not be more than $4t_w$.

14.7.3 *Load Carrying Stiffeners*

14.7.3.1 *Web check*

Load carrying web stiffeners should be provided where compressive forces applied through a flange by loads or reactions exceed the buckling strength, F_{cdw}, of the unstiffened web, calculated using the following:

The effective length of the web for evaluating the slenderness ratio is calculated as in **14.7.1.5**. The area of cross-section is taken as $(b_1+n_1)\, t_w$.

where

b_1 = width of stiff bearing on the flange (*see* **14.7.1.3**), and

n_1 = dispersion of the load through the web at 45°, to the level of half the depth of the cross-section.

The buckling strength of this web about axis parallel to the web is calculated as given in **13.1.2.1**, using curve 'c'.

14.7.4 *Bearing Stiffeners*

Bearing stiffeners should be provided for webs where forces applied through a flange by loads or reactions exceeding the local capacity of the web at its connection to the flange, F_w, given by:

$$F_w = (b_1 + n_2)\, t_w\, f_{yw} / \gamma_{m0}$$

where

b_1 = stiff bearing length (*see* **14.7.1.3**),

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n_2 = length obtained by dispersion through the flange to the web junction at a slope of 1:2.5 to the plane of the flange,

t_w = thickness of the web, and

f_{yw} = yield stress of the web.

14.7.5 *Design of Load Carrying Stiffeners*

14.7.5.1 *Buckling check*

The external load or reaction, F_x on a stiffener should not exceed the buckling resistance, F_{xd} of the stiffener as given in **14.7.1.5**.

Where the stiffener also acts as an intermediate stiffener it should be checked for the effect of combined loads in accordance with **14.7.2.5**.

14.7.5.2 *Bearing check*

Load carrying web stiffeners should also be of sufficient size that the bearing strength of the stiffener, $F_{psd,}$ given below is not less than the load transferred, F_x

$$F_{psd} = A_q f_{yq}/(0.8\gamma_{m0}) \geq F_x$$

where

F_x = external load or reaction,

A_q = area of the stiffener in contact with the flange, and

f_{yq} = yield stress of the stiffener.

14.7.6 *Design of Bearing Stiffeners*

Bearing stiffeners should be designed for the applied load or reaction less the local capacity of the web as given in **14.7.4**. Where the web and the stiffener material are of different strengths the lesser value should be assumed to calculate the capacity of the web and the stiffener. Bearing stiffeners should project nearly as much as the overhang of the flange through which load is transferred.

14.7.7 *Design of Diagonal Stiffeners*

Diagonal stiffeners should be designed to carry the portion of the applied shear and bearing that exceeds the capacity of the web.

Where the web and the stiffener are of different strengths, the value for design should be taken as given in **14.7.6**.

14.7.8 *Design of Tension Stiffeners*

Tension stiffeners should be designed to carry the portion of the applied load or reaction less the capacity of the web as given in **14.7.4** for bearing stiffeners.

Where the web and the stiffener are of different strengths, the value for design should be taken as given in **14.7.6**.

14.7.9 *Torsional Stiffeners*

Where bearing stiffeners are required to provide torsional restraint at the supports of the beam, they should meet the following criteria:

a) Conditions of **14.7.4**, and

b) Second moment of area of the stiffener section about the centerline of the web, I_s should be such that:

$$I_s \geq 0.34\, \alpha_s D^3 T_{cf}$$

where

α_s = 0.006 for $L_{LT}/r_y \leq 50$;

= $0.3/(L_{LT}/r_y)$ for $50 < L_{LT}/r_y \leq 100$;

= $30/(L_{LT}/r_y)^2$ for $L_{LT}/r_y > 100$;

D = Overall depth of beam at support,

T_{cf} = Maximum thickness of compression flange in the span under consideration,

KL = Laterally unsupported effective length of the compression flange of the beam, and

r_y = Radius of gyration of the beam about the minor axis.

14.7.10 *Connection to Web of Load Carrying and Bearing Stiffeners*

Stiffeners, which resist loads or reactions applied through a flange, should be connected to the web by sufficient welds or fasteners to transmit a design force equal to the lesser of,

a) tension capacity of the stiffener; and

b) sum of the forces applied at the two ends of the stiffener when they act in the same direction or the larger of the forces when they act in opposite directions.

Stiffeners, which do not extend right across the web, should be of such length that the shear stress in the web due to the design force transmitted by the stiffener does not exceed the shear strength of the web. In addition, the capacity of the web beyond the end of the stiffener should be sufficient to resist the applied force.

14.7.11 *Connection to Flanges*

14.7.11.1 *In tension*

Stiffeners required to resist tension should be connected to the flange transmitting the load by continuous welds or non-slip fasteners.

14.7.11.2 *In compression*

Stiffeners required to resist compression should either be fitted against the loaded flange or connected by continuous welds or non-slip fasteners.

The stiffener should be fitted against or connected to both flanges when,

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a) a load is applied directly over a support; or
b) it forms the end stiffener of a stiffened web; or
c) it acts as a torsion stiffener.

14.7.12 *Hollow Sections*

Where concentrated loads are applied to hollow sections consideration should be given to local stresses and deformations and the section reinforced as necessary.

14.7.13 *Horizontal Stiffeners*

Where horizontal stiffeners are used in addition to vertical stiffeners, they shall be as follows:

a) One horizontal stiffener shall be placed on the web at a distance from the compression flange equal to 1/5 of the distance from the compression flange angle, plate or tongue plate to the neutral axis when the thickness of the web is less than the limits specified in **14.6.1**. The stiffener shall be designed so that I_s is not less than $4ct_w^3$ where I_s and t_w are as defined in **14.7.2.4** and c is the actual distance between the vertical stiffeners;
b) A second horizontal stiffener (single or double) shall be placed at the neutral axis of the girder when the thickness of the web is less than the limit specified in **14.6.1**. This stiffener shall be designed so that I_s is not less than $d_2 t_w^3$ where I_s and t_w are as defined in **14.7.2.4** and d_2 is twice the clear distance from the compression flange angles, plates or tongue plates to the neutral axis;
c) Horizontal web stiffeners shall extend between vertical stiffeners, but need not be continuous over them; and
d) Horizontal stiffeners may be in pairs arranged on each side of the web, or single located on one side of the web.

14.8 Box Girders

The design and detailing of box girders shall be such as to give full advantage of its higher load carrying capacity. Box girder shall be designed in accordance with specialist literature. The diaphragms and horizontal stiffeners should conform to **14.7.12** and **14.7.13**.

14.8.1 All diaphragms shall be connected so as to transfer the resultant shears to the web and flanges.

14.8.2 Where the concentrated or moving load does not act directly on top of the web, the local effect shall be considered in the design of flanges and the diaphragms.

14.9 Purlins and Sheeting Rails (Girts)

All purlins shall be designed in accordance with the requirements for beams as specified in **14.2.1** and **14.2.2**. The limitations of bending stress based on lateral instability of the compression flange shall be considered if the purlin does not receive adequate support from bracings and sheathings in the plane of compression flange. In any case the maximum bending moment shall not exceed the values specified in **14.2.1**. The calculated deflections should not exceed those permitted for the type of roof cladding used, as specified in **11.6.1**. In calculating the bending moment, advantage may be taken of the continuity of the purlin over supports. The bending about the two axes shall be determined separately and checked according to the biaxial bending requirements specified in Section 6(j).

14.10 Bending in a Non-principal Plane

14.10.1 When the flexural deflection of a member is constrained to a non-principal plane by lateral restraints preventing lateral deflection, then the force exerted by the restraints shall be determined, and the principal axes bending moments acting on the member shall be calculated from these forces and applied forces, by a rational analysis. The combined effect of bending about the principal axes shall satisfy the requirements of Section 6(j).

14.10.2 When the deflections of a member loaded in a non-principal plane are unconstrained; the principal axes bending moments shall be calculated by a rational analysis. The combined effect of bending about the principal axes shall satisfy the requirements of Section 6(j).

SECTION 6(j) MEMBER SUBJECTED TO COMBINED FORCES

15 MEMBER SUBJECTED TO COMBINED FORCES

15.1 General

This Section governs the design of members subjected to combined forces, such as shear force and bending, axial force and bending, or shear force, axial force and bending.

15.2 Combined Shear and Bending

15.2.1 No reduction in moment capacity of the section is necessary as long as the cross-section is not subjected to high shear force (factored value of applied shear force is less than or equal to 60 percent of the shear strength of the section as given in **14.4**). The moment capacity may be taken as, M_d (*see* **14.2**) without any reduction.

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15.2.2 When the factored value of the applied shear force is high (exceeds the limit specified in **15.2.1**), the factored moment of the section should be less than the moment capacity of the section under higher shear force, M_{dv}, calculated as given below:

a) *Plastic or compact section*

$$M_{dv} = M_d - \beta(M_d - M_{fd}) \leq 1.2\, Z_e\, f_y / \gamma_{m0}$$

where

β = $(2V/V_d - 1)^2$,

M_d = plastic design moment of the whole section disregarding high shear force effect (*see* **14.2.1.2**) considering web buckling effects (*see* **14.2.1.1**),

V = factored applied shear force as governed by web yielding or web buckling,

V_d = design shear strength as governed by web yielding or web buckling (*see* **14.4.1** or **14.4.2**),

M_{fd} = plastic design strength of the area of the cross-section excluding the shear area, considering partial safety factor γ_{m0}, and

Z_e = elastic section modulus of the whole section.

b) *Semi-compact section*

$$M_{dv} = Z_e f_y / \gamma_{m0}$$

15.3 Combined Axial Force and Bending Moment

Under combined axial force and bending moment, section strength as governed by material failure and member strength as governed by buckling failure shall be checked in accordance with **15.3.1** and **15.3.2** respectively.

15.3.1 *Section Strength*

15.3.1.1 *Plastic and compact sections*

In the design of members subjected to combined axial force (tension or compression) and bending moment, the following should be satisfied:

$$\left(\frac{M_y}{M_{ndy}}\right)^{\alpha_1} + \left(\frac{M_z}{M_{ndz}}\right)^{\alpha_2} \leq 1.0$$

Conservatively, the following equation may also be used under combined axial force and bending moment:

$$\frac{N}{N_d} + \frac{M_y}{M_{dy}} + \frac{M_z}{M_{dz}} \leq 1.0$$

where

$M_{y,}\, M_z$ = factored applied moments about the minor and major axis of the cross-section, respectively;

$M_{ndy,}\, M_{ndz}$ = design reduced flexural strength under combined axial force and the respective uniaxial moment acting alone (*see* **15.3.1.2**);

N = factored applied axial force (Tension, T or Compression, P);

N_d = design strength in tension, T_d as obtained from **12** or in compression due to yielding given by $N_d = A_g f_y / \gamma_{m0}$;

$M_{dy,}\, M_{dz}$ = design strength under corresponding moment acting alone (*see* **14.2**);

A_g = gross area of the cross-section;

α_1, α_2 = constants as given in Table 17; and

γ_{m0} = partial factor of safety in yielding.

15.3.1.2 For plastic and compact sections without bolts holes, the following approximations may be used for evaluating M_{ndy} and M_{ndz}:

a) *Plates*

$$M_{nd} = M_d (1 - n^2)$$

b) *Welded I or H-sections*

$$M_{ndy} = M_{dy}\left[1 - \left(\frac{n-a}{1-a}\right)^2\right] \leq M_{dy}, \text{where } n \geq a$$

$$M_{ndz} = M_{dz}\,(1 - n) / (1 - 0.5a) \leq M_{dz}$$

where

$$n = N / N_d \text{ and } a = (A - 2\, b\, t_f) / A \leq 0.5$$

c) *For standard I or H sections*

$$M_{ndz} = 1.11\, M_{dz}\,(1 - n) \leq M_{dz}$$

for $n \leq 0.2$, $M_{ndy} = M_{dy}$

for $n > 0.2$, $M_{ndy} = 1.56\, M_{dy}\,(1 - n)\,(n + 0.6)$

$$M_{ndz} = 1.11\, M_{dz}\,(1 - n) \leq M_{dz}$$

d) *For rectangular hollow sections and welded box sections*

When the section is symmetric about both axes and without bolt holes

$$M_{ndy} = M_{dy}\,(1 - n) / (1 - 0.5a_f) \leq M_{dy}$$

$$M_{ndz} = M_{dz}\,(1 - n) / (1 - 0.5a_w) \leq M_{dz}$$

where

$$a_w = (A - 2\, b\, t_f) / A \leq 0.5$$

$$a_f = (A - 2\, h\, t_w) / A \leq 0.5$$

e) *Circular hollow tubes without bolt holes*

$$M_{nd} = 1.04\, M_d\,(1 - n^{1.7}) \leq M_d$$

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Table 17 Constants a_1 and $_2$

(*Clause* 15.3.1.1)

Sl No.	Section	α_1	α_2
(1)	(2)	(3)	(4)
i)	I and channel	$5n \geq 1$	2
ii)	Circular tubes	2	2
iii)	Rectangular tubes	$1.66/(1-1.13n^2) \leq 6$	$1.66/(1-1.13n^2) \leq 6$
iv)	Solid rectangles	$1.73 + 1.8n^3$	$1.73+1.8\ n^3$

NOTE — $n = N/N_d$.

15.3.1.3 *Semi-compact section*

In the absence of high shear force (*see* **15.2.1**), semi-compact section design is satisfactory under combined axial force and bending, if the maximum longitudinal stress under combined axial force and bending, f_x satisfies the following criteria:

$$f_x \leq f_y / \gamma_{m0}$$

For cross-section without holes, the above criteria reduces to,

$$\frac{N}{N_d} + \frac{M_y}{M_{dy}} + \frac{M_z}{M_{dz}} \leq 1.0$$

where

N_d, M_{dy}, M_{dz} are as defined in **15.3.1.1**.

15.3.2 *Overall Member Strength*

Members subjected to combined axial force and bending moment shall be checked for overall buckling failure as given in this section.

15.3.2.1 *Bending and axial tension*

The reduced effective moment, M_{eff}, under tension and bending calculated as given below, should not exceed the bending strength due to lateral torsional buckling, M_d (*see* **14.2.2**),

$$M_{eff} = \left[M - \psi\ T\ Z_{ec} / A\right] \leq M_d$$

where

M, T = factored applied moment and tension, respectively;

A = area of cross-section;

Z_{ec} = elastic section modulus of the section with respect to extreme compression fibre; and

ψ = 0.8, if T and M can vary independently, or otherwise

= 1.0.

15.3.2.2 *Bending and axial compression*

Members subjected to combined axial compression and biaxial bending shall satisfy the following interaction relationships:

$$\frac{P}{P_{dy}} + K_y \frac{C_{my} M_y}{M_{dy}} + K_{LT} \frac{M_z}{M_{dz}} \leq 1.0$$

$$\frac{P}{P_{dz}} + 0.6 K_y \frac{C_{my}\ M_y}{M_{dy}} + K_z \frac{C_{mz} M_z}{M_{dz}} \leq 1.0$$

where

C_{my}, C_{mz} = equivalent uniform moment factor as per Table 18;

P = applied axial compression under factored load;

M_y, M_z = maximum factored applied bending moments about y and z-axis of the member, respectively;

P_{dy}, P_{dz} = design strength under axial compression as governed by buckling about minor (y) and major (z) axis, respectively;

M_{dy}, M_{dz} = design bending strength about y (minor) or z (major) axis considering laterally unsupported length of the cross-section [*see* Section 6(h)];

K_y = $1 + (\lambda_y - 0.2) n_y \leq 1 + 0.8\ n_y$;

K_z = $1 + (\lambda_z - 0.2) n_z \leq 1 + 0.8\ n_z$, and

$$K_{LT} = 1 - \frac{0.1 \lambda_{LT} n_y}{(C_{mLT} - 0.25)} \geq 1 - \frac{0.1 n_y}{(C_{mLT} - 0.25)}$$

where

n_y, n_z = ratio of actual applied axial force to the design axial strength for buckling about the y and z-axis, respectively, and

C_{mLT} = Equivalent uniform moment factor for lateral torsional buckling as per Table 18 corresponding to the actual moment gradient between lateral supports against torsional deformation in the critical region under consideration.

SECTION 6(k) CONNECTIONS

16 CONNECTIONS

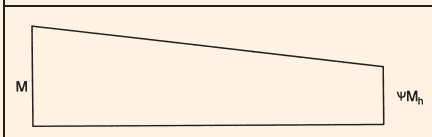
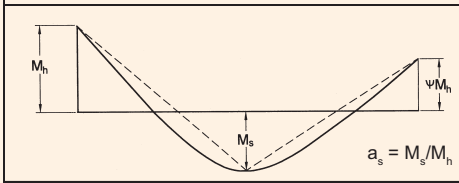
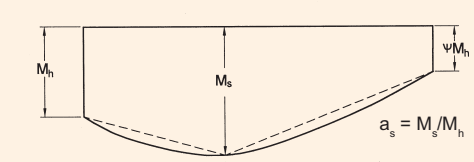
16.1 General

16.1.1 This Section deals with the design and detailing requirements for joints between members. Connection elements consist of components such as cleats, gusset plates, brackets, connecting plates and connectors such as rivets, bolts, pins, and welds. The connections in a structure shall be designed so as to be consistent with the assumptions made in the analysis of the structure and comply with the requirements specified in this

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Table 18 Equivalent Uniform Moment Factor

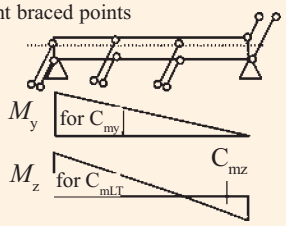
(*Clause* 9.3.2.2)

Bending Moment Diagram	Range		C_{my}, C_{mz}, C_m	
			Uniform Loading	Concentrated Load
(1)	(2)		(3)	(4)
	$-1 \le \psi \le 1$		$0.6 + 0.4\ \psi \ge 0.4$	
	$0 \le \alpha_s \le 1$	$-1 \le \psi \le 1$	$0.2 + 0.8\ \alpha_s \ge 0.4$	$0.2 + 0.8\ \alpha_s \ge 0.4$
	$-1 \le \alpha_s \le 0$	$0 \le \psi \le 1$	$0.1 - 0.8\ \alpha_s \ge 0.4$	$-0.8\ \alpha_s \ge 0.4$
		$-1 \le \psi \le 0$	$0.1(1-\psi) - 0.8\ \alpha_s \ge 0.4$	$0.2(1-\psi) - 0.8\ \alpha_s \ge 0.4$
	$0 \le \alpha_h \le 1$	$-1 \le \psi \le 1$	$0.95 - 0.05\ \alpha_h$	$0.90 + 0.10\ \alpha_h$
	$-1 \le \alpha_h \le 0$	$0 \le \psi \le 1$	$0.95 + 0.05\ \alpha_h$	$0.90 + 0.10\ \alpha_h$
		$-1 \le \psi \le 0$	$0.95 + 0.05\ \alpha_h\ (1+2\ \psi)$	$0.90 + 0.1\alpha_h\ (1+2\ \psi)$

For members with sway buckling mode, the equivalent uniform moment factor $C_{my} = C_{mz} = 0.9$.

C_{my}, C_{mz}, C_{mMLT} shall be obtained according to the bending moment diagram between the relevant braced points

Moment factor	Bending axis	Points braced in direction
C_{my}	z-z	y-y
C_{mz}	y-y	z-z
C_{mLT}	z-z	*z-z*



section. Connections shall be capable of transmitting the calculated design actions.

16.1.2 Where members are connected to the surface of a web or the flange of a section, the ability of the web or the flange to transfer the applied forces locally should be checked and where necessary, local stiffening provided.

16.1.3 Ease of fabrication and erection should be considered in the design of connections. Attention should be paid to clearances necessary for field erection, tolerances, tightening of fasteners, welding procedures, subsequent inspection, surface treatment and maintenance.

16.1.4 The ductility of steel assists the distribution of forces generated within a joint. Effects of residual stresses and stresses due to tightening of fasteners and normal tolerances of fit-up need not therefore be considered in connection design, provided ductile behaviour is ensured.

16.1.5 In general, use of different forms of fasteners to transfer the same force shall be avoided. However, when different forms of fasteners are used to carry a shear load or when welding and fasteners are combined, then one form of fastener shall be normally designed to carry the total load. Nevertheless, fully tensioned friction grip bolts may be designed to share the load with welding, provided the bolts are fully tightened to develop necessary pretension after welding.

16.1.6 The partial safety factor in the evaluation of design strength of connections shall be taken as given in Table 5.

16.2 Location Details of Fasteners

16.2.1 *Clearances for Holes for Fasteners*

Bolts may be located in standard size, over size, short slotted or long slotted hole, as follows.

a) *Standard clearance hole* — Except where fitted bolts, bolts in low-clearance or oversize holes are specified, the diameter of standard clearance holes for fasteners shall be as given in Table 19.

b) *Oversize hole* — Holes of size larger than the standard clearance holes, as given in Table 19 may be used in slip resistant connections and

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hold down bolted connections, only where specified, provided the oversize

c) Holes in the outer ply is covered by a cover plate of sufficiently large size and thickness and having a hole not larger than the standard clearance hole (and hardened washer in slip resistant connections).

d) *Short and long slots* — Slotted holes of size larger than the standard clearance hole, as given in Table 19 may be used in slip resistant connections and hold down bolted connections, only where specified, provided the oversize holes in the outer ply is covered by a cover plate of sufficiently large size and thickness and having a hole of size not larger than the standard clearance hole (and hardened washer in slip resistant connection).

Table 19 Clearances for Fastener Holes

(*Clause* 16.2.1)

Sl No.	Nominal Size of Fastener, *d* mm	Size of the Hole = Nominal Diameter of the Fastener + Clearances mm			
		Standard Clearance in Diameter and Width of Slot	Over Size Clearance in Diameter	Clearance in the Length of the Slot	
				Short Slot	Long Slot
(1)	(2)	(3)	(4)	(5)	(6)
i)	12-14	1.0	3.0	4.0	2.5 *d*
ii)	16-22	2.0	4.0	6.0	2.5 *d*
iii)	24	2.0	6.0	8.0	2.5 *d*
iv)	Larger than 24	3.0	8.0	10.0	2.5 *d*

16.2.2 *Minimum Spacing*

The distance between centres of fasteners shall not be less than 2.5 times the nominal diameter of the fastener.

16.2.3 *Maximum Spacing*

16.2.3.1 The distance between the centres of any two adjacent fasteners shall not exceed 32*t* or 300 mm, whichever is less, where *t* is the thickness of the thinner plate.

16.2.3.2 The distance between the centres of two adjacent fasteners (pitch) in a line lying in the direction of stress, shall not exceed 16*t* or 200 mm, whichever is less, in tension members and 12*t* or 200 mm, whichever is less, in compression members; where *t* is the thickness of the thinner plate. In the case of compression members wherein forces are transferred through butting faces, this distance shall not exceed 4.5 times the diameter of the fasteners for a distance equal to 1.5 times the width of the member from the butting faces.

16.2.3.3 The distance between the centres of any two consecutive fasteners in a line adjacent and parallel to an edge of an outside plate shall not exceed 100 mm plus 4*t* or 200 mm, whichever is less, in compression and tension members; where *t* is the thickness of the thinner outside plate.

16.2.3.4 When fasteners are staggered at equal intervals and the gauge does not exceed 75 mm, the spacing specified in **16.2.3.2** and **16.2.3.3** between centres of fasteners may be increased by 50 percent, subject to the maximum spacing specified in **16.2.3.1**.

16.2.4 *Edge and End Distances*

16.2.4.1 The edge distance is the distance at right angles to the direction of stress from the centre of a hole to the adjacent edge. The end distance is the distance in the direction of stress from the centre of a hole to the end of the element.

In slotted holes, the edge and end distances should be measured from the edge or end of the material to the centre of its end radius or the centre line of the slot, whichever is smaller. In oversize holes, the edge and end distances should be taken as the distance from the relevant edge/end plus half the diameter of the standard clearance hole corresponding to the fastener, less the nominal diameter of the oversize hole.

16.2.4.2 The minimum edge and end distances from the centre of any hole to the nearest edge of a plate shall not be less than 1.7 times the hole diameter in case of sheared or hand-flame cut edges; and 1.5 times the hole diameter in case of rolled, machine-flame cut, sawn and planed edges.

16.2.4.3 The maximum edge distance to the nearest line of fasteners from an edge of any un-stiffened part should not exceed $12t\varepsilon$, where $\varepsilon = (250/f_y)^{1/2}$ and *t* is the thickness of the thinner outer plate. This would not apply to fasteners interconnecting the components of back to back tension members. Where the members are exposed to corrosive influences, the maximum edge distance shall not exceed 40 mm plus 4*t*, where *t* is the thickness of thinner connected plate.

16.2.5 *Tacking Fasteners*

16.2.5.1 In case of members covered under **16.2.4.3**, when the maximum distance between centres of two adjacent fasteners as specified in **16.2.4.3** is exceeded, tacking fasteners not subjected to calculated stress shall be used.

16.2.5.2 Tacking fasteners shall have spacing in a line not exceeding 32 times the thickness of the thinner outside plate or 300 mm, whichever is less. Where the plates are exposed to the weather, the spacing in line shall not exceed 16 times the thickness of the thinner

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outside plate or 200 mm, whichever is less. In both cases, the distance between the lines of fasteners shall not be greater than the respective pitches.

16.2.5.3 All the requirements specified in **16.2.5.2** shall generally apply to compression members, subject to the stipulations in Section 6(g) affecting the design and construction of compression members.

16.2.5.4 In tension members [*see* Section 6(f)] composed of two flats, angles, channels or tees in contact back to back or separated back to back by a distance not exceeding the aggregate thickness of the connected parts, tacking fasteners with solid distance pieces shall be provided at a spacing in line not exceeding 1 000 mm.

16.2.5.5 For compression members covered in Section 6(g), tacking fasteners in a line shall be spaced at a distance not exceeding 600 mm.

16.2.6 *Countersunk Heads*

For countersunk heads, one-half of the depth of the countersinking shall be neglected in calculating the length of the fastener in bearing in accordance with **16.3.3**. For fasteners in tension having countersunk heads, the tensile strength shall be reduced by 33.3 percent. No reduction is required to be made in shear strength calculations.

16.3 Bearing Type Bolts

16.3.1 *Effective Areas of Bolts*

16.3.1.1 Since threads can occur in the shear plane, the area A_e for resisting shear should normally be taken as the net tensile stress area, A_n of the bolts. For bolts where the net tensile stress area is not defined, A_n shall be taken as the area at the root of the threads.

16.3.1.2 Where it can be shown that the threads do not occur in the shear plane, A_e may be taken as the cross-section area, A_s at the shank.

16.3.1.3 In the calculation of thread length, allowance should be made for tolerance and thread run off.

16.3.2 A bolt subjected to a factored shear force (V_{sb}) shall satisfy the condition

$$V_{sb} \le V_{db}$$

where V_{db} is the design strength of the bolt, taken as the smaller of the value as governed by shear, V_{dsb} (*see* **16.3.3**) and bearing, V_{dpb} (*see* **16.3.4**).

16.3.3 *Shear Capacity of Bolt*

The design strength of the bolt, V_{dsb} as governed by shear strength is given by:

$$V_{dsb} = V_{nsb} / \gamma_{mb}$$

where

V_{nsb} = nominal shear capacity of a bolt, calculated as follows:

$$V_{nsb} = \frac{f_u}{\sqrt{3}}\left(n_n A_{nb} + n_s A_{sb}\right)$$

where

f_u = ultimate tensile strength of a bolt;

n_n = number of shear planes with threads intercepting the shear plane;

n_s = number of shear planes without threads intercepting the shear plane;

A_{sb} = nominal plain shank area of the bolt; and

A_{nb} = net shear area of the bolt at threads, may be taken as the area corresponding to root diameter at the thread.

16.3.3.1 *Long joints*

When the length of the joint, l_j of a splice or end connection in a compression or tension element containing more than two bolts (that is, the distance between the first and last rows of bolts in the joint, measured in the direction of the load transfer) exceeds $15d$ in the direction of load, the nominal shear capacity (*see* **16.3.2**), V_{db} shall be reduced by the factor β_{lj}, given by:

$$\beta_{lj} = 1.075 - l_j / (200\, d) \quad \text{but } 0.75 \le \beta_{lj} \le 1.0$$
$$= 1.075 - 0.005(l_j / d)$$

where

d = Nominal diameter of the fastener.

NOTE — This provision does not apply when the distribution of shear over the length of joint is uniform, as in the connection of web of a section to the flanges.

16.3.3.2 *Large grip lengths*

When the grip length, l_g (equal to the total thickness of the connected plates) exceeds 5 times the diameter, d of the bolts, the design shear capacity shall be reduced by a factor b_{lg}, given by:

$$\beta_{lg} = 8d /(3d + l_g) = 8/(3 + l_g/d)$$

β_{lg} shall not be more than β_{lj} given in **16.3.3.1**. The grip length, l_g shall in no case be greater than $8d$.

16.3.3.3 *Packing plates*

The design shear capacity of bolts carrying shear through a packing plate in excess of 6 mm shall be decreased by a factor, β_{pk} given by:

$$\beta_{pk} = (1 - 0.012\ 5t_{pk})$$

where

t_{pk} = thickness of the thicker packing, in mm.

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16.3.4 *Bearing Capacity of the Bolt*

The design bearing strength of a bolt on any plate, V_{dpb} as governed by bearing is given by:

$$V_{dpb} = V_{npb} / \gamma_{mb}$$

where

V_{npb} = nominal bearing strength of a bolt
= $2.5\, k_b\, d\, t\, f_u$

where

k_b is smaller of $\frac{e}{3d_0}$, $\frac{p}{3d_0} - 0.25$, $\frac{f_{ub}}{f_u}$, 1.0;

e, p = end and pitch distances of the fastener along bearing direction;

d_0 = diameter of the hole;

f_{ub}, f_u = ultimate tensile stress of the bolt and the ultimate tensile stress of the plate, respectively;

d = nominal diameter of the bolt; and

t = summation of the thicknesses of the connected plates experiencing bearing stress in the same direction, or if the bolts are countersunk, the thickness of the plate minus one half of the depth of countersinking.

The bearing resistance (in the direction normal to the slots in slotted holes) of bolts in holes other than standard clearance holes may be reduced by multiplying the bearing resistance obtained as above, V_{npb}, by the factors given below:

a) Over size and short slotted holes : 0.7, and
b) Long slotted holes : 0.5.

NOTE — The block shear of the edge distance due to bearing force may be checked as given in **12.4**.

16.3.5 *Tension Capacity*

A bolt subjected to a factored tensile force, T_b shall satisfy,

$$T_b \le T_{db}$$

where

$T_{db} = T_{nb} / \gamma_{mb}$

T_{nb} = nominal tensile capacity of the bolt, calculated as:

$$T_{nb} = 0.90 f_{ub} A_n < f_{yb} A_{sb} (\gamma_{mb} / \gamma_{m0})$$

where

f_{ub} = ultimate tensile stress of the bolt,

f_{yb} = yield stress of the bolt,

A_n = net tensile stress area as specified in the appropriate Indian Standard (for bolts where the tensile stress area is not defined, A_n shall be taken as the area at the bottom of the threads), and

A_{sb} = shank area of the bolt.

16.3.6 *Bolt Subjected to Combined Shear and Tension*

A bolt required to resist both design shear force (V_{sd}) and design tensile force (T_b) at the same time shall satisfy,

$$\left(\frac{V_{sb}}{V_{db}}\right)^2 + \left(\frac{T_b}{T_{db}}\right)^2 \le 1.0$$

where

V_{sb} = factored shear force acting on the bolt,

V_{db} = design shear capacity (*see* **16.3.2**),

T_b = factored tensile force acting on the bolt, and

T_{db} = design tension capacity (*see* **16.3.5**).

16.4 Friction Grip Type Bolting

16.4.1 In friction grip type bolting, initial pretension in bolt (usually high strength) develops clamping force at the interfaces of elements being joined. The frictional resistance to slip between the plate surfaces subjected to clamping force opposes slip due to externally applied shear. Friction grip type bolts and nuts shall conform to the accepted standard [6-6(37)]. Their installation procedures shall conform to good practice [6-6(15)].

16.4.2 Where slip between bolted plates cannot be tolerated at working loads/strength limit states loads (slip critical connections), the requirements of **16.4.3** shall be satisfied at service and strength limit states loads, respectively. However, the requirements of **16.4.4** shall be satisfied by all connections at the strength limit states.

16.4.3 *Slip Resistance*

Design for friction type bolting, where slip resistance is required at factored design force V_{sf}, shall satisfy the following:

$$V_{sf} \le V_{dsf}$$

where

$V_{dsf} = V_{nsf} / \gamma_{mf}$

V_{nsf} = nominal shear capacity of a bolt as governed by slip for friction type connection, calculated as follows:

$$V_{nsf} = \mu_f n_e K_h F_o$$

where

μ_f = coefficient of friction (slip factor) as specified in Table 20 ($\mu_f \le 0.55$);

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n_e = number of effective interfaces offering frictional resistance to slip;

K_h = 1.0 for fasteners in clearance holes,

= 0.85 for fasteners in oversized and short slotted holes and for fasteners in long slotted holes loaded perpendicular to the slot,

= 0.7 for fasteners in long slotted holes loaded parallel to the slot;

γ_{mf} = 1.10 (if slip resistance is designed at service load),

= 1.25 (if slip resistance is designed at ultimate load);

F_o = minimum bolt tension (proof load) at installation and may be taken as $A_{nb} f_o$,

A_{nb} = net area of the bolt at threads, and

f_o = proof stress (= 0.70 f_{ub}).

NOTE — V_{nsf} may be evaluated at a service load or ultimate load using appropriate partial safety factors, depending upon whether slip resistance is required at service load or ultimate load.

Table 20 Typical Average Values for Coefficient of Friction (μ_f)

(*Clause* 16.4.3)

Sl No.	Treatment of Surface	Coefficient of Friction μ_f
(1)	(2)	(3)
i)	Surfaces not treated	0.20
ii)	Surfaces blasted with short or grit with any loose rust removed, no pitting	0.50
iii)	Surfaces blasted with shot or grit and hot-dip galvanized	0.10
iv)	Surfaces blasted with shot or grit and spray-metallized with zinc (thickness 50-70 μm)	0.25
v)	Surfaces blasted with shot or grit and painted with ethyl zinc silicate coat (thickness 30-60 μm)	0.30
vi)	Sand blasted surface, after light rusting	0.52
vii)	Surfaces blasted with shot or grit and painted with ethyl zinc silicate coat (thickness 60-80 μm)	0.30
viii)	Surfaces blasted with shot or grit and painted with alkali zinc silicate coat (thickness 60-80 μm)	0.30
ix)	Surface blasted with shot or grit and spray metallized with aluminium (thickness > 50 μm)	0.50
x)	Clean mill scale	0.33
xi)	Sand blasted surface	0.48
xii)	Red lead painted surface	0.1

16.4.3.1 *Long joints*

The provision for the long joints in **16.3.3.1** shall apply to friction grip connections also.

16.4.4 *Capacity after Slipping*

When friction type bolts are designed not to slip only under service loads, the design capacity at ultimate load may be calculated as per bearing type connection (*see* **16.3.2** and **16.3.3).**

NOTE — The block shear resistance of the edge distance due to bearing force may be checked as given in **12.4**.

16.4.5 *Tension Resistance*

A friction bolt subjected to a factored tension force (T_f) shall satisfy:

$$T_f \le T_{df}$$

where

$T_{df} = T_{nf} / \gamma_{mf}$

T_{nf} = nominal tensile strength of the friction bolt, calculated as:

$$T_{nf} = 0.9 f_{ub} A_n \le f_{yb} A_{sb} (\gamma_{m1} / \gamma_{m0})$$

where

f_{ub} = ultimate tensile stress of the bolt;

A_n = net tensile stress area as specified in various parts of the accepted standard [6-6(38)] (for bolts where the tensile stress area is not defined, A_n shall be taken as the area at the root of the threads);

A_{sb} = shank area of the bolt; and

γ_{mf} = partial factor of safety.

16.4.6 *Combined Shear and Tension*

Bolts in a connection for which slip in the serviceability limit state shall be limited, which are subjected to a tension force, *T,* and shear force, *V*, shall satisfy:

$$\left(\frac{V_{sf}}{V_{df}}\right)^2 + \left(\frac{T_f}{T_{df}}\right)^2 \le 1.0$$

where

V_{sf} = applied factored shear at design load;

V_{df} = design shear strength;

T_f = externally applied factored tension at design load; and

T_{df} = design tension strength.

16.4.7 Where prying force, *Q* as illustrated in Fig. 16 shall be calculated as given below and added to the tension in the bolt:

$$Q = \frac{l_v}{2 l_e}\left[T_e - \frac{\beta \eta f_o b_e t^4}{27 l_e l_v^2}\right]$$

where

l_v = distance from the bolt centreline to the toe of the fillet weld or to half the root radius for a rolled section, and

l_e = distance between prying force and bolt

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centreline and is the minimum of either the end distance or the value given by:

$$l_e = 1.1\, t \sqrt{\frac{\beta\, f_o}{f_y}}$$

where

β = 2, for non pre-tensioned bolt and 1, for pre-tensioned bolt;

η = 1.5;

b_e = effective width of flange per pair of bolts;

f_o = proof stress in consistent units; and

t = thickness of the end plate.

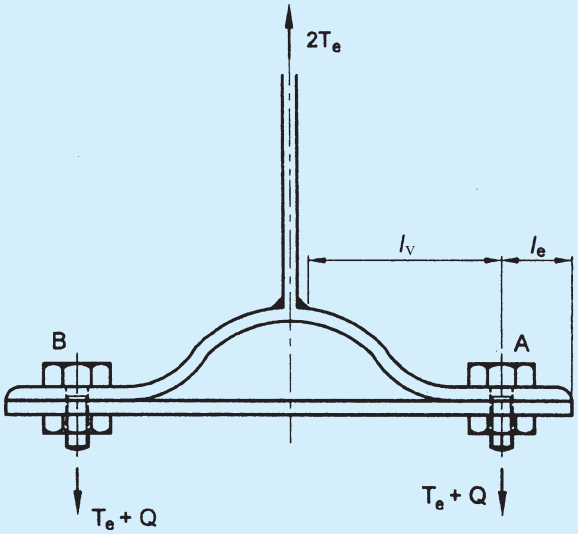


FIG. 16 COMBINED PRYING FORCE AND TENSION

16.5 Welds and Welding

16.5.1 *General*

Requirements of welds and welding shall conform to the accepted standards [6-6(39)], as appropriate.

16.5.1.1 *End returns*

Fillet welds terminating at the ends or sides of parts should be returned continuously around the corners for a distance of not less than twice the size of the weld, unless it is impractical to do so. This is particularly important on the tension end of parts carrying bending loads.

16.5.1.2 *Lap joint*

In the case of lap joints, the minimum lap should not be less than four times the thickness of the thinner part joined or 40 mm, whichever is more. Single end fillet should be used only when lapped parts are restrained from openings. When end of an element is connected only by parallel longitudinal fillet welds, the length of the weld along either edge should not be less than the transverse spacing between longitudinal welds.

16.5.1.3 A single fillet weld should not be subjected to moment about the longitudinal axis of the weld.

16.5.2 *Size of Weld*

16.5.2.1 The size of normal fillets shall be taken as the minimum weld leg size. For deep penetration welds, where the depth of penetration beyond the root run is a minimum of 2.4 mm, the size of the fillet should be taken as the minimum leg size plus 2.4 mm.

16.5.2.2 For fillet welds made by semi-automatic or automatic processes, where the depth of penetration is considerably in excess of 2.4 mm, the size shall be taken considering actual depth of penetration subject to agreement between the purchaser and the contractor.

16.5.2.3 The size of fillet welds shall not be less than 3 mm. The minimum size of the first run or of a single run fillet weld shall be as given in Table 21, to avoid the risk of cracking in the absence of preheating.

16.5.2.4 The size of butt weld shall be specified by the effective throat thickness.

16.5.3 *Effective Throat Thickness*

16.5.3.1 The effective throat thickness of a fillet weld shall not be less than 3 mm and shall generally not exceed 0.7*t,* or 1.0*t* under special circumstances, where *t* is the thickness of the thinner plate of elements being welded.

16.5.3.2 For the purpose of stress calculation in fillet welds joining faces inclined to each other, the effective throat thickness shall be taken as *K* times the fillet size, where *K* is a constant, depending upon the angle between fusion faces, as given in Table 22.

Table 21 Minimum Size of First Run or of a Single Run Fillet Weld

(*Clause* 16.5.2.3)

Sl No.	Thickness of Thicker Part mm		Minimum Size mm
	Over	Up to and Including	
(1)	(2)	(3)	(4)
i)	–	10	3
ii)	10	20	5
iii)	20	32	6
iv)	32	50	8 of first run 10 for minimum size of weld

NOTES

1 When the minimum size of the fillet weld given in the table is greater than the thickness of the thinner part, the minimum size of the weld should be equal to the thickness of the thinner part. The thicker part shall be adequately preheated to prevent cracking of the weld.

2 Where the thicker part is more than 50 mm thick, special precautions like preheating should be taken.

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Table 22 Values of *K* for Different Angles Between Fusion Faces

(*Clause* 16.5.3.2)

Angle Between Fusion Faces	60°-90°	91°-100°	101°-106°	107°-113°	114°-120°
Constant, *K*	0.70	0.65	0.60	0.55	0.50

16.5.3.3 The effective throat thickness of a complete penetration butt weld shall be taken as the thickness of the thinner part joined, and that of an incomplete penetration butt weld shall be taken as the minimum thickness of the weld metal common to the parts joined, excluding reinforcements.

16.5.4 *Effective Length or Area of Weld*

16.5.4.1 The effective length of fillet weld shall be taken as only that length which is of the specified size and required throat thickness. In practice the actual length of weld is made of the effective length shown in drawing plus two times the weld size, but not less than four times the size of the weld.

16.5.4.2 The effective length of butt weld shall be taken as the length of the continuous full size weld, but not less than four times the size of the weld.

16.5.4.3 The effective area of a plug weld shall be considered as the nominal area of the hole in the plane of the faying surface. These welds shall not be designed to carry stresses.

16.5.4.4 If the maximum length l_j of the side welds transferring shear along its length exceeds 150 times the throat size of the weld, t_t, the reduction in weld strength as per the long joint (*see* **16.5.7.3**) should be considered. For flange to web connection, where the welds are loaded for the full length, the above limitation would not apply.

16.5.5 *Intermittent Welds*

16.5.5.1 Unless otherwise specified, the intermittent fillet welding shall have an effective length of not less than four times the weld size, with a minimum of 40 mm.

16.5.5.2 The clear spacing between the effective lengths of intermittent fillet weld shall not exceed 12 and 16 times the thickness of thinner plate joined, for compression and tension joint, respectively, and in no case be more than 200 mm.

16.5.5.3 Unless otherwise specified, the intermittent butt weld shall have an effective length of not less than four times the weld size and the longitudinal space between the effective length of welds shall not be more than 16 times the thickness of the thinner part joined. The intermittent welds shall not be used in positions subject to dynamic, repetitive and alternating stresses.

16.5.6 *Weld Types and Quality*

For the purpose of this code, weld shall be fillet, butt, slot or plug or compound welds. Welding electrodes shall conform to the accepted standard [6-6(18)].

16.5.7 *Design Stresses in Welds*

16.5.7.1 *Shop welds*

16.5.7.1.1 *Fillet welds*

Design strength of a fillet weld, f_{wd} shall be based on its throat area and shall be given by:

$$f_{wd} = f_{wn} / \gamma_{mw}$$

where

$f_{wn} = f_u / \sqrt{3}$,

f_u = smaller of the ultimate stress of the weld or of the parent metal, and

γ_{mw} = partial safety factor (*see* Table 5).

16.5.7.1.2 *Butt welds*

Butt welds shall be treated as parent metal with a thickness equal to the throat thickness, and the stresses shall not exceed those permitted in the parent metal.

16.5.7.1.3 *Slot or plug welds*

The design shear stress on slot or plug welds shall be as per **16.5.7.1.1**.

16.5.7.2 *Site welds*

The design strength in shear and tension for site welds made during erection of structural members shall be calculated according to **16.5.7.1** but using a partial safety factor γ_{mw} of 1.5.

16.5.7.3 *Long joints*

When the length of the welded joint, l_j of a splice or end connection in a compression or tension element is greater than 150 t_t, the design capacity of weld (*see* **16.5.7.1.1**), f_{wd} shall be reduced by the factor:

$$\beta_{lw} = 1.2 - \frac{0.2 l_j}{150 t_t} \leq 1.0$$

where

l_j = length of the joint in the direction of the force transfer, and

t_t = throat size of the weld.

16.5.8 *Fillet Weld Applied to the Edge of a Plate or Section*

16.5.8.1 Where a fillet weld is applied to the square edge of a part, the specified size of the weld should generally be at least 1.5 mm less than the edge thickness

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in order to avoid washing down of the exposed corner (*see* Fig. 17A).

16.5.8.2 Where the fillet weld is applied to the rounded toe of a rolled section, the specified size of the weld should generally not exceed 3/4 of the thickness of the section at the toe (*see* Fig. 17B).

16.5.8.3 Where the size specified for a fillet weld is such that the parent metal will not project beyond the weld, no melting of the outer cover or covers shall be allowed to occur to such an extent as to reduce the throat thickness (*see* Fig. 18)

16.5.8.4 When fillet welds are applied to the edges of a plate or section in members subject to dynamic loading, the fillet weld shall be of full size with its leg length equal to the thickness of the plate or section, with the limitations specified in **16.5.8.3**.

16.5.8.5 End fillet weld, normal to the direction of force shall be of unequal size with a throat thickness not less than $0.5t$, where t is the thickness of the part, as shown in Fig. 19. The difference in thickness of the welds shall be negotiated at a uniform slope.

16.5.9 *Stresses Due to Individual Forces*

When subjected to either compressive or tensile or shear force alone, the stress in the weld is given by:

$$f_a \text{ or } q = \frac{P}{t_t \, l_w}$$

where

f_a = calculated normal stress due to axial force, in N/mm^2;

q = shear stress, in N/mm^2;

P = force transmitted (axial force N or the shear force Q);

t_t = effective throat thickness of weld, in mm; and

l_w = effective length of weld, in mm.

16.5.10 *Combination of Stresses*

16.5.10.1 *Fillet welds*

16.5.10.1.1 When subjected to a combination of normal and shear stress, the equivalent stress f_e shall satisfy the following:

$$f_e = \sqrt{f_a^2 + 3q^2} \leq \frac{f_u}{\sqrt{3}\gamma_{mw}}$$

where

f_a = normal stresses, compression or tension, due to axial force or bending moment (*see* **16.5.9**), and

q = shear stress due to shear force or tension (*see* **16.5.9**).

16.5.10.1.2 Check for the combination of stresses need not be done for,

a) side fillet welds joining cover plates and flange plates; and

b) fillet welds where sum of normal and shear stresses does not exceed f_{wd} (*see* **16.5.7.1.1**).

16.5.10.2 *Butt welds*

16.5.10.2.1 Check for the combination of stresses in butt welds need not be carried out provided that,

a) butt welds are axially loaded, and

b) in single and double bevel welds the sum of normal and shear stresses does not exceed the design normal stress, and the shear stress does not exceed 50 percent of the design shear stress.

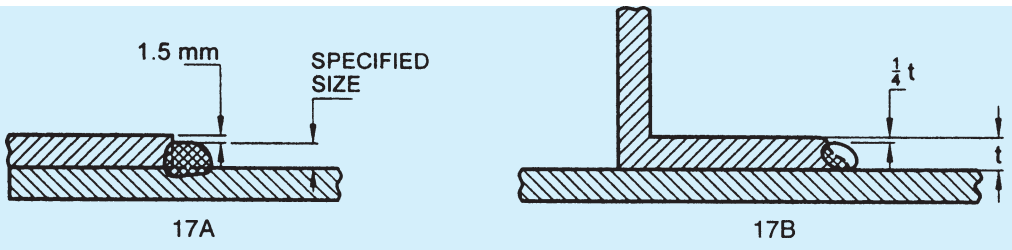


FIG. 17 FILLET WELDS ON SQUARE EDGE OF PLATE OR ROUND TOE OF ROLLED SECTION

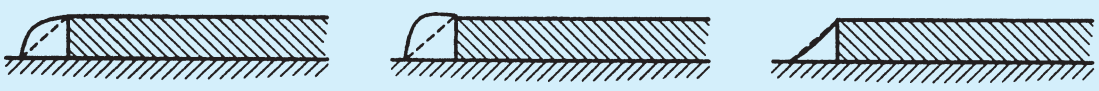


FIG. 18 FULL SIZE FILLET WELD APPLIED TO THE EDGE OF A PLATE OR SECTION

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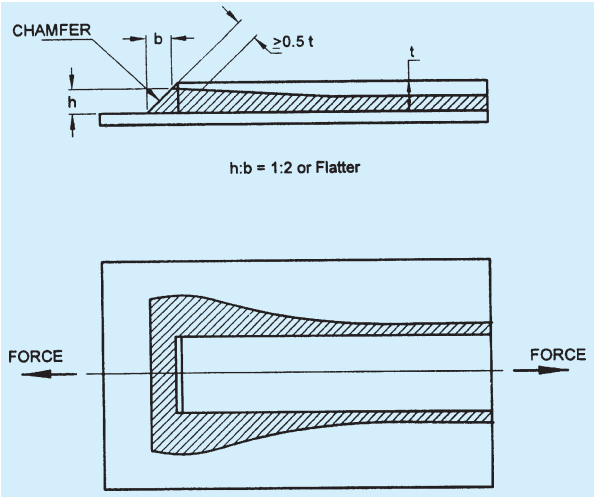


FIG. 19 END FILLET WELD NORMAL TO DIRECTION OR FORCE

16.5.10.2.2 *Combined bearing, bending and shear*

Where bearing stress, f_{br} is combined with bending (tensile or compressive), f_b and shear stresses, q under the most unfavorable conditions of loading in butt welds, the equivalent stress, f_e as obtained from the following formula, shall not exceed the values allowed for the parent metal:

$$f_e = \sqrt{f_b^2 + f_{br}^2 + f_b f_{br} + 3q^2}$$

where

f_e = equivalent stress;

f_b = calculated stress due to bending, in N/mm^2;

f_{br} = calculated stress due to bearing, in N/mm^2; and

q = shear stress, in N/mm^2.

16.5.11 Where a packing is welded between two members and is less than 6 mm thick, or is too thin to allow provision of adequate welds or to prevent buckling, the packing shall be trimmed flush with the edges of the element subject to the design action and the size of the welds along the edges shall be increased over the required size by an amount equal to the thickness of the packing. Otherwise, the packing shall extend beyond the edges and shall be fillet welded to the pieces between which it is fitted.

16.6 Design of Connections

Each element in a connection shall be designed so that the structure is capable of resisting the design actions. Connections and adjacent regions of the members shall be designed by distributing the design action effects such that the following requirements are satisfied:

a) Design action effects distributed to various elements shall be in equilibrium with the design action effects on the connection,

b) Required deformations in the elements of the connections are within their deformations capacities,

c) All elements in the connections and the adjacent areas of members shall be capable of resisting the design action effects acting on them, and

d) Connection elements shall remain stable under the design action effects and deformations.

16.6.1 Connections can be classified as rigid, semi-rigid and flexible for the purpose of analysis and design as per the recommendation in Annex E. Connections with sufficient rotational stiffness may be considered as rigid. Examples of rigid connections include flush end-plate connection and extended end-plate connections. Connections with negligible rotational stiffness may be considered as flexible (pinned). Examples of flexible connections include single and double web angle connections and header plate connections. Where a connection cannot be classified as either rigid or flexible, it shall be assumed to be semi-rigid. Examples of semi-rigid connections include top and seat angle connection and top and seat angle with single/double web angles.

16.6.2 Design shall be on the basis of any rational method supported by experimental evidence. Residual stresses due to installation of bolts or welding normally need not be considered in statically loaded structures. Connections in cyclically loaded structures shall be designed considering fatigue as given in Section 6(p). For earthquake load combinations, the connections shall be designed to withstand the calculated design action effects and exhibit required ductility as specified in Section 6(n).

16.6.3 Beam and column splice shall be designed in accordance with the recommendation given in **F-2** and **F-3**.

16.7 Minimum Design Action on Connection

Connections carrying design action effects, except for lacing connections, connections of sag rods, purlins and girts, shall be designed to transmit the greater of,

a) the design action in the member; and

b) the minimum design action effects expressed either as the value or the factor times the member design capacity for the minimum size of member required by the strength limit state, specified as follows:

1) *Connections in rigid construction* — A bending moment of at least 0.5 times the member design moment capacity.

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2) *Connections to beam in simple construction* — A shear force of at least 0.15 times the member design shear capacity or 40 kN, whichever is lesser.
3) *Connections at the ends of tensile or compression member* — A force of at least 0.3 times the member design capacity.
4) *Splices in members subjected to axial tension* — A force of at least 0.3 times the member design capacity in tension.
5) *Splices in members subjected to axial compression* — For ends prepared for full contact in accordance with **23.7.1**, it shall be permissible to carry compressive actions by bearing on contact surfaces. When members are prepared for full contact to bear at splices, there shall be sufficient fasteners to hold all parts securely in place. The fasteners shall be sufficient to transmit a force of at least 0.15 times the member design capacity in axial compression.

   When members are not prepared for full contact, the splice material and its fasteners shall be arranged to hold all parts in line and shall be designed to transmit a force of at least 0.3 times the member design capacity in axial compression.

   In addition, splices located between points of effective lateral support shall be designed for the design axial force, P_d plus a design bending moment, not less than the design bending moment $M_d = P_d l_s/1\ 000$ where, l_s is the distance between points of effective lateral support.
6) *Splices in flexural members* — A bending moment of 0.3 times the member design capacity in bending. This provision shall not apply to splices designed to transmit shear force only.

   A splice subjected to a shear force only shall be designed to transmit the design shear force together with any bending moment resulting from the eccentricity of the force with respect to the centroid of the group.
7) *Splices in members subject to combined actions* – A splice in a member subject to a combination of design axial tension or design axial compression and design bending moment shall satisfy requirements in (4), (5) and (6), simultaneously.

For earthquake load combinations, the design action effects specified in this section may need to be increased to meet the required behaviour of the steel frame and shall comply with Section 6(n).

16.8 Intersections

Members or components meeting at a joint shall be arranged to transfer the design actions between the parts, wherever practicable, with their centroidal axes meeting at a point. Where there is eccentricity at joints, the members and components shall be designed for the design bending moments which result due to eccentricity.

The disposition of fillet welds to balance the design actions about the centroidal axis or axes for end connections of single angle, double angle and similar type members is not required for statically loaded members but is required for members, connection components subject to fatigue loading.

Eccentricity between the centroidal axes of angle members and the gauge lines for their bolted end connections may be neglected in statically loaded members, but shall be considered in members and connection components subject to fatigue loading.

16.9 Choice of Fasteners

Where slip in the serviceability limit state is to be avoided in a connection, high-strength bolts in a friction-type joint, fitted bolts or welds shall be used.

Where a joint is subjected to impact or vibration, either high strength bolts in a friction type joint or ordinary bolts with locking devices or welds shall be used.

16.10 Connection Components

Connection components (cleats, gusset plates, brackets and the like) other than connectors, shall have their capacities assessed using the provisions of Sections 6(e), 6(f), 6(g), 6(h) and 6(i), as applicable.

16.11 Analysis of a Bolt/Weld Group

16.11.1 *Bolt/Weld Group Subject to In-plane Loading*

16.11.1.1 *General method of analysis*

The design force in a bolt/weld or design force per unit length in a bolt/weld group subject to in-plane loading shall be determined in accordance with the following:

a) The connection plates shall be considered to be rigid and to rotate relative to each other about a point known as the instantaneous centre of rotation of the group.

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b) In the case of a group subject to a pure couple only, the instantaneous centre of rotation coincides with the group centroid. In the case of in-plane shear force applied at the group centroid, the instantaneous centre of the rotation is at infinity and the design force is uniformly distributed throughout the group. In all other cases, either the results of independent analyses for a pure couple alone and for an in-plane shear force applied at the group centroid shall be superposed, or a recognized method of analysis shall be used.

c) The design force in a bolt or design force per unit length at any point in the group shall be assumed to act at right angles to the radius from that point to the instantaneous centre, and shall be taken as proportional to that radius.

16.11.2 *Bolt/Weld Group Subject to Out-of-Plane Loading*

16.11.2.1 *General method of analysis*

The design force of a bolt in bolt group or design force per unit length in the fillet weld group subject to out-of-plane loading shall be determined in accordance with the following:

a) Design force in the bolts or per unit length in the fillet weld group resulting from any shear force or axial force shall be considered to be equally shared by all bolts in the group or uniformly distributed over the length of the fillet weld group.

b) Design force resulting from a design bending moment shall be considered to vary linearly with distance from the relevant centroidal axes. The following shall also be considered:

   1) In bearing type of bolt group plates in the compression side of the neutral axis and only bolts in the tension side of the neutral axis may be considered for calculating the neutral axis and second moment of area.

   2) In the friction grip bolt group, only the bolts shall be considered in the calculation of neutral axis and second moment of area.

   3) The fillet weld group shall be considered in isolation from the connected element; for the calculation of centroid and second moment of the weld length.

16.11.2.2 *Alternative analysis*

The design force per unit length in a fillet weld/bolt group may alternatively be determined by considering the fillet weld group as an extension of the connected member and distributing the design forces among the welds of the fillet weld group so as to satisfy equilibrium between the fillet weld group and the elements of the connected member.

16.11.3 *Bolt/Weld Group Subject to In-Plane and Out-of-Plane Loading*

16.11.3.1 *General method of analysis*

The design force in a bolt or per unit length of the weld shall be determined by the superposition of analysis for in-plane and out-of-plane cases discussed in **16.11.1** and **16.11.2**.

16.11.3.2 *Alternative analysis*

The design force in a bolt or per unit length in the fillet weld group may alternatively be determined by considering the fillet weld group as an extension of the connected member and proportioning the design force per bolt or unit length in the weld group to satisfy equilibrium between the bolt/weld group and the elements of the connected member.

Force calculated in the most stressed bolt or highest force per unit length of the weld shall satisfy the strength requirements of **16.3**, **16.4** or **16.5**, as appropriate.

16.12 Lug Angles

16.12.1 Lug angles connecting outstanding leg of a channel-shaped member shall, as far as possible, be disposed symmetrically with respect to the section of the member.

16.12.2 In the case of angle members, the lug angles and their connections to the gusset or other supporting member shall be capable of developing a strength not less than 20 percent in excess of the force in the outstanding leg of the member, and the attachment of the lug angle to the main angle shall be capable of developing a strength not less than 40 percent in excess of the force in the outstanding leg of the angle.

16.12.3 In the case of channel members and the like, the lug angles and their connection to the gusset or other supporting member shall be capable of developing a strength of not less than 10 percent in excess of the force not accounted for by the direct connection of the member, and the attachment of the lug angles to the member shall be capable of developing 20 percent in excess of that force.

16.12.4 In no case shall fewer than two bolts, rivets or equivalent welds be used for attaching the lug angle to the gusset or other supporting member.

16.12.5 The effective connection of the lug angle shall, as far as possible terminate at the end of the member connected, and the fastening of the lug angle to the main member shall preferably start in advance of the

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direct connection of the member to the gusset or other supporting member.

16.12.6 Where lug angles are used to connect an angle member, the whole area of the member shall be taken as effective notwithstanding the requirements of Section 6(f).

SECTION 6(m) WORKING STRESS DESIGN

17 WORKING STRESS DESIGN

17.1 General

17.1.1 General design requirements of Section 6(c) shall apply in this section.

17.1.2 Methods of structural analysis of Section 6(d) shall also apply to this section. The elastic analysis method shall be used in the working stress design.

17.1.3 The working stress shall be calculated applying respective partial safety factors for loads, specified in Table 4 for the limit states of serviceability.

17.1.4 In load combinations involving wind or seismic loads, the permissible stresses in steel structural members may be increased by 33 percent. For anchor bolts and construction loads this increase shall be limited to 25 percent. Such an increase in allowable stresses should not be considered if the wind or seismic load is the major load in the load combination (such as acting along with dead load alone).

17.2 Tension Members

17.2.1 *Actual Tensile Stress*

The actual tensile stress, f_t on the gross area of cross-section, A_g of plates, angles and other tension members shall be less than or equal to the smaller value of permissible tensile stresses, $f_{at,}$ as given below:

Actual tensile stress, $f_t = T_s / A_g$

The permissible stress, f_{at} is smallest of the values as obtained below:

a) As governed by yielding of gross section:

$$f_{at} = 0.6 f_y$$

b) As governed by rupture of net section

1) *Plates under tension*:

$$f_{at} = 0.69\ T_{dn}/A_g$$

2) *Angles under tension*:

$$f_{at} = 0.69\ T_{dn}/A_g$$

c) As governed by block shear:

$$f_{at} = 0.69\ T_{db} / A_g$$

where

T_s = actual tension under working (service) load,

A_g = gross area,

T_{dn} = design strength in tension of respective plate/angle calculated in accordance with **12.3**, and

T_{db} = design block shear strength in tension of respective plate/angle calculated in accordance with **12.4**.

17.3 Compression Members

17.3.1 *Actual Compressive Stress*

The actual compressive stress, f_c at working (service) load, P_s of a compression member shall be less than or equal to the permissible compressive stress, f_{ac} as given below:

Actual compressive stress, $f_c = P_s / A_e$

The permissible compressive stress, $f_{ac} = 0.60 f_{cd}$

where

A_e = effective sectional area as defined in **13.3.2**, and

f_{cd} = design compressive stress as defined in **13.1.2.1** (for angles, *see* **13.5.1.2**), calculated without the partial safety factor, $\gamma_{m0.}$

17.3.2 *Design Details*

Design of the compression members shall conform to **13.3**.

17.3.3 *Column Bases*

The provisions of **13.4** shall be followed for the design of column bases, except that the thickness of a simple column base, t_s shall be calculated as:

$$t_s = \sqrt{3w\left(a^2 - 0.3b^2\right) / f_{bs}}$$

where

w = uniform pressure from below on the slab base due to axial compression;

a,b = larger and smaller projection of the slab base beyond the rectangle circumscribing the column, respectively; and

f_{bs} = permissible bending stress in column base equal to $0.75 f_y$.

17.3.4 *Angle Struts*

Provisions of **13.5** shall be used for design of angle struts, except that the limiting actual stresses shall be calculated in accordance with **17.3.1**.

17.3.5 *Laced and Battened Columns*

The laced and battened columns shall be designed in accordance with **13.6** and **13.7**, except that the actual stresses shall be less than the permissible stresses given in **17.3.1**.

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17.4 Members Subjected to Bending

17.4.1 *Bending Stresses*

The actual bending tensile and compressive stresses, f_{bt}, f_{bc} at working (service) load moment, M_s of a bending member shall be less than or equal to the permissible bending stresses, f_{abt}, f_{abc}, respectively, as given herein. The actual bending stresses shall be calculated as:

$$f_{bc} = M_s / Z_{ec} \qquad \text{and} \qquad f_{bt} = M_s / Z_{et}$$

The permissible bending stresses, f_{abc} or f_{abt} shall be the smaller of the values obtained from the following:

a) *Laterally supported beams and beams bending about the minor axis*:

i) Plastic and compact sections:

$$f_{abc} \text{ or } f_{abt} = 0.66 f_y$$

ii) Semi-compact sections:

$$f_{abc} \text{ or } f_{abt} = 0.60 f_y$$

b) *Laterally unsupported beams subjected to major axis bending*:

$$f_{abc} = 0.60\ M_d / Z_{ec}$$
$$f_{abt} = 0.60\ M_d / Z_{et}$$

c) *Plates and solid rectangles bending about minor axis*:

$$f_{abc} = f_{abt} = 0.75 f_y$$

where

Z_{ec}, Z_{et} = elastic section modulus for the cross-section with respect to extreme compression and tension fibres, respectively;

f_y = yield stress of the material; and

M_d = design bending strength of a laterally unsupported beam bent about major axis, calculated in accordance with **14.2.2**.

17.4.2 *Shear Stress in Bending Members*

The actual shear stress, τ_b at working load, V_s of a bending member shall be less than or equal to the permissible shear stress, τ_{ab} given below:

Actual shear stress, $\tau_b = V_s / A_v$

The permissible shear stress is given by:

a) When subjected to pure shear:

$$\tau_{ab} = 0.40 f_y$$

b) When subjected to shear buckling (*see* **14.4.2.1**):

$$\tau_{ab} = 0.70\ V_n / A_v$$

where

V_n = deesign shear strength as given in **14.4.2.2** (a), and

A_v = shear area of the cross-section as given in **14.4.1**.

17.4.3 *Plate Girder*

Provisions of **14.3**, **14.4**, **14.5**, **14.6** and **14.7** shall apply, for the design of plate girder, except that the allowable stresses shall conform to **17.4.1** and **17.4.2.**

17.4.4 *Box Girder*

In design of box girder the provisions of **14.8** shall apply, except that the allowable bending stresses shall conform to **17.4.1**.

17.5 Combined Stresses

17.5.1 *Combined Bending and Shear*

Reduction in allowable moment need not be considered under combined bending and shear.

17.5.2 *Combined Bending and Axial Force*

Members subjected to combined axial compression and bending shall be so proportioned to satisfy the following requirements:

a) *Member stability requirement*:

$$\frac{f_c}{f_{acy}} + 0.6\ K_y \frac{C_{my}\ f_{bcy}}{f_{abcy}} + K_{LT} \frac{f_{bcz}}{f_{abcz}} \le 1.0;$$

$$\frac{f_c}{f_{acz}} + 0.6\ K_y \frac{C_{my}\ f_{bcy}}{f_{abcy}} + K_z \frac{C_{mz} f_{bcz}}{f_{abcz}} \le 1.0$$

where

C_{my}, C_{mz} = equivalent uniform moment factor as per Table 18,

f_c = applied axial compressive stress under service load,

f_{bcy}, f_{bcz} = applied compressive stresses due to bending about the major (y) and minor (z) axis of the member, respectively,

f_{acy}, f_{acz} = allowable axial compressive stress as governed by buckling about minor (y) and major (z) axis, respectively,

f_{abcy}, f_{abcz} = allowable bending compressive stresses due to bending about minor (y) and major (z) axes of the cross-section (*see* **17.4**),

$K_y = 1 + (\lambda_y - 0.2) n_y \le 1 + 0.8\ n_y$,

$K_z = 1 + (\lambda_z - 0.2) n_z \le 1 + 0.8\ n_z$,

$$K_{LT} = 1 - \frac{0.1 \lambda_{LT} n_y}{(C_{mLT} - 0.25)} \ge 1 - \frac{0.1 n_y}{(C_{mLT} - 0.25)},$$

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where

n_y, n_z = ratio of actual applied axial stress to the allowable axial stress for buckling about the y and z axis, respectively,

C_{mLT} = equivalent uniform moment factor; and

λ_{LT} = non-dimensional slenderness ratio (*see* **14.2.2**).

b) *Member strength requirement*:

At a support the values f_{abcy} and f_{abcz} shall be calculated using laterally supported member and shall satisfy:

$$\frac{f_c}{0.6 f_y} + \frac{f_{bcy}}{f_{abcy}} + \frac{f_{bcz}}{f_{abcz}} \leq 1.0$$

17.5.3 *Combined Bending and Axial Tension*

Members subjected to both axial tension and bending shall be proportioned so that the following condition is satisfied:

$$\frac{f_t}{f_{at}} + \frac{f_{bty}}{f_{abty}} + \frac{f_{btz}}{f_{abtz}} \leq 1.0$$

where

f_{abty}, f_{abtz} = permissible tensile stresses under bending about minor (y) and major (z) axis when bending alone is acting, as given in **17.4.1**.

17.5.4 *Combined Bearing, Bending and Shear Stresses*

Where a bearing stress is combined with tensile or compressive stress, bending and shear stresses under the most unfavourable conditions of loading, the equivalent stress, f_e obtained from the following formula, shall not exceed $0.9 f_y$

$$f_e = \sqrt{f_b^2 + f_p^2 + f_b f_p + 3\tau_b^2}$$

where

τ_b = actual shear stress,

f_t = actual tensile stress,

f_b = actual bending stress,

f_y = yield stress, and

f_p = actual bearing stress.

The value of permissible bending stresses f_{bcy} and f_{bcz} to be used in the above formula shall each be lesser of the values of the maximum allowable stresses f_{abc} and f_{abt} in bending about appropriate axis.

17.6 Connections

17.6.1 All design provisions of Section 6(k), except for the actual and permissible stress calculations, shall apply.

17.6.2 *Actual Stresses in Fasteners*

17.6.2.1 Actual stress in bolt in shear, f_{sb} should be less than or equal to permissible stress of the bolt, f_{asb} as given below:

The actual stress in bolt in shear, $f_{sb} = V_{sb} / A_{sb}$

The permissible stress in bolt in shear, $f_{asb} = 0.60\ V_{nsb} / A_{sb}$

where

V_{sb} = actual shear force under working (service) load,

V_{nsb} = nominal shear capacity of the bolt as given in **16.3.3**, and

A_{sb} = nominal plain shank area of the bolt.

17.6.2.2 Actual stress of bolt in bearing on any plate, f_{pb} should be less than or equal to the permissible bearing stress of the bolt/plate, f_{apb} as given below:

Actual stress of bolt in bearing on any plate, $f_{pb} = V_{sb} / A_{pb}$

The permissible bearing stress of the bolt/plate, $f_{apb} = 0.60\ V_{npb} / A_{pb}$

where

V_{npb} = nominal bearing capacity of a bolt on any plate as given in **16.3.4**, and

A_{pb} = nominal bearing area of the bolt on any plate.

17.6.2.3 Actual tensile stress of the bolt, f_{tb} should be less than or equal to permissible tensile stress of the bolt, f_{atb} as given below:

Actual tensile stress of the bolt, $f_{tb} = T_s / A_{sb}$

The permissible tensile stress of the bolt, $f_{atb} = 0.60\ T_{nb} / A_{sb}$

where

T_s = tension in bolt under working (service) load,

T_{nb} = design tensile capacity of a bolt as given in **16.3.5**, and

A_{sb} = nominal plain shank area of the bolt.

17.6.2.4 Actual compressive or tensile or shear stress of a weld, f_w should be less than or equal to permissible stress of the weld, f_{aw} as given below:

The permissible stress of the weld, $f_{aw} = 0.6\, f_{wn}$

where

f_{wn} = nominal shear capacity of the weld as calculated in **16.5.7.1.1**.

17.6.2.5 If the bolt is subjected to combined shear and tension, the actual shear and axial stresses calculated in accordance with **17.6.2.1** and **17.6.2.3** do not exceed

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the respective permissible stresses f_{asb} and f_{atb} and the expression given below should satisfy:

$$\left[\frac{f_{sb}}{f_{asb}}\right]^2 + \left[\frac{f_{tb}}{f_{atb}}\right]^2 \leq 1.0$$

where

f_{sb}, f_{tb} = actual shear and tensile stresses, respectively; and

f_{asb}, f_{atb} = permissible shear and tensile stresses respectively.

17.6.3 *Stresses in Welds*

17.6.3.1 Actual stresses in the throat area of fillet welds shall be less than or equal to permissible stresses, f_{aw}, as given below:

$$f_{aw} = 0.4 f_y$$

17.6.3.2 Actual stresses in the butt welds shall be less than the permissible stress as governed by the parent metal welded together.

SECTION 6(n) DESIGN AND DETAILING FOR EARTHQUAKE LOADS

18 DESIGN AND DETAILING FOR EARTHQUAKE LOADS

18.1 General

Steel frames shall be so designed and detailed as to give them adequate strength, stability and ductility to resist severe earthquakes in all zones classified in **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code without collapse. Ductility requirements in **18.4** to **18.11** and **18.13** need not be satisfied in case of non-ductile frames as defined in **18.12**. Frames, which form a part of the gravity load resisting system but are not intended to resist the lateral earthquake loads, need not satisfy the requirements of this section, provided they can accommodate the resulting deformation without premature failure.

18.2 Load and Load Combinations

18.2.1 Earthquake loads shall be calculated as per **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code, except that the reduction factors recommended in **18.3** may be used.

18.2.2 In the limit state design of frames resisting earthquake loads, the load combinations shall conform to Table 4.

18.2.3 In addition the following load combination shall be considered as required in **18.5.1.1**, **18.7.3.1** and **18.11.2.2**:

a) 1.2 Dead Load (DL)+ 0.5 Imposed Load (IL) ± 2.5 Earthquake Load (EL); and

b) 0.9 Dead Load (DL) ± 2.5 Earthquake Load (EL).

NOTE — The above combinations need to be considered for only the design axial forces of members, ignoring simultaneous bending moments.

18.3 Response Reduction Factor

For structures designed and detailed as per the provision of this section, the response reduction factors specified in Table 23 may be used in conjunction with the provision in **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code for calculating the design earthquake forces.

Table 23 Response Reduction Factor, *R*, for Building System

(*Clause* 18.3)

Sl No. (1)	Lateral Load Resisting System (2)	*R* (3)
i)	Braced frame systems:	
	a) Ordinary concentrically braced frame (OCBF)	4.0
	b) Special concentrically braced frame (SCBF)	4.5
	c) Ordinary eccentrically braced frame (OEBF)	4.5
	d) Special eccentrically braced frame (SEBF)	5.0
ii)	Moment frame system:	
	a) Ordinary moment resisting frame (OMRF)	4.0
	b) Special moment resisting frame (SMRF)	5.0
iii)	Non-ductile frames	1.5

The braced and moment resisting frames can be designed as non-ductile frames, if their overall height to overall width ratio does not exceed 1.0, such as in industrial buildings. Such frames need not meet the ductility requirements of other types of frames as specified in **18.4** to **18.11** and **18.13**.

18.4 Connections, Joints and Fasteners

18.4.1 All bolts used in critical zones of frames designed to resist earthquake loads shall be fully tensioned High Strength Friction Grip (HSFG) bolts or turned and fitted bolts. Critical zones of frames are zones of plastic hinges of moment resisting frames and beam to column as well as bracing end connections of braced frames. The plastic hinge zones shall be taken as a distance equal to 2 times the depth of the member from the section of maximum bending moment.

18.4.2 All weld connections used in the critical zones of frames designed to resist earthquake loads shall be complete penetration butt welds, except in column splices, which shall conform to **18.5.2**.

18.4.3 Bolted joints shall be designed not to share load in combination with welds on the same faying surface.

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18.5 Columns

18.5.1 *Column Strength*

When P_r/P_d is greater than 0.4, the requirements in **18.5.1.1** and **18.5.1.2** shall be met,

where

P_r = required compressive strength of the member as evaluated for load combination in Table 4, and

P_d = design strength in axial compression as obtained from **13.1.2**.

18.5.1.1 The required axial compressive and axial tensile strength, shall be determined from the load combination in **18.2.3**, without considering the simultaneous moments as obtained from the analysis.

18.5.1.2 The required axial strength determined in **18.5.1.1** need not exceed the maximum load transferred to the column considering 1.2 times the design strength of the connecting beam or brace element, or the resistance of the foundation to uplift.

18.5.2 *Splices*

18.5.2.1 A partial-joint penetration groove weld may be provided in axially loaded member splice, such that the design strength of the joints shall be at least equal to 200 percent of the required strength.

18.5.2.2 The minimum required strength for each flange splice shall be 1.2 times f_yA_f as shown in Fig. 20, where A_f is the smaller of the area of each flange in the connected columns, and 1.2 times f_yA_w as minimum required strength in cases where web splices are provided.

18.5.2.3 The bolted column splice shall meet the requirements of **18.4 and 18.5.1**.

18.6 Storey Drift

The storey drift limits shall conform to **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. The deformation compatibility of members not designed to resist seismic lateral load shall also conform to **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

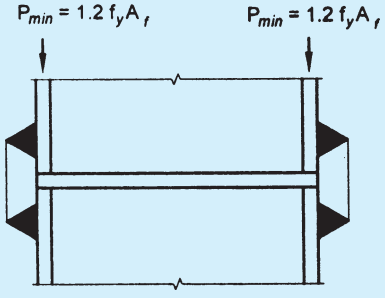


FIG. 20 PARTIAL PENETRATION GROOVE WELD IN COLUMN SPLICE

18.7 Ordinary Concentrically Braced Frames (OCBF)

18.7.1 Ordinary concentrically braced frames (OCBF) should be shown to withstand inelastic deformation corresponding to a joint rotation of at least 0.02 radians without degradation in strength and stiffness below the full yield value. Ordinary concentrically braced frames meeting the requirements of this section shall be deemed to satisfy the required inelastic deformation.

18.7.1.1 Ordinary concentrically braced frames shall not be used in seismic zones IV and V and for buildings with importance factor greater than unity (I >1.0) in Seismic Zone III.

18.7.1.2 The provision in this Section apply for diagonal and X-bracing only. Specialist literature may be consulted for V and inverted V-type bracing. K-bracing shall not be permitted in systems to resist earthquake.

18.7.2 *Bracing Members*

18.7.2.1 The slenderness of bracing members, columns and beams shall not exceed 120.

18.7.2.2 The required compressive strength of bracing member shall not exceed 0.8 times P_d, where P_d is the design strength in axial compression (*see* **13.1.2**)

18.7.2.3 Along any line of bracing, braces at all levels shall be provided such that for lateral loading in either direction, the tension braces will have to resist between 30 and 70 percent of the total floor shear at that level.

18.7.2.4 Bracing cross-section can be plastic, compact or semi-compact, but not slender, as defined in **9.7.2**.

18.7.2.5 For all built-up braces, the spacing of tack fasteners shall be such that the unfavourable slenderness ratio of individual element, between such fasteners, shall not exceed 0.4 times the governing slenderness ratio of the brace itself. Bolted connections shall be avoided within the middle one-fourth of the clear brace length (0.25 times the length in the middle) in such built-up braces.

18.7.2.6 The bracing members shall be designed so that gross area yielding (*see* **12.2)** and not the net area rupture (*see* **12.3)** would govern the design tensile strength.

18.7.3 *Bracing Connections*

18.7.3.1 End connections in bracings shall be designed to withstand the minimum of the following:

a) A tensile force in the bracing equal to $1.2f_yA_g$;

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b) Force in the brace due to load combinations in **18.2.3**; and

c) Maximum force that is transferred to the brace by the system, based on analysis.

18.7.3.2 The connection should be checked for tension rupture and block shear under the load determined in **18.7.3.1**.

18.7.3.3 The connection shall be designed to withstand a moment of 1.2 times the full plastic moment of the braced section about the buckling axis.

18.7.3.4 Gusset plates shall be checked for buckling out of their plane.

18.8 Special Concentrically Braced Frames (SCBF)

18.8.1 Special concentrically braced frames (SCBF) should be shown to withstand inelastic deformation corresponding to a joint rotation of at least 0.04 radians without degradation in strength and stiffness below the full yield value. Special concentrically braced frames meeting the requirements of this Section shall be deemed to satisfy the required inelastic deformation.

18.8.1.1 Special concentrically braced frames (SCBF) may be used in any seismic zone (*see* **5** of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code) and for any building (importance-factor value).

18.8.1.2 The provision in this Section apply for diagonal and X-bracing only. Specialist literature may be consulted for V and inverted-V type bracing. K bracing shall not be permitted in system to resist earthquake.

18.8.2 *Bracing Members*

18.8.2.1 Bracing members shall be made of E250B steel of the accepted standard [6-6(6)] or of steel having Charpy V-notch energy not less than 27 J at the minimum design temperature.

18.8.2.2 The slenderness of bracing members shall not exceed 160 (except for hanger elements, which support only gravity load).

18.8.2.3 The required compressive strength of bracing member shall not exceed the design strength in axial compression P_d (*see* **13.1.2**).

18.8.2.4 Along any line of bracing, braces shall be provided such that for lateral loading in either direction, the tension braces will resist between 30 and 70 percent of the load.

18.8.2.5 Braced cross-section shall be plastic as defined in **9.7.2**.

18.8.2.6 In built-up braces, the spacing of tack connections shall be such that the slenderness ratio of individual element between such connections shall not exceed 0.4 times the governing slenderness ratio of the brace itself. Bolted connection shall be avoided within the middle one-fourth of the clear brace length (0.25 times the length in the middle).

18.8.2.7 The bracing members shall be designed so that gross area yielding (*see* **12.2**) and not the net area rupture (*see* **12.3**) would govern the design tensile strength.

18.8.3 *Bracing Connections*

18.8.3.1 Bracing end connections shall be designed to withstand the minimum of the following:

a) A tensile force in the bracing equal to $1.1 f_y A_g$; and

b) Maximum force that can be transferred to the brace by the system.

18.8.3.2 The connection should be checked for tension rupture and block shear under the load determined in **18.8.3.1**.

18.8.3.3 The connection shall be designed to withstand a moment of 1.2 times the full plastic moment of the braced section about the critical buckling axis.

18.8.3.4 Gusset plates shall be checked for buckling out of their plane.

18.8.4 *Column*

18.8.4.1 The column sections used in special concentrically braced frames (SCBF) shall be plastic as defined in **9.7.2**.

18.8.4.2 Splices shall be located within the middle one-third of the column clear height. Splices shall be designed for the forces that can be transferred to it. In addition, splices in columns shall be designed to develop at least the nominal shear strength of the smaller connected member and 50 percent of the nominal flexural strength of the smaller connected section.

18.9 Eccentrically Braced Frames (EBF)

Eccentrically braced frames (EBF) shall be designed in accordance with specialist literature.

18.10 Ordinary Moment Resisting Frames (OMRF)

18.10.1 Ordinary moment resisting frames (OMRF) should be shown to withstand inelastic deformation corresponding to a joint rotation of 0.02 radians without degradation in strength and stiffness below the full yield value (M_p). Ordinary moment resisting frames meeting the requirements of this section shall be deemed to satisfy the required inelastic deformation.

18.10.1.1 Ordinary moment resisting frames (OMRF)

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shall not be used in Seismic Zones IV and V and for buildings with importance factor greater than unity (I >1.0) in Seismic Zone III.

18.10.2 *Beam-to-Column Joints and Connections*

Connections are permitted to be rigid or semi-rigid moment connections and should satisfy the criteria in **18.10.2.1** to **18.10.2.5**.

18.10.2.1 Rigid moment connections should be designed to withstand a moment of at least 1.2 times of either the full plastic moment of the connected beam or the maximum moment that can be delivered by the beam to the joint due to the induced weakness at the ends of the beam, whichever is less.

18.10.2.2 Semi-rigid connections should be designed to withstand either a moment of at least 0.5 times the full plastic moment of the connected beam or the maximum moment that can be delivered by the system, whichever is less. The design moment shall be achieved within a rotation of 0.01 radians. The information given in Annex E may be used for checking.

18.10.2.3 The stiffness and strength of semi-rigid connections shall be accounted for in the design and the overall stability of the frame shall be ensured.

18.10.2.4 The rigid and semi-rigid connections should be designed to withstand a shear resulting from the load combination 1.2DL + 0.5IL plus the shear corresponding to the design moment defined in **18.10.2.1** and **18.10.2.2**, respectively.

18.10.2.5 In rigid fully welded connections, continuity plates [for tension stiffeners, *see* **14.7.1.1**(f)] of thickness equal to or greater than the thickness of the beam flange shall be provided and welded to the column flanges and web.

18.11 Special Moment Resisting Frames (SMRF)

18.11.1 Special moment resisting frames (SMRF) shall be made of E250B steel of the accepted standard [6-6(6)] or of steel having Charpy V-notch energy, E > 27J and should be shown to withstand inelastic deformation corresponding to a joint rotation of 0.04 radian without degradation in strength and stiffness below the full yield value (M_p). Special moment resisting frames meeting the requirements of this Section shall be deemed to satisfy the required inelastic deformation.

18.11.1.1 Special moment resisting frames (SMRF) may be used in any seismic zone (*see* 5 of Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code) and for any buildings (importance-factor values).

18.11.2 *Beam-to-column Joints and Connections*

18.11.2.1 All beam-to-column connections shall be rigid (*see* Annex E) and designed to withstand a moment of at least 1.2 times the full plastic moment of the connected beam. When a reduced beam section is used in the plastic hinge zone, its minimum flexural strength shall be at least equal to 0.8 times the full plastic moment of the unreduced section.

18.11.2.2 The connection shall be designed to withstand a shear resulting from the load combination 1.2DL + 0.5IL plus the shear resulting from the application of $1.2M_p$ in the same direction, at each end of the beam (causing double curvature bending). The shear strength need not exceed the required value corresponding to the load combination in **18.2.3**.

18.11.2.3 In column strong axis connections (beam and column web in the same plane), the panel zone shall be checked for shear buckling in accordance with **14.4.2** at the design shear defined in **18.11.2.2**. Column web doubler plates or diagonal stiffeners may be used to strengthen the web against shear buckling.

18.11.2.4 The individual thickness of the column webs and doubler plates, shall satisfy the following:

$$t > (d_p + b_p) / 90$$

where

t = thickness of column web or doubler plate,

d_p = panel-zone depth between continuity plates (*see* Fig. 21), and

b_p = panel-zone width between column flanges.

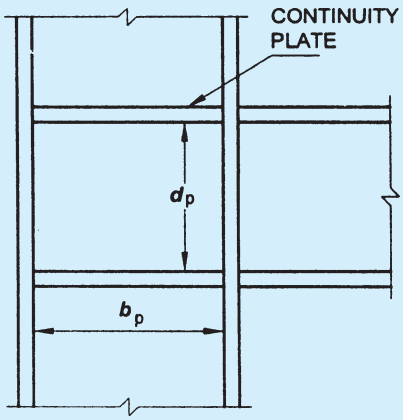


FIG. 21 CONTINUITY PLATES

18.11.2.5 Continuity plates (tension stiffener) (*see* **14.7**) shall be provided in all strong axis welded connections except in end plate connection.

18.11.3 *Beam and Column Limitation*

18.11.3.1 Beam and column sections shall be either plastic or compact as defined in **9.7.2**. At potential plastic hinge locations, they shall necessarily be plastic.

18.11.3.2 The section selected for beams and columns

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shall satisfy the following relation:

$$\frac{\sum M_{pc}}{\sum M_{pb}} \geq 1.2$$

where

ΣM_{pc} = sum of the moment capacity in the column above and below the beam centreline; and

ΣM_{pb} = sum of the moment capacity in the beams at the intersection of the beam and column centrelines.

In tall buildings, higher mode effects shall be accounted for in accordance with specialist literature.

18.11.3.3 Lateral support to the column in a direction perpendicular to the web of the beam shall be provided at both top and bottom beam flange levels so as to resist at least 2 percent of the beam flange strength, except for the case described in **18.11.3.4**.

18.11.3.4 A plane frame designed as non-sway in the direction perpendicular to its plane, shall be checked for buckling, under the load combination as specified in **18.5.1.1**.

18.12 Non-Ductile Braced and Moment Resisting Frames

Frames which do not meet the ductility requirements of the **18.4** to **18.11** and **18.13** and designed as per the response reduction factor for non-ductile frames specified in Table 23 shall be classified as non-ductile frames. These frames shall have height to span ratio not exceeding 1.0, such as in industrial buildings.

18.13 Column Base Connections

18.13.1 Fixed column bases and their anchor bolts should be designed to withstand a moment of 1.2 times the full plastic moment capacity of the column section. The anchor bolts shall be designed to withstand the combined action of shear and tension under the above moment and shear as well as prying action, if any.

18.13.2 Both fixed and hinged column base connections shall be designed to withstand higher value of (a) the full shear under any load case, and (b) 1.2 times the shear capacity of the column section.

SECTION 6(p) FATIGUE

19 FATIGUE

19.1 General

Structure and structural elements subject to loading that could lead to fatigue failure shall be designed against fatigue as given in this section. This shall however not cover the following:

a) Corrosion fatigue,
b) Low cycle (high stress) fatigue,
c) Thermal fatigue,
d) Stress corrosion cracking,
e) Effects of high temperature (> 150°C), and
f) Effects of low temperature (< brittle transition temperature).

19.1.1 For the purpose of design against fatigue, different details (of members and connections) are classified under different fatigue class. The design stress range corresponding to various number of cycles, are given for each fatigue class. The requirements of this Section shall be satisfied with, at each critical location of the structure subjected to cyclic loading, considering relevant number of cycles and magnitudes of stress range expected to be experienced during the life of the structure.

19.2 Design

19.2.1 *Reference Design Condition*

The standard S-N curves for each detail category are given for the following conditions:

a) Detail is located in a redundant load path, wherein local failure at that detail alone will not lead to overall collapse of the structure.
b) Nominal stress history at the local point in the detail is estimated/evaluated by a conventional method without taking into account the local stress concentration effects due to the detail.
c) Load cycles are not highly irregular.
d) Details are accessible for and subject to regular inspection.
e) Structure is exposed to only mildly corrosive environment as in normal atmospheric condition and suitably protected against corrosion (pit depth <1 mm).
f) Structure is not subjected to temperature exceeding 150 °C.
g) Transverse fillet or butt weld connects plates of thickness not greater than 25 mm.

19.2.1.1 *Thickness correction factor*

The values obtained from the standard S-N curve shall be modified by a capacity reduction factor μ_r, when plates greater than 25 mm in thickness are joined together by transverse fillet or butt welding, given by:

$$\mu_r = (25/t_p)^{0.25} \leq 1.0$$

where

t_p = actual thickness of the thicker plate being joined, in mm.

No thickness correction is necessary when full

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penetration butt weld reinforcements are machined flush and proved free of defect through non-destructive testing.

19.2.1.2 *Necessity for fatigue assessment*

a) Fatigue assessment is not normally required for building structures except as follows:
   1) Members supporting lifting or rolling loads,
   2) Member subjected to repeated stress cycles from vibrating machinery,
   3) Members subjected to wind induced oscillations of a large number of cycles in life, and
   4) Members subjected to crowd induced oscillations of a large number of cycles in life.

b) No fatigue assessment is necessary, if the following conditions are satisfied.
   1) The highest normal stress range $f_{f\,max}$ satisfies:
   $$f_{fmax} \leq 27\ \mu_r/\gamma_{mft}$$
   2) The highest shear stress range τ_{fmax} satisfies:
   $$\tau_{fmax} \leq 67\ \mu_r/\gamma_{mft}$$
   3) The total number of actual stress cycles N_{SC}, satisfies:
   $$N_{SC} \leq 5\times10^6\left(\frac{27\mu_r}{\gamma_{mft} f_{feq}}\right)^3$$

where

f_{feq} = equivalent constant amplitude stress range, in MPa, given by:

$$f_{feq} = \left[\frac{\sum_{i=1}^{r_5} n_i f_i^3 + \sum_{j=r_5}^{r} n_j f_j^5}{n}\right]^{1/3}$$

where

$$n = \sum_{i=1}^{r} n_i$$

f_i, f_j = stress ranges falling above and below the f_{fn}, the stress range corresponding to the detail at 5×10^6 number of life cycles.

r_5 = summation upper limit of all the normal stress ranges (fi) having magnitude lesser than ($\mu_r f_{fn} \gamma_{mft}$) for that detail and the lower limit of all the normal stress ranges (f_j) having magnitude greater than ($\mu_r f_{fn} \gamma_{mft}$) for that detail.

19.2.2 *Design Spectrum*

19.2.2.1 *Stress evaluation*

Design stress shall be determined by elastic analysis of the structure to obtain stress resultants and the local stresses may be obtained by a conventional stress analysis method. The normal and shear stresses shall be determined considering all design actions on the members, but excluding stress concentration due to the geometry of the detail. The stress concentration effect is accounted for in detail category classification (*see* Table 26). The stress concentration, however, not characteristic of the detail shall be accounted for separately in the stress calculation.

In the fatigue design of trusses made of members with open sections, in which the end connections are not pinned, the stresses due to secondary bending moments shall be taken into account, unless the slenderness ratio (KL/r), of the member is greater than 40.

In the determination of stress range at the end connections between hollow sections, the effect of connection stiffness and eccentricities may be disregarded, provided,

a) the calculated stress range is multiplied by appropriate factor given in Table 24(a) in the case of circular hollow section connections and Table 24(b) in the case of rectangular hollow section connections.
b) the design throat thickness of fillet welds in the joints is greater than the wall thickness of the connected member.

19.2.2.2 *Design stress spectrum*

In the case of loading events producing non-uniform stress range cycle, the stress spectrum may be obtained by a rational method, such as 'rain flow counting' or an equivalent method.

Table 24(a) Multiplying Factors for Calculated Stress Range (Circular Hollow Sections)

(*Clause* 19.2.2.1)

Sl No.	Type of Connection		Chords	Verticals	Diagonals
(1)	(2)		(3)	(4)	(5)
i)	Gap connections	K type	1.5	1.0	1.3
		N type	1.5	1.8	1.4
ii)	Overlap connections	K type	1.5	1.0	1.2
		N type	1.5	1.65	1.25

Table 24(b) Multiplying Factors for Calculated Stress Range (Rectangular Hollow Sections)

(*Clause* 19.2.2.1)

Sl No.	Types of Joint		Chords	Verticals	Diagonals
(1)	(2)		(3)	(4)	(5)
i)	Gap connections	K type	1.5	1.0	1.5
		N type	1.5	2.2	1.6
ii)	Overlap connections	K type	1.5	1.0	1.3
		N type	1.5	2.0	1.4

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19.2.3 *Partial Safety Factors*

19.2.3.1 *Partial safety factor for actions and their effects* (γ_{fft})

Unless and otherwise the uncertainty in the estimation of the applied actions and their effects demand a higher value, the partial safety factor for loads in the evaluation of stress range in fatigue design shall be taken as 1.0.

19.2.3.2 *Partial safety factor for fatigue strength* (γ_{mft})

Partial safety factor for strength is influenced by consequences of fatigue damage and level of inspection capabilities.

19.2.3.3 Based on consequences of fatigue failure, component details have been classified as given in the Table 25 and the corresponding partial safety factor for fatigue strength shall be used:

a) Failsafe structural component/detail is the one where local failure of one component due to fatigue crack does not result in the failure of the structure due to availability of alternate load path (redundant system).

b) Non-failsafe structural component/detail is the one where local failure of one component leads rapidly to failure of the structure due to its non-redundant nature.

Table 25 Partial Safety Factors for Fatigue Strength (γ_{mft})

(*Clause* 19.2.3.3)

Sl No.	Inspection and Access	Consequence of Failure	
		Failsafe	Non-Failsafe
(1)	(2)	(3)	(4)
i)	Periodic inspection, maintenance and accessibility to detail is good	1.00	1.25
ii)	Periodic inspection, maintenance and accessibility to detail is poor	1.15	1.35

19.3 Detail Category

Tables 26(a) to (d) indicate the classification of different details into various categories for the purpose of assessing fatigue strength. Details not classified in the table may be treated as the lowest detail category of a similar detail, unless superior fatigue strength is proved by testing and/or analysis.

Holes in members and connections subjected to fatigue loading shall not be made,

a) using punching in plates having thickness greater than 12 mm unless he holes are sub-punched and subsequently reamed to remove the affected material around the punched hole; and

b) using gas cutting unless the holes are reamed to remove the material in the heat affected zone.

19.4 Fatigue Strength

The fatigue strength of the standard detail for the normal or shear fatigue stress range, not corrected for thickness effects discussed in **19.4.1**, is given below (*see also* Fig. 22 and Fig. 23):

a) Normal stress range:

1) when $N_{SC} \le 5 \times 10^6$

$$f_f = f_{fn} \sqrt[3]{5\times10^6 / N_{SC}}$$

2) when $5\times10^6 \le N_{SC} \le 10^8$

$$f_f = f_{fn} \sqrt[5]{5\times10^6 / N_{SC}}$$

b) Shear stress:

$$\tau_f = \tau_{fn} \sqrt[5]{5\times10^6 / N_{SC}}$$

where

f_f, τ_f = design normal and shear fatigue stress range of the detail, respectively, for life cycle of N_{SC} , and

f_{fn}, τ_{fn} = normal and shear fatigue strength of the detail for 5×10^6 cycles, for the detail category (*see* Table 26).

19.5 Fatigue Assessment

19.5.1 The design fatigue strength for N_{SC} life cycles (f_{fd}, t_{fd}) may be obtained from the standard fatigue strength for N_{SC} cycles by multiplying with correction factor, m_r, for thickness, as mentioned in **19.2.1** and dividing by partial safety factor given in Table 25.

19.5.2 *Stress Limitations*

19.5.2.1 The maximum (absolute) value of the normal and shear stresses shall never exceed the elastic limit (f_y, τ_y) for the material under cyclic loading.

19.5.2.2 The maximum stress range shall not exceed $1.5 f_y$ for normal stresses and $1.5 f_y \sqrt{3}$ for the shear stresses under any circumstance.

19.5.2.3 *Constant stress range*

The actual normal and shear stress range f and t at a point of the structure subjected to N_{SC} cycles in life shall satisfy:

$$f \le f_{fd} = \mu_r f_f / \gamma_{mft}$$

$$\tau \le \tau_{fd} = \mu_r \tau_f / \gamma_{mft}$$

where

μ_r = correction factor (*see* **19.2.1**),

γ_{mf} = partial safety factor against fatigue failure, given in Table 25, and

f_f , τ_f = normal and shear fatigue strength ranges for the actual life cycle, N_{SC}, obtained from **19.4**.

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19.5.2.4 *Variable stress range*

Fatigue assessment at any point in a structure, wherein variable stress ranges f_i or τ_i for n_i number of cycles (i =1 to r) are encountered, shall satisfy the following:

a) For normal stress (f):

$$\frac{\sum_{i=1}^{r_5} n_i f_i^3}{5\times10^6\left(\mu_r f_{fn}/\gamma_{mft}\right)^3}+\frac{\sum_{j=r_5}^{r} n_j f_j^5}{5\times10^6\left(\mu_r f_{fn}/\gamma_{mft}\right)^5}\le 1.0$$

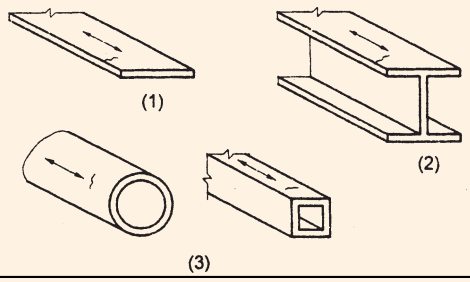
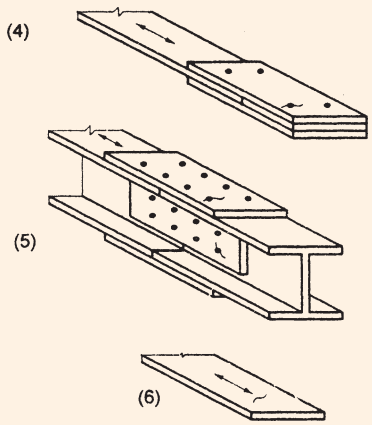
b) For shear stresses (t):

$$\sum_{i=1}^{r_5} n_i \tau_i^5 \le 5\times10^6\left(\mu\tau_{fn}/\gamma_{mft}\right)^5$$

Where r_5 is the summation upper limit of all the normal stress ranges (f_i) having magnitude lesser than ($\mu_r f_{fn}/\gamma_{mft}$) for that detail and the lower limit of all the normal stress ranges (f_j) having magnitude greater than ($\mu_r f_{fn}/\gamma_{mft}$) for the detail. In the above summation all normal stress ranges, f_i, and shear stress ranges τ_i having magnitude less than $0.55\mu_r f_{fn}$, and $0.55\mu_r\tau_{fn}$, respectively may be disregarded.

Table 26(a) Detail Category Classification, Group 1 Non-Welded Details (f_{fn})

(*Clause* 19.3)

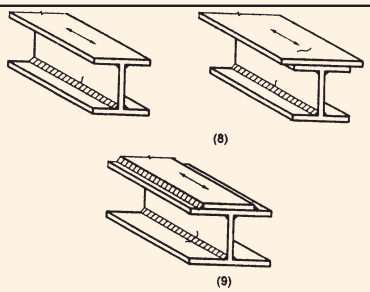
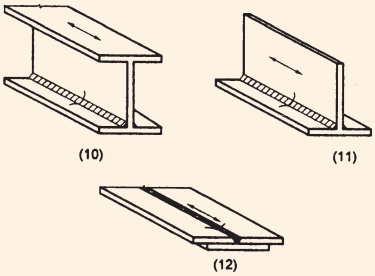
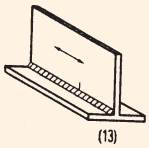
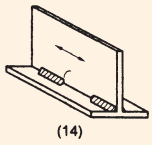
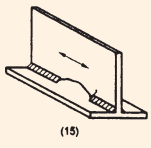
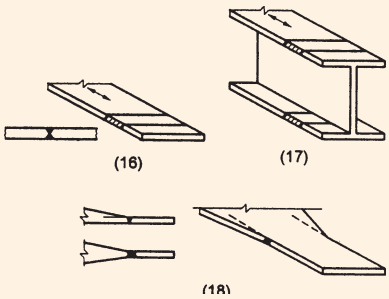
Sl No. (1)	Detail Category (2)	Constructional Details	
		Illustration (*see* Note) (3)	Description (4)
i)	118		**Rolled and extruded products:`** a) Plates and flats (1) b) Rolled sections (2) c) Seamless tubes (3) Sharp edges, surface and rolling flaws to be removed by grinding in the direction of applied stress
ii)	103		**(a) Bolted connections:** (4) and (5): Stress range calculated on the gross section and on the net section Unsupported one-sided cover plate connections shall be avoided or the effect of the eccentricity taken into account in calculating stresses **(b) Material with gas-cut or sheared edges with no draglines:** (6): All hardened material and visible signs of edge discontinuities to be removed by machining or grinding in the direction of applied stress
iii)	92		**Material with machine gas-cut edges with draglines or manual gas-cut material:** (7) Corners and visible signs of edge discontinuities to be removed by grinding in the direction of the applied stress

NOTE — The arrow indicates the location and direction of the stresses acting in the basic material for which the stress range is to be calculated on a plane normal to the arrow.

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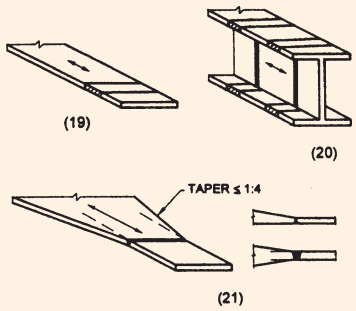
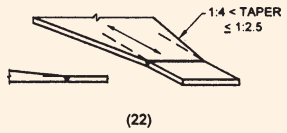
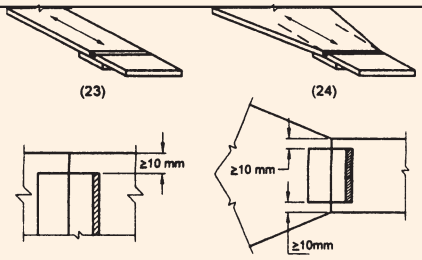
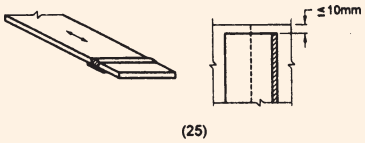
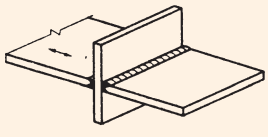
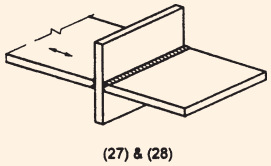
Table 26(b) Detail Category Classification, Group 2 Welded Details — Not in Hollow Sections (f_{fn})

(*Clause* 19.3)

Sl No.	Detail Category	Constructional Details	
		Illustration (*see* Note)	Description
i)	92		**Welded plate I-section and box girders with continuous longitudinal welds:** (8) and (9): Zones of continuous automatic longitudinal fillet or butt welds carried out from both sides and all welds not having un-repaired stop-start positions
ii)	83		**Welded plate I-section and box girders with continuous longitudinal welds:** (10) and (11): Zones of continuous automatic butt welds made from one side only with a continuous backing bar and all welds not having un-repaired stop-start positions (12): Zones of continuous longitudinal fillet or butt welds carried out from both sides but containing stop-start positions. For continuous manual longitudinal fillet or butt welds carried out from both sides, use Detail Category 92
iii)	66		**Welded plate I-section and box girders with continuous longitudinal welds:** (13): Zones of continuous longitudinal welds carried out from one side only, with or without stop-start positions
iv)	59		**Intermittent longitudinal welds:** (14): Zones of intermittent longitudinal welds
v)	52		**Intermittent longitudinal welds:** (15): Zones containing cope holes in longitudinally welded T-joints. Cope hole not to be filled with weld
vi)	83		**Transverse butt welds (complete penetration):** Weld run-off tabs to be used, subsequently removed and ends of welds ground flush in the direction of stress. Welds to be made from two sides (16): Transverse splices in plates, flats and rolled sections having the weld reinforcement ground flush to plate surface. 100 percent NDT inspection, and weld surface to be free of exposed porosity in the weld metal (17): Plate girders welded as in (16) before assembly (18): Transverse splices as in (16) with reduced or tapered transition with taper ≤ 1:4

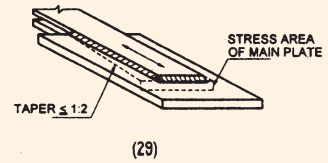
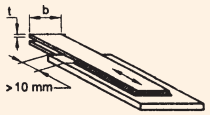
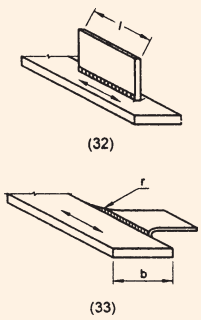
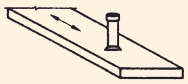
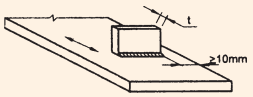
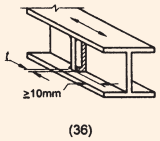
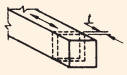
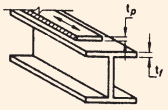
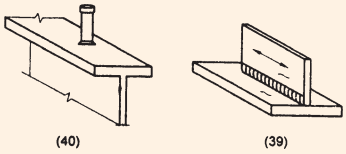
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Table 26(b) — (*Continued*)

Sl No.	Detail Category		Constructional Details	
			Illustration (*see* Note)	Description
(1)	(2)		(3)	(4)
vii)	66			**Transverse butt welds (complete penetration):** Welds run-off tabs to be used, subsequently removed and ends of welds ground flush in the direction of stress. Welds to be made from two sides (19): Transverse splices of plates, rolled sections or plate girders (20): Transverse splice of rolled sections or welded plate girders, without cope hole. With cope hole use Detail Category 52, as in (15) (21): Transverse splices in plates or flats being tapered in width or in thickness where the taper is ≤ 1:4
viii)	59			**Transverse butt welds (complete penetration):** Weld run-off tabs to be used, subsequently removed and ends of welds ground flush in the direction of stress. Welds to be made from two sides (22): Transverse splices as in (21) with taper in width or thickness >1:4 but ≤ 1:2.5
ix)	52			**Transverse butt welds (complete penetration):** (23): Transverse butt-welded splices made on a backing bar. The end of the fillet weld of the backing strip shall stop short by more than 10 mm from the edges of the stressed plate (24): Transverse butt welds as per (23) with taper on width or thickness <1:2.5
x)	37			**Transverse butt welds (complete penetration):** (25): Transverse butt welds as in (23) where fillet welds end closer than 10 mm to plate edge
xi)	52			**Cruciform joints with load-carrying welds:** (26): Full penetration welds with intermediate plate NDT inspected and free of defects. Maximum misalignment of plates either side of joint to be < 0.15 times the thickness of intermediate plate
xii)	41	(27)		(27): Partial penetration or fillet welds with stress range calculated on plate area (28): Partial penetration or fillet welds with stress range calculated on throat area of weld
	27	(28)		

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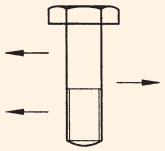
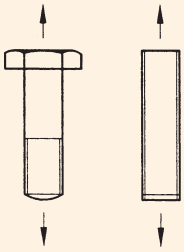
Table 26(b) — (*Concluded*)

Sl No.	Detail Category		Constructional Details		
			Illustration (*see* Note)		Description
(1)	(2)		(3)		(4)
xiii)	46			 (29)	**Overlapped welded joints:** (29): Fillet welded lap joint, with welds and overlapping elements having a design capacity greater than the main plate. Stress in the main plate to be calculated on the basis of area shown in the illustration
xiv)	41	(30)		 (30) & (31)	**Overlapped weld joints:** (30): Fillet welded lap joint, with welds and main plate both having a design capacity greater than the overlapping elements
xv)	33	(31)			(31): Fillet welded lap joint, with main plate and overlapping elements both having a design capacity greater than the weld
xvi)	66		(32)	(33)	**Welded attachments (non-load carrying welds) – Longitudinal welds:** (32): Longitudinal fillet welds. Class of detail varies according to the length of the attachment weld as noted (33): Gusset welded to the edge of a plate or beam flange. Smooth transition radius (r), formed by machining or flame cutting plus grinding. Class of detail varies according to r/b ratio as noted
			—	$1/3 \le r/b$	
	59		$l \le 50$mm	—	
	52		$50 < l \le 100$mm	$1/6 \le r/b < 1/3$	
	37		100 mm < l	—	
	33		—	$r/b < 1/6$	
				 (32) (33)	
xvii)	59			 (34)	**Welded attachments:** (34): Shear connectors on base material (failure in base material)
xviii)	59		$t \le 12$mm	 (35)	**Transverse welds:** (35): Transverse fillet welds with the end of the weld ≥10 mm from the edge of the plate (36): Vertical stiffeners welded to a beam or plate girder flange or web by continuous or intermittent welds. In the case of webs carrying combined bending and shear design actions, the fatigue strength shall be determined using the stress range of the principal stresses (37): Diaphragms of box girders welded to the flange or web by continuous or intermittent welds
	52		t > 12mm	 (36)  (37)	
xix)	37		t_f or t_p ≤25mm	 (38)	**Cover plates in beams and plate girders:** (38): End zones of single or multiple welded cover plates, with or without a weld across the end. For a reinforcing plate wider than the flange, an end weld is essential
	27		t_f or t_p >25 mm		
xx)	67			 (40) (39)	**Welds loaded in shear:** (39): Fillet welds transmitting shear. Stress range to be calculated on weld throat area (40): Stud welded shear connectors (failure in the weld) loaded in shear (the shear stress range to be calculated on the nominal section of the stud)
NOTE — The arrow indicates the location and direction of the stresses acting in the basic material for which the stress range is to be calculated on a plane normal to the arrow.					

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Table 26(c) Detail Category Classification, Group 3 Bolts

(*Clause* 19.3)

Sl No.	Detail Category	Constructional Details	
		Illustration (*see* Note)	Description
(1)	(2)	(3)	(4)
i)	83	 (41)	**Bolts in shear (8.8/TB Bolting category only):** (41): Shear stress range calculated on the minor diameter area of the bolt (A_c) NOTE – If the shear on the joint is insufficient to cause slip of the joint the shear in the bolt need not be considered in fatigue
ii)	27	 (42)	**Bolts and threaded rods in tension (tensile stress to be calculated on the tensile stress area, A_t):** (42): Additional forces due to prying effects shall be taken into account. For tensional bolts, the stress range depends on the connection geometry NOTE – In connections with tensioned bolts, the change in the force in the bolts is often less than the applied force, but this effect is dependent on the geometry of the connection. It is not normally required that any allowance for fatigue be made in calculating the required number of bolts in such connections
NOTE – The arrow indicates the location and direction of the stresses acting in the basic material for which the stress range is to be calculated on a plane normal to the arrow.			

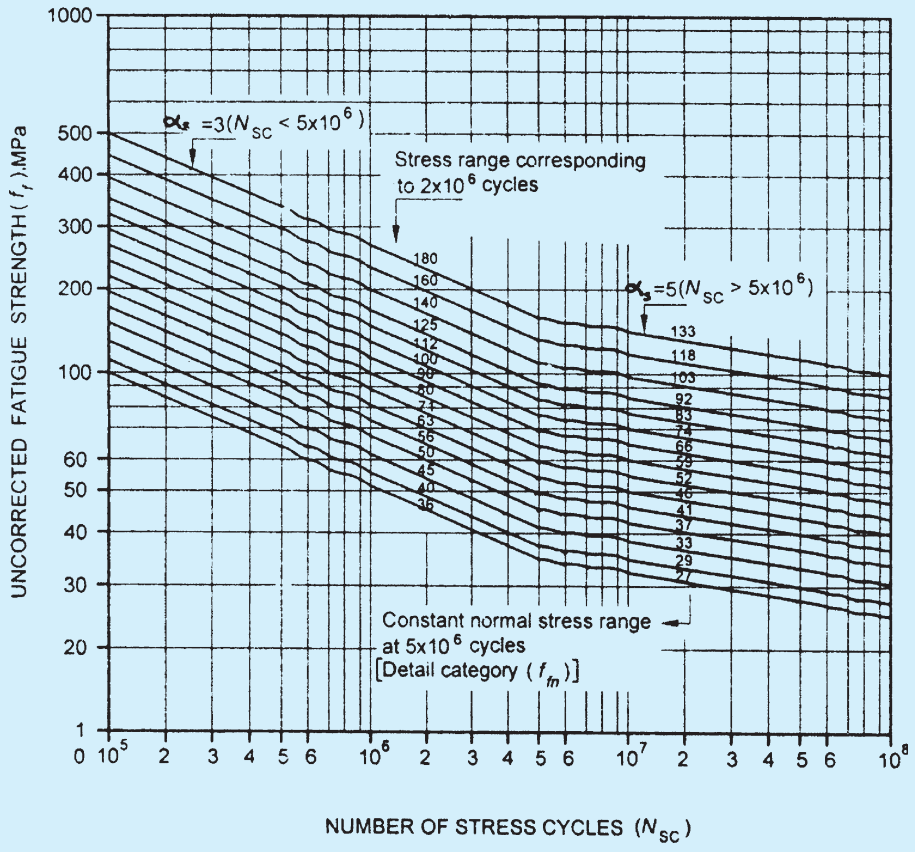
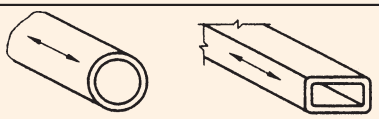
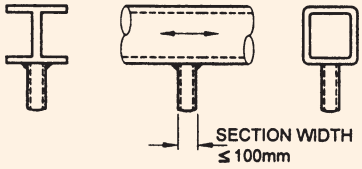


FIG. 22 *S-N* CURVE FOR NORMAL STRESS

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Table 26(d) Detail Category Classification, Group 4 Welded Details – In Hollow Sections (f_{fn})

(*Clause* 19.3)

Sl No.	Detail Category	Constructional Details	
		Illustration (*see* Note)	Description
(1)	(2)	(3)	(4)
i)	103	 (43)	**Continuous automatic longitudinal welds:** (43): No stop-starts, or as manufactured, proven free to detachable discontinuities.
ii)	66 ($t \geq 8$ mm) 52 ($t < 8$ mm)	 (44)	**Transverse butt welds:** (44): Butt-welded end-to-end connection of circular hollow sections NOTE — Height of the weld reinforcement less than 10 percent of weld with smooth transition to the plate surface. Welds made in flat position and proven free to detachable discontinuities)
iii)	52 ($t \geq 8$ mm) 41 ($t < 8$ mm)	 (45)	(45): Butt-welded end-to-end connection of rectangular hollow sections
iv)	41 ($t \geq 8$ mm) 37 ($t < 8$ mm)	 (46)	**Butt welds to intermediate plate:** (46): Circular hollow sections, end-to-end butt-welded with an intermediate plate
v)	37 ($t \geq 8$ mm) 30 ($t < 8$ mm)	 (47)	(47): Rectangular hollow sections, end-to-end butt welded with an intermediate plate
vi)	52	 (48)	**Welded attachments (non-load-carrying):** (48): Circular or rectangular hollow section, fillet welded to another section. Section width parallel to stress direction ≤ 100 mm
vii)	33 ($t < 8$ mm) 29 ($t < 8$ mm)	 (49)	**Fillet welds to intermediate plate** (49): Circular hollow sections, end-to-end fillet welded with an intermediate plate
viii)	29 ($t \geq 8$ mm) 27 ($t < 8$ mm)	 (50)	(50): Rectangular hollow sections, end-to-end fillet welded with an intermediate plate

NOTE The arrow indicates the location and direction of the stresses acting in the basic material for which the stress range is to be calculated on a plane normal to the arrow.

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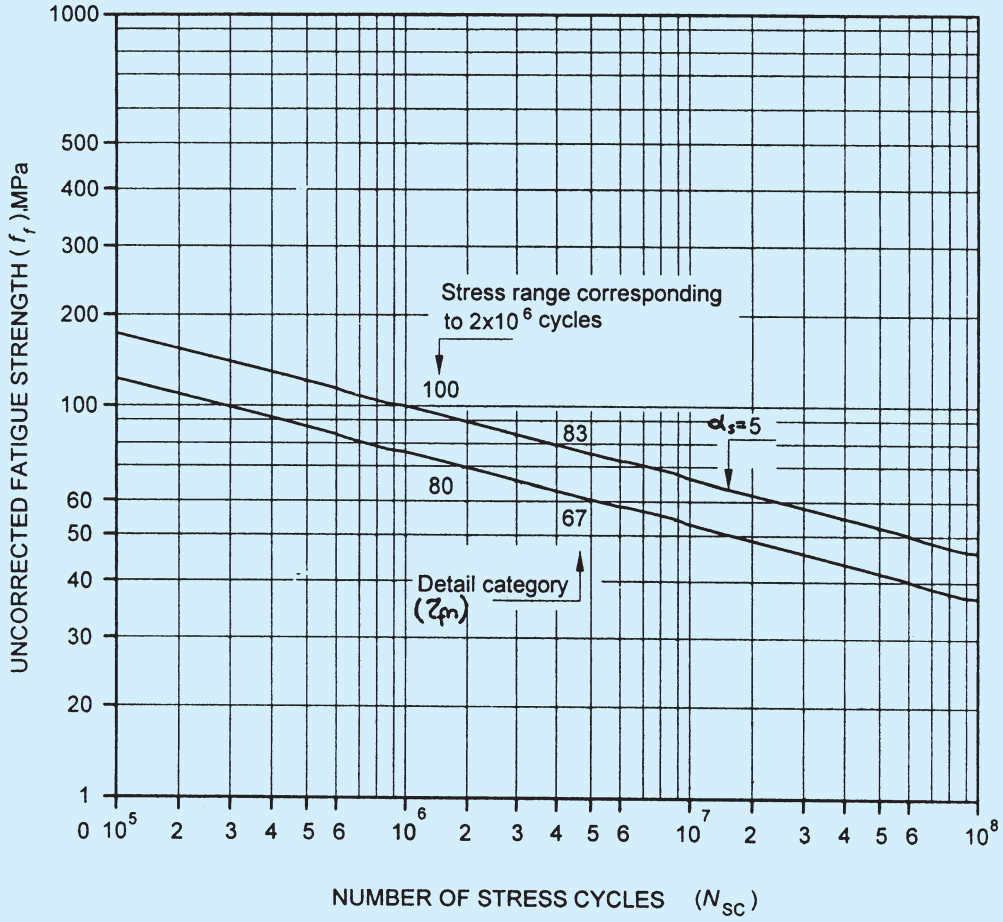


FIG. 23 *S-N* CURVE FOR SHEAR STRESS

SECTION 6(q) DESIGN ASSISTED BY TESTING

20 DESIGN ASSISTED BY TESTING

20.1 Need for Testing

Testing of structures, members or components of structures is not required when designed in accordance with this standard. Testing may be accepted as an alternative to calculations or may become necessary in special circumstances.

Testing of a structural system, member or component may be required to assist the design in the following cases:

a) When the calculation methods available are not adequate for the design of a particular structure, member or component, testing shall be undertaken in place of design by calculation or to supplement the design by calculation;

b) Where rules or methods for design by calculation would lead to uneconomical design, experimental verification may be undertaken to avoid conservative design;

c) When the design or construction is not entirely in accordance with sections of this standard, experimental verification is recommended;

d) When confirmation is required on the consistency of production of material, components, members or structures originally designed by calculations or testing;

e) When the actual performance of an existing structure capacity is in question, testing shall be used to confirm it.

20.1.1 Testing of structural system, member or component shall be of the following categories:

a) *Proof testing* — The application of test loads to a structure, sub-structure, member or connection to ascertain the structural characteristics of only that specific unit.

b) *Prototype testing* — Testing of structures, sub-structures, members or connections is done to ascertain the structural characteristics of a class of such structures, sub-structures members or connection, which are nominally identical to the units tested.

20.2 Types of Test

20.2.1 *Acceptance Test*

This is intended as a non-destructive test for confirming structural performance. It should be recognized that

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the loading applied to certain structures might cause permanent distortions. Such effects do not necessarily indicate structural failure in acceptance test. However, the possibility of their occurrence should be agreed to before testing.

The load for acceptance test, $F_{test,a}$ shall be determined from:

$F_{test,a}$ = (Self weight) + (1.15 × Remainder of the permanent load) + (1.25 × Variable load)

The assembly shall satisfy the following criteria:

a) It shall demonstrate substantially linear behaviour under test loading; and

b) On removal of the test load, the residual deflection shall not exceed 20 percent of the maximum-recorded deflection.

If the above criteria are not satisfied the test may be repeated one more time only, when the assembly shall satisfy the following criteria:

1) It shall demonstrate substantially linear behaviour on the second application of test loading, and

2) Corresponding recorded residual deflection in the second test shall not exceed 10 percent of the maximum deflection during the test.

20.2.2 *Strength Test*

Strength test is used to confirm the calculated resistance of a structure or component. Where a number of items are to be constructed to a common design, and one or more prototypes are tested to confirm their strength, the others may be accepted without any additional test, provided they are similar in all relevant respects to the prototype.

Before carrying out the strength test, the specimen should first be subjected to and satisfy the acceptance test. Since the resistance of the assembly under test depends on the material properties, the actual yield strength of all the steel materials in the assembly shall be determined from coupon {test piece as defined in the accepted standard [6-6(7)]} tests. The mean value of the yield strength, $f_{ym,}$ taken from such tests shall be determined with due regard to the importance of each element in the assembly. The strength test load $F_{test,\ s}$ (including self weight) shall be determined from:

$$F_{test,s} = \gamma_{mi} F_d \left(f_{ym} / f_y \right)$$

where

f_y = characteristic yield stress of the material as assumed in the design;

F_d = factored design load for the ultimate limit state; and

γ_{mi} = partial safety factor for the type of failure, as prescribed in this standard.

At this load there shall be no failure by buckling or rupture of any part of the structure or component tested. On removal of the test load, the deflection should decrease by at least 20 percent of the maximum deflection at $F_{test,s}$.

20.2.3 *Test to Failure (Ultimate Strength Test)*

The objective of a test to failure is to determine the design resistance from the ultimate resistance. In this situation it is still desirable to carry out the acceptance and strength tests, before test to failure.

Not less than three tests shall be carried out on nominally identical specimens. An estimate should be made of the anticipated ultimate resistance as a basis for such tests. During a test to failure, the loading shall first be applied in increments up to the strength test load. Subsequent load increments shall then be determined from consideration of the principal load deflection plot. The test load resistance, $F_{test.R}$ shall be determined as that load at which the specimen is unable to sustain any further increase in load. At this load, gross permanent distortion is likely to have occurred and in some cases such large gross deformation may define the test limit. If the deviation of any individual test result exceeds 10 percent of the mean value obtained for all the three tests, at least three more tests shall be carried out. When the deviation from the mean does not exceed 10 percent of the mean, the design resistance may be evaluated as given below:

a) When the failure is ductile, the design resistance, F_d may be determined from:

$$F_d = 0.9 F_{test,\ Min} (f_y / f_{ym}) / \gamma_{m0}$$

where

$F_{test,\ Min}$ = minimum test result from the tests to failure,

f_{ym} = average yield strength as obtained from the material tests, and

f_y = characteristic yield stress of the grade of steel.

b) In the case of a sudden (brittle) rupture type failure, the design resistance may be determined from:

$$F_d = 0.9 F_{test,\ Min} (f_u / f_{um}) / \gamma_{m1}$$

where

f_u = characteristic ultimate stress of the grade of steel used, and

f_{um} = average ultimate tensile strength of the material obtained from tests.

c) In the case of a sudden (brittle) buckling type failure, the design resistance shall be determined from:

$$F_d = 0.75 F_{test,\ Min} (f_y / f_{ym}) / \gamma_{m0}$$

d) In ductile buckling type failure in which the relevant slenderness λ can be reliably assessed, the design resistance may be determined from:

$$F_d = 0.9 F_{test,Min} \left[(\chi f_y / \chi_m f_{ym}) / \gamma_{m0} \right]$$

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where

χ = reduction factor for the relevant buckling curve, and

χ_m = value of χ when the yield strength is f_{ym}.

20.2.4 *Check Tests*

Where a component or assembly is designed on the basis of strength tests or tests to failure and a production run is carried out of such items, an appropriate number of samples (not less than two) shall be selected from each production batch at random for check tests.

20.2.4.1 The samples shall be carefully examined to ensure that they are similar in all respects to the prototype tested, particular attention being given to the following:

a) Dimensions of components and connections,

b) Tolerance and workmanship, and

c) Quality of steel used, checked with reference to mill test certificates.

20.2.4.2 Where it is not possible to determine either the variations or the effect of variations from the prototype, an acceptance test shall be carried out as a check test.

20.2.4.3 In this check test, the deflections shall be measured at the same positions as in the acceptance test of the prototype. The maximum measured deflection shall not exceed 120 percent of the deflection recorded during the acceptance test on the prototype and the residual deflection should not be more than 105 percent of that recorded for the prototype.

20.3 Test Conditions

a) Loading and measuring devices shall be calibrated in advance.

b) The design of the test rig shall be such that:

1) Loading system adequately simulates the magnitude and distribution of the loading,

2) It allows the specimen to perform in a manner representative of service conditions,

3) Lateral and torsional restraint, if any, should be representative of those in service,

4) Specimen should be free to deflect under load according to service condition,

5) Loading system shall be able to follow the movements of the specimen without interruption or abnormal restraints,

6) Inadvertent eccentricities at the point of application of the test loads and at the supports are avoided.

c) Test load shall be applied to the unit at a rate as uniform as practicable.

d) Deflections should be measured at sufficient points of high movements to ensure that the maximum value is determined.

e) If the magnitude of stresses in a specimen is to be determined, the strain at the desired location may be measured and the corresponding stress calculated.

f) Prior to any test, preliminary loading (not exceeding the characteristic values of the relevant loads) may be applied and then removed, in order to set the test specimen on to the test rig.

20.4 Test Loading

20.4.1 Where the self-weight of the specimen is not representative of the actual permanent load in service, allowance for the difference shall be made in the calculation of test loads to be applied.

20.4.2 On the attainment of maximum load for either acceptance or strength tests, this load shall be maintained for at least 1 h. Reading of load and deflection shall be taken at intervals of 15 min and the loading shall be maintained constant until there is no significant increase in deflection during a 15 min period or until at least 1 h has elapsed.

20.4.3 The test load shall be equal to the design load for the relevant limit state in proof testing.

20.4.4 The test load in prototype testing shall be equal to the design load for the relevant limit state as multiplied by the appropriate factor given in Table 27.

20.5 Criteria for Acceptance

20.5.1 *Acceptance for Strength*

The test structure, sub-structure, member or connection shall be deemed to comply with the requirements for strength if it is able to sustain the strength test load for at least 15 min.

It shall then be inspected to determine the nature and extent of any damage incurred during the test. The effects of the damage shall be considered and if necessary appropriate repairs to the damaged parts carried out.

20.5.2 *Acceptance for Serviceability*

The maximum deformation of the structure or member under the serviceability limit state test load shall be within the serviceability limit values appropriate to the structure.

Table 27 Factors to Allow for Variability of Structural Units

(*Clause* 20.4.4)

Sl No.	No. of Similar Units to be Tested	For Strength Limit State	For Serviceability Limit State
(1)	(2)	(3)	(4)
i)	1	1.5	1.2
ii)	2	1.4	1.2
iii)	3	1.3	1.2
iv)	4	1.3	1.1
v)	5	1.3	1.1
vi)	10	1.2	1.1

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SECTION 6(r) DURABILITY

21 DURABILITY

21.1 General

A durable steel structure is one that performs satisfactorily the desired function in the working environment under the anticipated exposure condition during its service life, without deterioration of the cross-sectional area and loss of strength due to corrosion.

The material used, the detailing, fabrication, erection and surface protection measures should all address the corrosion protection and durability requirements.

21.2 Requirements for Durability

21.2.1 *Shape, Size, Orientation of Members, Connections and Details*

The design, fabrication and erection details of exposed structures should be such that good drainage of water is ensured. Standing pool of water, moisture accumulation and rundown of water for extended duration shall be avoided.

The details of connections should ensure that,

a) all exposed surfaces are easily accessible for inspection and maintenance; and

b) all surfaces, not so easily accessible are completely sealed against ingress of moisture.

21.2.2 *Exposure Condition*

21.2.2.1 *General environment*

The general environment, to which a steel structure is exposed during its working life is classified into five levels of severity, as given in Table 28.

21.2.2.2 *Abrasion*

Specialist literature may be referred for durability of surfaces exposed to abrasive action as in machinery, conveyor belt support system, storage bins for grains or aggregates.

21.2.2.3 *Exposure to sulphate attack*

Appropriate coatings may be used when surfaces of structural steel are exposed to concentration of sulphates (SO_3) in soil, ground water, etc.

When exposed to very high sulphate concentrations of more than 2 percent in soil and 5 percent in water, some form of lining such as polyethylene, polychloroprene sheet or surface coating based on asphalt, chlorinated rubber, epoxy or polymethane material should be used to completely avoid access of the solution to the steel surface.

Table 28 Environmental Exposure Conditions

(*Clause* 21.2.2.1)

Sl No. (1)	Environmental Classifications (2)	Exposure Conditions (3)
i)	Mild	Surfaces normally protected against exposure to weather or aggressive condition as in interior of buildings, except when located in coastal areas
ii)	Moderate	Structural steel surfaces: a) Exposed to condensation and rain b) Continuously under water c) Exposed to non-aggressive soil/ groundwater d) Sheltered from saturated salt air in coastal areas
iii)	Severe	Structural steel surfaces: a) Exposed to severe frequent rain b) Exposed to alternate wetting and drying c) Severe condensation d) Completely immersed in sea water e) Exposed to saturated salt air in coastal area
iv)	Very severe	Structural steel surface exposed to: a) Sea water spray b) Corrosive fumes c) Aggressive sub-soil or ground water
v)	Extreme	Structural steel surfaces exposed to: a) Tidal zones and splash zones in the sea b) Aggressive liquid or solid chemicals

21.2.3 *Corrosion Protection Methods*

The methods of corrosion protection are governed by actual environmental conditions as specified in good practices [6-6(40)]. The main corrosion protection methods are given below:

a) Controlling the electrode potential,
b) Inhibitors, and
c) Inorganic/metal coatings or organic/paint systems.

21.2.4 *Surface Protection*

21.2.4.1 In the case of mild exposure, a coat of primer after removal of any loose mill scale may be adequate. As the exposure condition becomes more critical, more elaborate surface preparations and coatings become necessary. In case of extreme environmental classification, protection shall be as per specialist literature. Table 29 gives guidance to protection of steelwork for different desired lives.

21.2.4.2 Steel surfaces shall be provided with at least one coat of primer immediately after its surface preparation, such as by sand blasting to remove all mill scale and rust and to expose the steel.

21.2.4.3 Steel without protective coating shall not be stored for long duration in outdoor environment.

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21.2.4.4 Surfaces to transfer forces by friction as in HSFG connections shall not be painted. However, it shall be ensured that moisture is not trapped on such surfaces after pre-tensioning of bolts by proper protective measures.

Table 29(a) Protection Guide for Steel Work Application – Desired Life of Coating System in Different Environments

(*Clause* 21.2.4.1)

Sl No.	Atmospheric Condition/ Environmental Classification	Coating System					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Normal inland (rural and urban areas), mild	12 years	18 years	20 years	About 20 years	About 20 years	Above 20 years
ii)	Polluted inland (high airborne sulphur dioxide), moderate	10 years	15 years	12 years	About 18 years	15 - 20 years	Above 20 years
iii)	Normal coastal (as normal inland plus high airborne salt levels), severe	10 years	12 years	20 years	About 20 years	About 20 years	Above 20 years
iv)	Polluted coastal (as polluted inland plus high airborne salt levels), very severe or extreme	8 years	10 years	10 years	About 15 years	15 - 20 years	Above 20 years

21.2.4.5 Members to be assembled by welding shall not be pre-painted at regions adjacent to the location of such welds. However, after welding, appropriate protective coatings shall be applied in the region, as required by the exposure conditions. If the contact surfaces cannot be properly protected against ingress of moisture by surface coating, they may be completely sealed by appropriate welds.

21.2.4.6 Pre-painted members shall be protected against abrasion of the coating during transportation, handling and erection.

21.2.5 *Special Steels*

Steels with special alloying elements and production process to obtain better corrosion resistance may be used as per specialist literature.

SECTION 6(s) FIRE RESISTANCE

22 FIRE RESISTANCE

22.1 Requirements

The requirements shall apply to steel building elements designed to exhibit a required fire-resistance level (FRL) as per the relevant specifications. The provisions of this section are quite rudimentary and simplistic. Specialist literature for design of steel structures for fire resistance and design based on testing may be necessary for a more comprehensive design of steel buildings to resist fire.

22.1.1 For protected steel members and connections, the thickness of protection material (h_i) shall be greater than or equal to that required to give a period of structural adequacy (PSA) greater than or equal to the required FRL.

Table 29(b) (i) Protection Guide for Steel Work Application — Specification for Different Coating System (Shop Applied Treatments)

(*Clause* 21.2.4.1)

Sl No.	Protection	Coating System					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Surface preparation	Blast clean	Blast clean	Blast clean	Blast clean	Girt blast	Blast clean
ii)	Pre-fabrication primer	Zinc phosphate epoxy, 20 μm	2 pack zinc-rich epoxy, 20 μm	–	2 pack zinc-rich epoxy, 20 μm	–	Ethyl zinc silicate, 20 μm
iii)	Post fabrication primer	High-build zinc phosphate modified alkyd, 60 μm	2 pack zinc-rich epoxy, 20 μm	Hot dip galvanized, 85 μm	2 pack zinc-rich epoxy, 25 μm	Sprayed zinc or sprayed aluminium	Ethyl zinc silicate, 60 μm
iv)	Intermediate coat	–	High-build zinc phosphate 25 μm	—	2 pack epoxy micaceous iron oxide	Sealer	Chlorinated rubber alkyd, 35 μm
v)	Top coat	–	–	—	2 pack epoxy micaceous iron oxide, 85 μm	Sealer	–

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Table 29(b) (ii) Protection Guide for Steel Work Application – Specification for Different Coating System (Site Applied Treatments)

(*Clause* 21.2.4.1)

Sl No.	Protection	Coating System					
		1	2	3	4	5	6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Surface preparation	As necessary	As necessary	No site treatment	As necessary	No site treatment	As necessary
ii)	Primer	Touch in	Touch in	–	–	–	Touch in
iii)	Intermediate coat	–	Modified Alkyd Micaceous iron oxide, 50 µm	–	Touch In	–	High-build micaceous iron oxide Chlorinated rubber Micaceous, 75 µm
iv)	Top coat	High-build Alkyd finish, 60µm	Modified Alkyd Micaceous iron oxide, 50 µm	–	High-build chlorinated rubber	–	High-build iron oxide Chlorinated rubber, 75 µm

22.1.2 For unprotected steel members and connections, the exposed surface area to mass ratio (k_{sm}) shall be less than or equal to that required to give a PSA equal to the required FRL.

22.2 Fire Resistance Level

The required FRL shall be as prescribed in Part 4 'Fire and Life Safety' of the Code as appropriate or in building specifications or as required by the user or the city ordinance. The FRL specified in terms of the duration (in min) of standard fire load without collapse depends upon;

a) the purpose for which structure is used; and

b) the time taken to evacuate in case of fire.

22.3 Period of Structural Adequacy (PSA)

22.3.1 The calculation of PSA involves:

a) Calculation of the strength of the element as a function of temperature of the element and the determination of limiting temperature;

b) Calculation of the thermal response of the element, that is calculation of the variation of the temperature of the element or the parts of the element with time, when exposed to fire; and

c) Determination of PSA at which the temperature of the element or parts of the element reaches the limiting temperature.

22.3.2 *Determination of Period of Structural Adequacy*

The period of structural adequacy (PSA) shall be determined using one of the following methods:

a) *By calculation:*

1) determining the limiting temperature of the steel (T_l) in accordance with **22.5**; and

2) determining the PSA as the time (t) (in min) from the start of the test to the time at which the limiting steel temperature is attained, in accordance with **22.6** for protected members and **22.7** for unprotected members.

b) By direct application of a single test in accordance with **22.8**; or

c) By calculation of the temperature of the steel member by using a rational method of analysis confirmed by test data or by methods available in specialist literature.

22.4 Variation of Mechanical Properties of Steel with Temperature

22.4.1 *Variation of Yield Stress with Temperature*

The influence of temperature on the yield stress of steel shall be taken as follows for structures of mild steels and high strength low alloy steels:

$$\frac{f_y(T)}{f_y(20)} = \frac{905 - T}{690} \leq 1.0$$

where,

$f_y(T)$ = yield stress of steel at T °C,

$f_y(20)$ = yield stress of steel at 20°C (room temperature), and

T = temperature of the steel, in °C.

This relationship is shown by Curve 1 in Fig. 24.

For temperature less than 215°C no reduction in the yield stress need to be considered.

22.4.2 *Variation of Modulus of Elasticity with Temperature*

The influence of temperature on the modulus of

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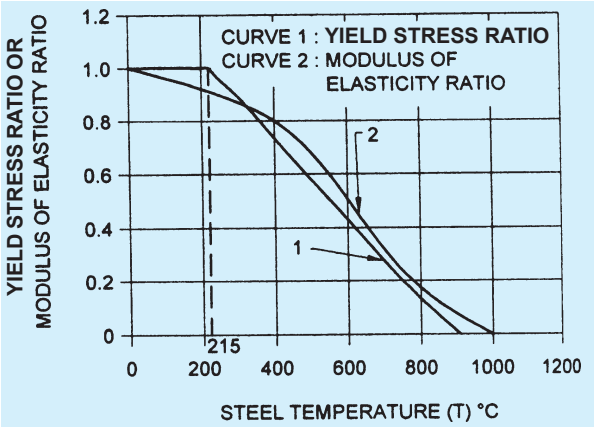


FIG. 24 VARIATION OF MECHANICAL PROPERTIES OF STEEL WITH TEMPERATURE

elasticity shall be taken as follows for structures of mild steels and high strength low alloy steels:

$$\frac{E(T)}{E(20)} = 1.0 + \left[\frac{T}{2\,000\left[\ln\left(\frac{T}{1\,100}\right)\right]}\right]$$

when $0°C < T \leq 600°C$

$$= \frac{690\left(1 - \frac{T}{1\,000}\right)}{T - 53.5} \text{ when } 600°C < T \leq 1\,000°C$$

where

$E(T)$ = modulus of elasticity of steel at T°C, and

$E(20)$ = modulus of elasticity of steel at 20°C (room temperature).

This relationship is shown by Curve 2 in Fig. 24.

22.4.3 For special steel with higher temperature resistance, such as TMCP steels, the manufacturer's recommendation shall be used to obtain the variation of yield strength and modulus of elasticity of steel with temperature.

22.5 Limiting Steel Temperature

The limiting steel temperature (T_l), in °C, in the case of ordinary steels, shall be calculated as follows:

$$T_l = 905 - 690\, r_f$$

where

r_f = ratio of the design action on the member under fire to the design capacity of the member ($R_d = R_u/\gamma_m$) at room temperature;

R_d, R_u = design strength and ultimate strength of the member at room temperature, respectively; and

γ_m = partial safety factor for strength.

The design action under fire shall consider the following:

a) Reduced bond likely under fire, and

b) Effects of restraint to expansion of the elements during fire.

Limiting steel temperature for special steels may be appropriately calculated using the thermal characteristics of the material obtained from the supplier of the steel.

22.6 Temperature Increase with Time in Protected Members

22.6.1 The time (t) at which the limiting temperature (T_l) is attained shall be determined by calculation on the basis of a suitable series of fire tests in accordance with **22.6.2** or from the results of a single test in accordance with **22.6.3**.

22.6.1.1 For beams and for all members with a four-sided fire exposure condition, the limiting temperature (T_l) shall be taken as the average of all of the temperatures measured at the thermocouple locations on all sides.

22.6.1.2 For columns with a three-sided fire exposure condition, the limiting temperature (T_l) shall be taken as the average of the temperatures measured at the thermocouple locations on the face farthest from the wall. Alternatively, the temperatures from members with a four-sided fire exposure condition and having the same surface area to mass ratio may be used.

22.6.2 *Temperature Based on Test Series*

Calculation of the variation of steel temperature with time shall be by interpolation of the results of a series of fire tests using the regression analysis equation specified in **22.6.2.1**, subject to the limitations and conditions of **22.6.2.3**.

22.6.2.1 *Regression analysis*

The relationship between temperature (T) and time (t) for a series of tests on a group shall be calculated by least-square regression as follows:

$$t = k_0 + k_1 h_i + k_2\left(\frac{h_i}{k_{sm}}\right) + k_3 T + k_4 h_i T + k_5\left(\frac{h_i T}{k_{sm}}\right) + k_6\left(\frac{T}{k_{sm}}\right)$$

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where

t = time from the start of the test, in min;

k_0 to k_6 = regression coefficients from test data (*see* **22.6.2.2**);

h_i = thickness of fire protection material, in mm;

T = steel temperature, in °C obtained from test as given in **22.6.1**, $T > 250$°C; and

k_{sm} = exposed surface area to mass ratio, in 10^3 mm^2/kg.

22.6.2.2 *In-lieu* of test results, the values for coefficients in Table 30 may be used in the equation **22.6.2.1** when the test satisfies the conditions specified in **22.6.2.3**.

Table 30 Regression Coefficients, *k*

(*Clause* 22.6.2.2)

k_0 (1)	k_1 (2)	k_2 (3)	k_3 (4)	k_4 (5)	k_5 (6)	k_6 (7)
–25.90	1.698	–13.71	0.030 0	0.000 5	0.514 4	6.633

22.6.2.3 *Limitations and conditions on use of regression analysis*

Test data to be utilized in accordance with **22.6.2.1,** shall satisfy the following:

a) Steel members shall be protected with board, sprayed blanket or similar insulation materials having a dry density less than 1 000 kg/m^3;
b) All tests shall incorporate the same fire protection system;
c) All members shall have the same fire exposure condition;
d) Test series shall include at least nine tests;
e) Test series may include prototypes which have not been loaded provided that stickability has been demonstrated; and
f) All members subject to a three-sided fire exposure condition shall be within a group in accordance with **22.9**.

The regression equation obtained for one fire protection system may be applied to another system using the same fire protection material and the same fire exposure condition provided that stickability has been demonstrated for the second system.

A regression equation obtained using prototypes with a four-sided fire exposure condition may be applied to a member with a three-sided fire exposure condition provided that stickability has been demonstrated for the three-sided case.

22.6.3 *Temperature Based on Single Test*

The variation of steel temperature with time measured in a standard fire test may be used without modification provided:

a) Fire protection system is the same as the prototype;
b) Fire exposure condition is the same as the prototype;
c) Fire protection material thickness is equal to or greater than that of the prototype;
d) Surface area to mass ratio is equal to or less than that of the prototype; and
e) Where the prototype has been submitted to a standard fire test in an unloaded condition, stickability has been separately demonstrated.

22.6.4 *Parameters of Importance in the Standard Fire Test*

a) Specimen type, loading, configuration,
b) Exposed surface area to mass ratio,
c) Insulation type, thermal properties and thickness, and
d) Moisture content of the insulation material.

22.7 Temperature Increase with Time in Unprotected Members

The time (t) at which the limiting temperature (T_l) is attained shall be calculated using the following equations:

a) Three-sided fire exposure condition

$$t = 5.2 + 0.022\,1\,T + \left(\frac{0.433T_l}{k_{sm}}\right)$$

b) Four-sided fire exposure condition

$$t = 4.7 + 0.026\,3\,T + \left(\frac{0.213T_l}{k_{sm}}\right)$$

where

t = time from the start of the test, in min;

T = steel temperature, in °C, 500°C ≤ T ≤ 750°C, and

k_{sm} = exposed surface area to mass ratio, 2×10^3 mm^2/kg ≤ k_{sm} ≤ 35×10^3 mm^2/kg.

For temperatures below 500°C, linear interpolation shall be used, based on the time at 500°C and an initial temperature of 20°C at t equals 0.

22.8 Determination of PSA from a Single Test

The period of structural adequacy (PSA) determined from a single test may be applied without modification provided:

a) Conditions, specified in **22.6.3** are satisfied,
b) Conditions of support are the same as the

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prototype and the restraints are not less favourable than those of the prototype, and

c) Ratio of the design load for fire to the design capacity of the member is less than or equal to that of the prototype.

22.9 Three-Sided Fire Exposure Condition

Members subject to a three-sided fire exposure condition shall be considered in separate groups unless the following conditions are satisfied:

a) The characteristics of the members of a group as given below, shall not vary from one another by more than:

1) Concrete density:

$$\left(\frac{\text{highest in group}}{\text{lowest in group}}\right) \leq 1.25, \text{ and}$$

2) Effective < thickness < (h_e):

$$\left(\frac{\text{largest in group}}{\text{smallest in group}}\right) \leq 1.25$$

where the effective thickness (h_e) is equal to the cross-sectional area excluding voids per unit width, as shown in Fig. 25A.

b) Rib voids shall either be:

1) all open; or

2) all blocked as shown in Fig. 25B.

c) Concrete slabs may incorporate permanent steel deck formwork.

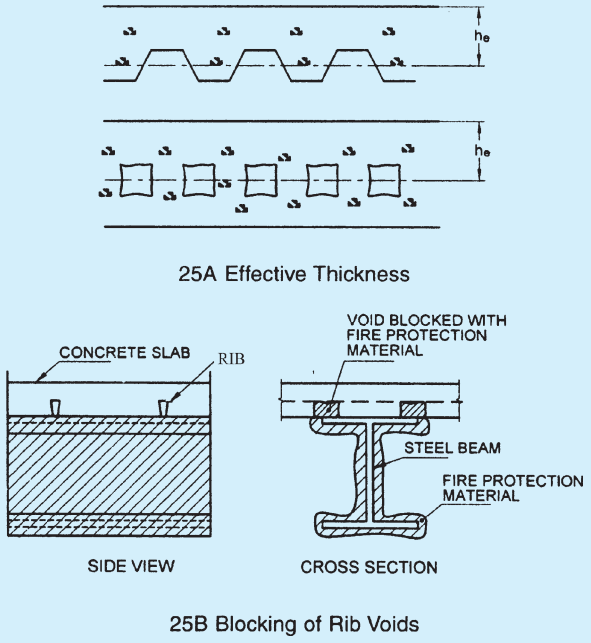


FIG. 25 THREE SIDED FIRE EXPOSURE CONDITION REQUIREMENTS

22.10 Special Considerations

22.10.1 *Connections*

Connections shall be protected with the maximum thickness of fire protection material required for any of the members framing into the connection to achieve their respective fire-resistance levels. This thickness shall be maintained over all connection components, including bolt heads, welds and splice plates.

22.10.2 *Web Penetrations*

The thickness of fire protection material at and adjacent to web penetrations shall be the greatest of that required, when:

a) area above the penetration is considered as a three-sided fire exposure condition (k_{sm1}) (*see* Fig. 26);

b) area below the penetration is considered as a four-sided fire exposure condition (k_{sm2}) (*see* Fig. 26); and

c) section as a whole is considered as a three-sided fire exposure condition (k_{sm}) (*see* Fig. 26).

This thickness shall be applied over the full beam depth and shall extend on each side of the penetration for a distance at least equal to the beam depth and not less than 300 mm.

22.11 Fire Resistance Rating

The fire resistance rating of various building components such as walls, columns, beams, and floors are given in Table 31 and Table 32. Fire damage assessment of various structural elements of the

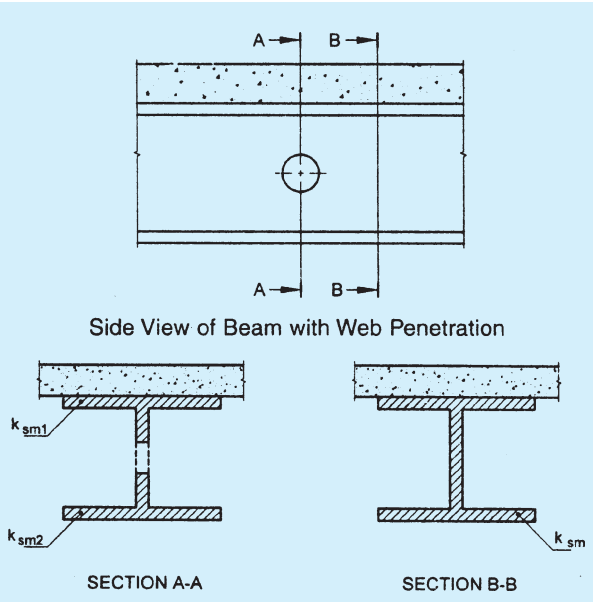


FIG. 26 WEB PENETRATION

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Table 31 Encased Steel Columns, 203 mm × 203 mm (Protection Applied on Four Sides)

(*Clause* 22.11)

Sl No.	Nature of Construction and Materials	Minimum Dimensions (in mm), Excluding Any Finish, for a Fire Resistance of				
		1 h	1 ½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Hollow protection (without an air cavity over the flanges):					
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster [1)]	13	15	20	32	—
	b) Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster less than the thickness specified:					
	1) 9.5 mm plaster board	10	15	—	—	—
	2) 19 mm plaster board	10	13	20	—	—
	c) Asbestos insulating boards, thickness of board:					
	1) Single thickness of board, with 6 mm cover fillets at transverse joints	—	19	25	—	—
	2) Two layers, of total thickness	—	—	—	38	50
	d) Solid bricks of clay, composition or sand lime, reinforced in every horizontal joint, unplastered	50	50	50	75	100
	e) Aerated concrete blocks	60	60	60	—	—
	f) Solid blocks of lightweight concrete hollow protection (with an air cavity over the flanges)	50	50	50	60	75
ii)	Asbestos insulating board screwed to 25 mm asbestos battens	12	19	—	—	—
iii)	Solid protections:					
	a) Concrete, not leaner than 1:2:4 mix (unplastered):					
	1) Concrete not assumed to be load bearing, reinforced [2)]	25	25	25	50	75
	2) Concrete assumed to be load bearing	50	50	50	75	75
	b) Lightweight concrete, not leaner than 1:2: 4 mix (unplastered) concrete not assumed to be load bearing, reinforced [2)]	25	25	25	25	25

[1)] So fixed or designed, as to allow full penetration for mechanical bond.

[2)] Reinforcement shall consist of steel binding wire not less than 2.3 mm diameter, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.

building and adequacy of the structural repairs can be done by the fire resistance rating for encased steel column and beam (*see* Table 31 and Table 32).

SECTION 6(t) FABRICATION AND ERECTION

23 FABRICATION AND ERECTION

23.1 General

Tolerances for fabrication of steel structures shall conform to the accepted standard [6-6(41)]. Tolerances for erection of steel structures shall conform to the accepted standard [6-6(42)]. For general guidance on fabrication by welding, reference may be made to good practice [6-6(43)].

23.2 Fabrication Procedures

23.2.1 *Straightening*

Material shall be straightened or formed to the specified configuration by methods that will not reduce the properties of the material below the values used in design. Local application of pressure at room or at elevated temperature or other thermal means may be used for straightening, provided the above is satisfied.

23.2.2 *Clearances*

The erection clearance for cleated ends of members, connecting steel to steel should preferably be not greater than 2.0 mm at each end. The erection clearance at ends of beams without web cleats should be not more than 3 mm at each end. Where for practical reasons, greater clearance is necessary, suitably designed seating should be provided.

23.2.2.1 The holes for bolts may be made as given in Table 19, unless otherwise specified by the engineer. The hole diameter in base plates shall not exceed the anchor bolt diameter by more than 6 mm.

23.2.2.2 In friction type of connection clearance may be maintained, unless specified otherwise in the design document.

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Table 32 Encased Steel Beams, 406 mm × 176 mm (Protection Applied on Three Sides)

(*Clause* 22.11)

Sl No.	Nature of Construction and Materials	Minimum Thickness (in mm) of Protection for a Fire Resistance of					
		½ h	1 h	1½ h	2 h	3 h	4 h
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Hollow protection (without an air cavity beneath the lower flanges):						
	a) Metal lathing with trowelled lightweight aggregate gypsum plaster [1)]	13	13	15	20	25	—
	b) Plasterboard with 1.6 mm wire binding at 100 mm pitch, finished with lightweight aggregate gypsum plaster less than the thickness specified [2)]:						
	1) 9.5 mm plaster board	10	10	15	—	—	—
	2) 19 mm plaster board	10	10	13	20	—	—
	c) Asbestos insulating boards, thickness of board:						
	1) Single thickness of board, with 6 mm cover fillets at transverse joints	—	—	19	25	—	—
	2) Two layers, of total thickness	—	—	—	—	38	50
ii)	Hollow protection (with an air cavity below the lower flange):						
	Asbestos insulating board screwed to 25 mm asbestos battens	9	12	—	—	—	—
iii)	Solid protections:						
	a) Concrete, not leaner than 1:2:4 mix (unplastered):						
	1) Concrete not assumed to be load bearing, reinforced [3)]	25	25	25	25	50	75
	2) Concrete assumed to be load bearing	50	50	50	50	75	75
	b) Lightweight concrete, not leaner than 1:2:4 mix (unplastered) [4)]	25	25	25	25	40	60

[1)] So fixed or designed, as to allow full penetration for mechanical bond.
[2)] Where wire binding cannot be used, expert advice should be sought regarding alternative methods of support to enable the lower edges of the plasterboard to be fixed together and to the lower flange, and for the top edge of the plasterboard to be held in position.
[3)] Reinforcement shall consist of steel binding wire not less than 2.3 mm in diameter, or a steel mesh weighing not less than 0.5 kg/m^2. In concrete protection, the spacing of that reinforcement shall not exceed 200 mm in any direction.
[4)] Concrete not assumed to be load bearing, reinforced.

23.2.3 *Cutting*

Cutting shall be effected by sawing, shearing, cropping, machining or thermal cutting process. Shearing, cropping and gas cutting shall be clean, reasonably square, and free from any distortion. Should the inspector find it necessary, the edges shall be ground after cutting. Planning or finishing of sheared or gas-cut edges of plates or shapes shall not be required, unless specially noted on drawing or included in stipulated edge preparation for welding or when specifically required in the following section.

Re-entrant corners shall be free from notches and shall have largest practical radii with a minimum radius of 15 mm.

23.2.3.1 *Shearing*

Shearing of items over 16 mm thick to be galvanized and subject to tensile force or bending moment shall not be carried out, unless the item is stress relieved subsequently.

The use of sheared edges in the tension area shall be avoided in location subject to plastic hinge rotation at factored loading.

23.2.3.2 *Thermal cutting*

Gas cutting of high tensile steel by mechanically controlled torch may be permitted, provided special care is taken to leave sufficient metal to be removed by machining, so that all metal that has been hardened by flame is removed. Hand flame cutting may be permitted only subject to the approval of the inspecting authority.

Except where the material is subsequently joined by welding, no load shall be transmitted through a gas cut surface.

Thermally cut free edges, which shall be subject to calculated static tensile stress shall be free from round bottom gouges greater than 5 mm deep. Gouges greater than 5 mm deep and notches shall be removed by grinding.

23.2.4 *Holing*

23.2.4.1 Holes through more than one thickness of material for members, such as compound stanchion and girder flanges, shall be where possible, drilled after the members are assembled and tightly clamped or bolted together. A round hole for a bolt shall either be machine flame cut, or drilled full size, or sub-punched 3 mm undersize and reamed to size or punched full size.

Hand flame cutting of a bolt hole shall not be permitted except as a site rectification measure for holes in column base plates.

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23.2.4.2 *Punching*

A punched hole shall be permitted only in material whose yield stress (f_y) does not exceed 360 MPa and where thickness does not exceed (5 600/f_y) mm. In cyclically loaded details, punching shall be avoided in plates with thickness greater than 12 mm.

For greater thickness and cyclically loaded details, holes shall be either drilled from the solid or sub-punched or sub drilled and reamed.

The die for all sub-punched holes or the drill for all sub-drilled holes shall be at least 3 mm smaller than the required diameter of finished hole.

23.2.4.3 *Oversize holes*

A special plate washer of minimum thickness 4 mm shall be used under the nut, if the hole diameter is larger than the bolt diameter by 3 mm or more.

Oversize hole shall not exceed 1.25d or (d + 8) mm in diameter, were d is the nominal bolt diameter, in mm.

A short slotted hole shall not exceed the appropriate hole size in width and 1.33d in length. A long slotted hole shall not exceed the appropriate hole size in width and 2.5d, in length. If the slot length is larger than those specified, shear transfer in the direction of slot is not admissible even in friction type of connection.

Slotted holes shall be punched either in one operation or else formed by punching or drilling two round holes apart and completed by high quality mechanically controlled flame cutting and dressing to ensure that bolt can freely travel the full length of the slot.

23.2.4.4 *Fitted bolt holes*

Holes for turned and fitted bolts shall be drilled to a diameter equal to the nominal diameter of the shank or barrel subject to tolerance specified in the accepted standards [6-6(44)]. Preferably, parts to be connected with close tolerance or barrel bolts shall be firmly held together by tacking bolts or clamps and the holes drilled through all the thicknesses at one operation and subsequently reamed to size. All holes not drilled through all thicknesses at one operation shall be drilled to a smaller size and reamed out after assembly. Where this is not practicable, the parts shall be drilled and reamed separately through hard bushed steel jigs.

23.2.4.5 Holes for rivets or bolts shall not be formed generally by gas cutting process. However, advanced gas cutting processes such as plasma cutting may be used to make holes in statically loaded members only. In cyclically loaded members subjected to tensile stresses which are vulnerable under fatigue, gas cutting shall not be used unless subsequent reaming is done to remove the material in the heat affected zone around the hole.

23.3 Assembly

All parts of bolted members shall be pinned or bolted and rigidly held together during assembly.

The component parts shall be assembled and aligned in such a manner that they are neither twisted nor otherwise damaged, and shall be so prepared that the specified camber, if any, is provided.

23.3.1 *Holes in Assembly*

When holes are drilled in one operation through two or more separable parts, these parts, when so specified by the engineer, shall be separated after drilling and the burrs removed.

Matching holes for rivets and black bolts shall register with each other so that a gauge of 1.5 mm or 2.0 mm (as the case may be, depending on whether the diameter of the rivet or bolt is less than or more than 25 mm) less in diameter than the diameter of the hole will pass freely through the assembled members in the direction at right angle to such members.

Drilling done during assembly to align holes shall not distort the metal or enlarge the holes.

Holes in adjacent part shall match sufficiently well to permit easy entry of bolts. If necessary, holes except oversize or slotted holes may be enlarged to admit bolts, by moderate amount of reaming.

23.3.2 *Thread Length*

When design is based on bolts with unthreaded shanks in the shear plane, appropriate measures shall be specified to ensure that, after allowing for tolerance, neither the threads nor the thread run-out be in the shear plane.

The length of bolt shall be such that at least one clear thread shows above the nut and at least one thread plus the thread run out is clear beneath the nut after tightening. One washer shall be provided under the rotated part.

23.3.3 *Assembly Subjected to Vibration*

When non-preloaded bolts are used in a structure subject to vibration, the nuts shall be secured by locking devices or other mechanical means. The nuts of preloaded bolts may be assumed to be sufficiently secured by the normal tightening procedure.

23.3.4 *Washers*

Washers are not normally required on non-preloaded bolts, unless specified otherwise. Tapered washers shall be used where the surface is inclined at more than 3° to a plane perpendicular to the bolt axis.

Hardened washer shall be used for preloaded bolts or the nut, whichever is to be rotated.

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All material within the grip of the bolt shall be steel and no compressible material shall be permitted in the grip.

23.4 Riveting

23.4.1 Rivets shall be heated uniformly throughout their length, without burning or excessive scaling, and shall be of sufficient length to provide a head of standard dimensions. These shall, when driven, completely fill the holes and, if countersunk, the countersinking shall be fully filled by the rivet. If required, any protrusion of the countersunk head shall be dressed off flush.

23.4.2 Riveted member shall have all parts firmly drawn and held together before and during riveting, and special care shall be taken in this respect for all single-riveted connections. For multiple riveted connections, a service bolt shall be provided in every third or fourth hole.

23.4.3 Wherever practicable, machine riveting shall be carried out by using machines of the steady pressure type.

23.4.4 All loose, burned or otherwise defective rivets shall be cut out and replaced before the structure is loaded, and special care shall be taken to inspect all single riveted connections.

23.4.5 Special care shall be taken in heating and driving long rivets.

23.5 Bolting

23.5.1 In all cases where the full bearing area of the bolt is to be developed, the bolt shall be provided with a washer of sufficient thickness under the nut to avoid any threaded portion of the bolt being within the thickness or the parts bolted together, unless accounted for in design.

23.5.2 Pre-tensioned bolts shall be subjected to initial tension (the proof stress) by an appropriate pre-calibrated method.

23.6 Welding

23.6.1 Welding shall be in accordance with good practices [6-6(45)], as appropriate.

23.6.2 For welding of any particular type of joint, welders shall give evidence acceptable to the purchaser of having satisfactorily completed appropriate tests as prescribed in good practices [6-6(46)], as relevant.

23.6.3 Assembly and welding shall be carried out in such a way to minimise distortion and residual stress and that the final dimensions are within appropriate tolerances.

23.7 Machining of Butts, Caps and Bases

23.7.1 Column splices and butt joints of struts and compression members, depending on contact for stress transmission, shall be accurately machined and close-butted over the whole section with a clearance not exceeding 0.2 mm locally, at any place. Sum of all such clearance shall not be more than 30 percent of the contact area for stress transmission. In column caps and bases, the ends of shafts together with the attached gussets, angles, channels, etc; after connecting together should be accurately machined so that clearance between the contact surfaces shall not exceed 2 mm locally, subject further to the condition that sum total of all such clearance shall not exceed 30 percent of the total contact area for stress transmission. Care should be taken that these gussets, connecting angles or channels are fixed with such accuracy that they are not reduced in thickness by machining by more than 2.0 mm.

23.7.2 Where sufficient gussets and rivets or welds are provided to transmit the entire loading [*see* Section 6(d)], the column ends need not be machined.

23.7.3 *Slab Bases and Caps*

Slab bases and slab caps, except when cut from material with true surfaces, shall be accurately machined over the bearing surfaces and shall be in effective contact with the end of the stanchion, the bearing face which is to be grouted to fit tightly at both top and bottom, unless welds are provided to transmit the entire column face.

23.7.4 To facilitate grouting, sufficient gap shall be left between the base plates and top of pedestal and holes shall be provided where necessary in stanchion bases for the escape of air.

23.8 Painting

23.8.1 Painting shall be done in accordance with the good practices [6-6(47)].

23.8.2 All surfaces, which are to be painted, oiled or otherwise treated, shall be dry and thoroughly cleaned to remove all loose scale and loose rust.

23.8.3 Shop contact surfaces need not be painted unless specified. If so specified, they shall be brought together while the paint is still wet.

23.8.4 Surfaces not in contact, but inaccessible after shop assembly, shall receive the full specified protective treatment before assembly. This does not apply to the interior of sealed hollow sections.

23.8.5 Chequered plates shall be painted but the details of painting shall be specified by the purchaser.

23.8.6 In case of surfaces to be welded, the steel shall not be painted or metal coated within a suitable distance

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of any edge to be welded, if the paint specified or the metal coating is likely to be harmful to welders or impair the quality of the welds.

23.8.7 Welds and adjacent parent metal shall not be painted prior to de-slagging, inspection and approval.

23.8.8 Parts to be encased in concrete shall not be painted or oiled.

23.8.9 Contact surface in friction type connection shall not be painted in advance.

23.9 Marking

Each piece of steel work shall be distinctly marked before dispatch, in accordance with a marking diagram and shall bear such other marks as will facilitate erection.

23.10 Shop Erection

23.10.1 The steel work shall be temporarily shop erected complete or as arranged with the inspection agency so that accuracy of fit may be checked before dispatch. The parts shall be shop assembled with sufficient numbers of parallel drifts to bring and keep the parts in place.

23.10.2 In the case of parts drilled or punched, through steel jigs with bushes resulting in all similar parts being interchangeable, the steelwork may be shop erected in such position as arranged with the inspection agency.

23.10.3 In case of shop fabrication using numerically controlled machine data generated by computer software (like CAD), the shop erection may be dispensed with at the discretion of the inspector.

23.11 Packing

All projecting plates or bars and all ends of members at joints shall be stiffened, all straight bars and plates shall be bundled, all screwed ends and machined surfaces shall be suitably packed and all rivets, bolts, nuts, washers and small and loose parts shall be packed separately in cases, so as to prevent damage or distortion during transit.

23.12 Inspection and Testing

23.12.1 The inspecting authority shall have free access at all reasonable times to those parts of the manufacturer's works which are concerned with the fabrication of the steelwork and shall be afforded all reasonable facilities for satisfying himself that the fabrication is being undertaken in accordance with the provisions of this section.

23.12.2 Unless specified otherwise, inspection shall be made at the place of manufacture prior to dispatch and shall be conducted so as not to interfere unnecessarily with the operation of the work.

23.12.3 The manufacturer shall guarantee compliance with the provisions of this standard, if required to do so by the purchaser.

23.12.4 Should any structure or part of a structure be found not to comply with any of the provisions of this section, it shall be liable to rejection. No structure or part of the structure, once rejected shall be resubmitted for test, except in cases where the purchaser or his authorized representative considers the defect as rectifiable.

23.12.5 Defects, which may appear during fabrication, shall be made good with the consent of and according to the procedure laid down by the inspecting authority.

23.12.6 All gauges and templates necessary to satisfy the inspection authority shall be supplied by the manufacturer. The inspecting authority may, at his discretion, check the test results obtained at the manufacturer's works by independent testing at outside laboratory, and should the material so tested be found to be unsatisfactory, the cost of such tests shall be borne by the manufacturer, and if found satisfactory, the cost shall be borne by the purchaser.

23.13 Site Erection

23.13.1 *Plant and Equipment*

The suitability and capacity of all plant and equipment used for erection shall be to the satisfaction of the engineer.

23.13.2 *Storing and Handling*

All structural steel should be so stored and handled at the site that the members are not subjected to excessive stresses and damage by corrosion due to exposure to environment.

23.13.3 *Setting Out*

The positioning and levelling of all steelwork, the plumbing of stanchions and the placing of every part of the structure with accuracy shall be in accordance with the approved drawings and to the satisfaction of the engineer in accordance with the deviation permitted below.

23.13.3.1 *Erection tolerances*

Unloaded steel structure, as erected, shall satisfy the criteria specified in Table 33 within the specified tolerance limits.

Each criterion given in the table shall be considered as a separate requirement, to be satisfied independent of any other tolerance criteria. The erection tolerances specified in Table 33 apply to the following reference points:

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a) For a column, the actual centre point of the column at each floor level and at the base, excluding any base-plate or cap-plate. The level of the base plate on pedestal shall be so as to avoid contact with soil and corrosive environment; and

b) For a beam, the actual centre point of the top surface at each end of the beam, excluding any end-plate.

Table 33 Normal Tolerances after Erection

(*Clause* 23.13.3.1)

Sl No.	Criterion	Permitted Deviation
(1)	(2)	(3)
i)	Deviation of distance between adjacent columns	5 mm
ii)	Inclination of a column in a multi-storey building between adjacent floor levels	$0.002h_s$ where h_s is the storey height
iii)	Deviation of location of a column in a multi-storey building at any floor level from a vertical line through the intended location of the column base	$0.003\ 5 \sum h_b/n^{0.5}$ where $\sum h_b$ is the total height from the base to the floor level concerned and n is the number of storeys from the base to the floor level concerned
iv)	Inclination of a column in a single storey building (not supporting a crane gantry) other than a portal frame	$0.003\ 5h_c$ where h_c is the height of the column
v)	Inclination of the column of a portal frame (not supporting a crane gantry)	Mean: $0.002h_c$ Individual: $0.010h_c$ where h_c is the height of the column

The straightness tolerances specified in Table 34 have been assumed in the derivation of the design stress for the relevant type of member. Where the curvature exceeds these values, the effect of additional curvature on the design calculations shall be reviewed.

Table 34 Straightness Tolerances incorporated in Design Rules

(*Clause* 23.13.3.1)

Sl No.	Criterion	Permitted Deviation
(1)	(2)	(3)
i)	Straightness of a column (or other compression member) between points which will be laterally restrained on completion of erection	$0.001L$ generally, and $0.002L$ for members with hollow cross sections; where, L is the length between points which will be laterally restrained
ii)	Straightness of a compression flange of a beam, relative to the weak axis, between points, which will be laterally restrained on completion of erection	$0.001L$ generally, and $0.002L$ for members with hollow cross sections; where, L is the length between points which will be laterally restrained

A tension member shall not deviate from its correct position relative to the members to which it is connected by more than 3 mm along any setting axis.

23.13.4 *Safety During Fabrication and Erection*

23.13.4.1 All steel materials including fabricated structures, either at fabrication shop or at erection site, shall be handled only by a worker skilled in such jobs; where necessary with load tested lifting devices, having tested wire rope slings of correct size. The devices should be well maintained and operated by experienced operators.

23.13.4.2 Oxygen and acetylene cylinders and their hoses shall have distinctive colours. Cylinders should be stored in upright position in well-ventilated rooms or in open air, not exposed to flames, naked lights or extreme heat and should also be in upright position when they are being used. All gas cutting works shall be done only by experienced skilled gas cutters, equipped with gloves, boots, aprons, goggles and good cutting sets of approved make.

23.13.4.3 While doing any welding work, it should be ensured that the welding machine is earthed and the welding cables are free from damage. The welder and his assistant shall use a face shield or head shield with a welding lens and clear cover glass and their hands, legs and bodies shall be well protected by leather gloves, shoes and aprons. Combustible materials should be kept away from the sparks and globules of molten metals generated in any arc welding. In case of welding in a confined place, it should be provided with an exhaust system to take care of the harmful gases, fumes and dusts generated.

23.13.4.4 In addition to precautions against all the hazards mentioned above, erection workers shall also be protected in the following manner:

a) All workers shall wear helmets and shall also be provided with gloves and shoes. In addition those working at heights shall use safety belts.

b) All structures shall be so braced/guyed during erection that there is no possibility of collapse before erection work is completed.

c) Warning signs such as 'Danger', 'Caution', '440 V', 'Do not smoke', 'Look ahead', etc; should be displayed at appropriate places.

23.13.4.5 For detailed safety precautions during erection, reference shall be made to the good practice [6-6(48)].

23.13.5 *Field Connections*

23.13.5.1 *Field riveting*

Rivets driven at the site shall be heated and driven with the same care as those driven in the shop.

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23.13.5.2 *Field bolting*

Field bolting shall be carried out with the same care as required for shop bolting.

23.13.5.3 *Fillet welding*

Field assembly and welding shall be executed in accordance with the requirements for shop fabrications excepting such as manifestly apply to shop conditions only. Where the steel has been delivered painted, the paint shall be removed for a distance of at least 50 mm on either side of the joint.

23.14 Painting after Erection

23.14.1 Before painting of such steel which is delivered unpainted is commenced, all surfaces to be painted shall be dry and thoroughly cleaned from all loose scale and rust, as required by the surface protection specification.

23.14.2 The specified protective treatment shall be completed after erection. All rivet and bolt heads and the site welds after de-slagging shall be cleaned. Damaged or deteriorated paint surfaces shall first be made good with the same type of paint as the shop coat. Where specified, surfaces which will be in contact after site assembly, shall receive a coat of paint (in addition to any shop priming) and shall be brought together while the paint is still wet. No painting shall be used on contact surfaces in the friction connection, unless specified otherwise by the design document.

23.14.3 Where the steel has received a metal coating in the shop, this coating shall be completed on site so as to be continuous over any welds and site rivets or bolts, subject to the approval of the engineer. Painting on site may complete protection. Bolts, which have been galvanized or similarly treated, are exempted from this requirement.

23.14.4 Surface, which will be inaccessible after site assembly, shall receive the full-specified protective treatment before assembly.

23.14.5 Site painting should not be done in frosty or foggy weather, or when humidity is such as to cause condensation on the surfaces to be painted.

23.15 Bedding Requirement

23.15.1 Bedding shall be carried out with Portland cement grout or mortar, as described under **23.15.4** or fine cement concrete in accordance with good practice [6-6(49)].

23.15.2 For multi-storeyed buildings, this operation shall not be carried out until a sufficient number of bottom lengths of stanchions have been properly lined, levelled and plumbed and sufficient floor beams are in position.

23.15.3 Whatever method is employed, the operation shall not be carried out until the steelwork has been finally levelled and plumbed, stanchion bases being supported meanwhile by steel wedges or nuts; and immediately before grouting, the space under the steel shall be thoroughly cleaned.

23.15.4 Bedding of structure shall be carried out with grout or mortar, which shall be of adequate strength and shall completely fill the space to be grouted and shall either be placed under pressure or by ramming against fixed supports. The grouts or mortar used shall be non-shrinking variety.

23.16 Steelwork Tenders and Contracts

A few recommendations are given in Annex F for general information.

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ANNEX A

[*Clause* 10.1.1(c)]

ANALYSIS AND DESIGN METHODS

A-1 ADVANCED STRUCTURAL ANALYSIS AND DESIGN

A-1.1 Analysis

For a frame, comprising members of compact section with full lateral restraint, an advanced structural analysis may be carried out, provided the analysis can be shown to accurately model the actual behaviour of that class of frames. The analysis shall take into account the relevant material properties, residual stresses, geometrical imperfections, reduction in stiffness due to axial compression, second-order effects, section strength and ductility, erection procedures and interaction with the foundations.

Advanced structural analysis for earthquake loads shall take into account, as appropriate the response history, torsional response, pounding against adjacent structures, and strain rate effects.

A-1.2 Design

For the strength limit state, it shall be sufficient to satisfy the section capacity requirements of Section 6(h) for the members subjected to bending, of Section 6(g) for axial members, of Section 6(j) for combined forces and of Section 6(k) for connections. Effect of moment magnification given in Section 6(j), instability given in Section 6(g) and lateral buckling given in Section 6(h) need not be considered while designing the member, since advanced analysis methods directly consider these.

An advanced structural analysis for earthquake loads shall recognize that the design basis earthquake loads calculated in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code is assumed to correspond to the load at which the first significant plastic hinge forms in the structure.

A-2 SECOND ORDER ELASTIC ANALYSIS AND DESIGN

A-2.1 Analysis

In a second-order elastic analysis, the members shall be assumed to remain elastic, and changes in frame geometry under the design load and changes in the effective stiffness of the members due to axial forces shall be accounted for. In a frame where the elastic buckling load factor (l_{cr}) of the frame as determined in accordance with **10.6** is greater than 5, the changes in the effective stiffness of the members due to axial forces may be neglected.

A-2.2 Design Bending Moment

The design bending moment under factored load shall be taken as the maximum bending moment in the length of the member. It shall be determined either,

a) directly from the second-order analysis; or
b) approximately, if the member is divided into a sufficient number of elements, as the greatest of the element end bending moments, or;
c) by amplifying the calculated design bending moment, taken as the maximum bending moment along the length of a member as obtained by superposition of the simple beam bending moments determined by the analysis.

For a member with zero axial force or a member subject to axial tension, the factored design bending moment shall be calculated as the moment obtained from second-order analysis without any amplification.

For a member with a design axial compressive force as determined from the analysis, the factored design bending moment shall be calculated as follows:

$$M = \delta_b M_m$$

where

δ_b = moment amplification factor for a braced member determined in accordance with Section 6(j).

A-3 FRAME INSTABILITY ANALYSIS

A-3.1 Analysis

Frame instability, as treated here, is related to the design of multi-storey rigid-jointed frames subject to side sway. The elastic critical load factor, λ_{cr} may be determined using the deflection method as given in **A-3.2** or any other recognized method. This is used to calculate the amplified sway moments for elastic designs and to check frame stability in plastic designs. The elastic critical load factor, λ_{cr} of a frame is the ratio by which each of the factored loads would have to be increased to cause elastic instability.

A-3.2 Deflection Method

An accurate method of analysis (ordinary linear elastic analysis) should be used to determine the horizontal deflections of the frame due to horizontal forces applied at each floor level, which is equal to the notional horizontal load in **10.3.6**. Allowance should be made

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for the degree of rigidity of the base as given in **A-3.2** in this deflection calculation.

The base stiffness should be determined by reference to **10.3.4**.

The elastic critical load factor, λ_{cr} is calculated as:

$$\lambda_{cr} = \frac{1}{200\phi_{s,\,Max}}$$

where

$\phi_{s,\,Max}$ = largest value of the sway index where, ϕ_s given by:

$$\phi_{si} = \frac{\delta_{ui} - \delta_{Li}}{h_i}$$

where

h_i = storey height;

δ_{ui} = horizontal deflection of the top of the storey due to the combined gravity and notional loads; and

δ_{Li} = horizontal deflection of the bottom of the storey due to gravity and notional load.

A-3.3 Partial Sway Bracing

In any storey the stiffening effect of infill wall panels may be allowed for by introducing a diagonal strut in that storey of area A, given by:

$$A = \frac{k_3 \sum K_c}{h(h/b)}\left[1+(h/b)^2\right]^{3/2}$$

where

h = storey height;

b = width of the braced bay;

$\sum K_c$ = sum of the stiffness I/L, of the columns in that storey;

$$k_3 = \frac{h^2 \sum S_p}{80E\sum K_C} \le 2 \text{ ; and}$$

$\sum S_p$ = Sum of spring stiffness (horizontal force per unit horizontal deflection of all the panels in that storey determined from:

$$S_p = \frac{0.6h/b}{\left[1 + (h/b)^2\right]^2} t_p E_p$$

where

t_p = thickness of the wall panel, and

E_p = modulus of elasticity of the panel material.

ANNEX B

[*Clauses* 11.2.2.2 (b) *and* 11.6.2]

DESIGN AGAINST FLOOR VIBRATION

B-1 GENERAL

Floor with longer spans of lighter construction and less inherent damping are vulnerable to vibrations under normal human activity. Natural frequency of the floor system corresponding to the lowest mode of vibration, damping characteristics, are important characteristics in floor vibration. Open web steel joists (trusses) or steel beams on the concrete deck may experience walking vibration problem. Fatigue, overloading of floor systems and vibrations due to rhythmic activities such as aerobic or dance classes are not within the scope of this annex.

B-2 ANNOYANCE CRITERIA

In the frequency range of 2 to 8 Hz in which people are most sensitive to vibration, the threshold level corresponds approximately to 0.5 percent g, where g is the acceleration due to gravity. Continuous vibration is generally more annoying than decaying vibration due to damping. Floor systems with the natural frequency less than 8 Hz in the case of floors supporting rhythmic activity and 5 Hz in the case of floors supporting normal human activity should be avoided.

B-3 FLOOR FREQUENCY

The fundamental natural frequency can be estimated by assuming full composite action, even in non-composite construction. This frequency, f_1 for a simply supported one way system is given by:

$$f_1 = 156\ \sqrt{EI_T/WL^4}$$

where

E = modulus of elasticity of steel, in MPa;

I_T = transformed moment of inertia of the one way system (in terms of equivalent steel) assuming the concrete flange of width equal to the spacing of the beam to be effective, in mm^4;

L = span length, in mm; and

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W = dead load of the one way joist, in N/mm.

If the one way joist system is supported by a flexible beam running perpendicular with the natural frequency f_2, the floor frequency may be reduced to f_r, given by:

$$\frac{1}{f_r^2} = \frac{1}{f_1^2} + \frac{1}{f_2^2}$$

B-4 DAMPING

The percentage of critical damping may be assumed approximately as given below:

Sl No.	*System*	*Critical Damping* Percent
(1)	(2)	(3)
i)	Fully composite construction	2
ii)	Bare steel beam and concrete deck	3-4
iii)	Floor with finishes, false ceiling, fire proofing, ducts, furniture	6
iv)	Partitions not located along a support or not spaced farther apart than 6 m and partitions oriented in orthogonal directions	Up to 12

B-5 ACCELERATION

The peak acceleration a_o, from heel impact for floors of spans greater than 7 m and natural frequency f_1, less than 10 Hz may be calculated as:

$$a_o/g = 600\, f_r / W$$

where

W = total weight of floors plus contents over the span length and equivalent floor width (b), in N;

b = $40t_s$ ($20\, t_s$ when overhang is only on one side of the beam);

t_s = equivalent thickness of the slab, averaging concrete in slab and ribs; and

g = acceleration due to gravity.

ANNEX C

(*Clause* 13.2.2)

DETERMINATION OF EFFECTIVE LENGTH OF COLUMNS

C-1 METHOD FOR DETERMINING EFFECTIVE LENGTH OF COLUMNS IN FRAMES

In the absence of a more exact analysis, the effective length of columns in framed structures may be obtained by multiplying the actual length of the column between the centres of laterally supporting members (beams) given in Fig. 27 and Fig. 28 with the effective length factor *K,* calculated by using the equations given below, provided the connection between beam and column is rigid type:

a) *Non-sway frames (Braced frame)* [(*see* **10.1.2** (a)]

A frame is designated as non-sway frame if the relative displacement between the two adjacent floors is restrained by bracings or shear walls (*see* **10.1.2**). The effective length factor, *K,* of column in non-sway frames is given by (*see* Fig. 27):

$$K = \frac{[1 + 0.145\ (\beta_1 + \beta_2) - 0.265\beta_1\beta_2]}{[2 - 0.364\ (\beta_1 + \beta_2) - 0.247\beta_1\beta_2]}$$

b) Sway frames (Moment Resisting Frames) [*see* **10.1.2** (b)]

The effective length factor *K*, of column in sway frames is given by (*see* Fig. 28):

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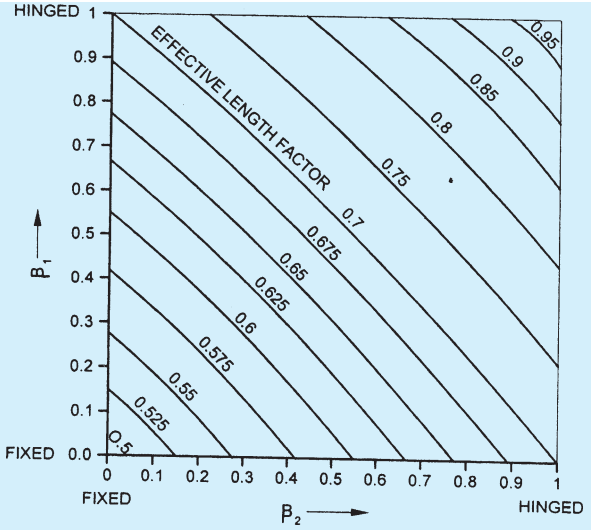


FIG. 27 COLUMN EFFECTIVE LENGTH FACTOR - NON-SWAY FRAME

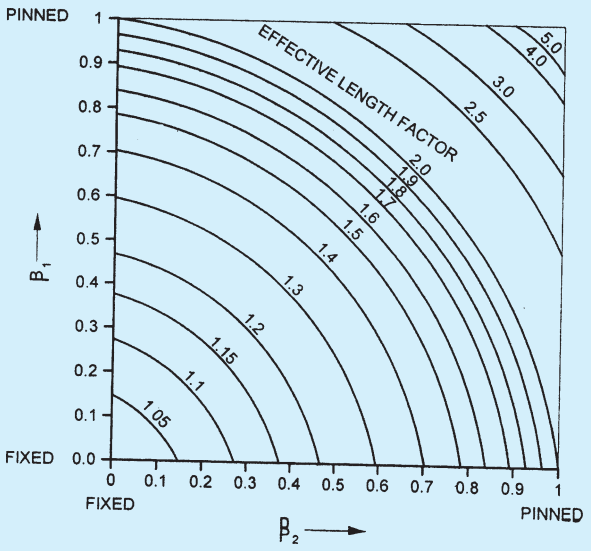


FIG. 28 COLUMN EFFECTIVE LENGTH FACTOR — SWAY FRAME

$$K = \left[\frac{1-0.2(\beta_1+\beta_2)-0.12\beta_1\beta_2}{1-0.8(\beta_1+\beta_2)+0.6\beta_1\beta_2}\right]^{0.5}$$

where

β_1, β_2 are given, $\beta = \dfrac{\sum K}{\sum K_c + \sum K_b}$

K_c, K_b = Effective flexural stiffness of the columns and beams meeting at the joint at the ends of the columns and rigidly connected at the joints, and these are calculated by:

$$K = C\,(I/L)$$

I = moment of inertia of the member about an axis perpendicular to the plan of the frame,

L = length of the member equal to centre-to-centre distance of the intersecting member, and

C = correction factor as shown in Table 35.

Table 35 Correction Factors for Effective Flexural Stiffness

(*Clause* C-1)

Sl No.	Far End Condition	Correction Factor, C	
		Braced Frame	Unbraced Frame
(1)	(2)	(3)	(4)
i)	Pinned	$1.5(1-\bar{n})$	$1.5\,(1-\bar{n})$
ii)	Rigidly connected to column	$1.0(1-\bar{n})$	$1.0\,(1-0.2\,\bar{n})$
iii)	Fixed	$2.0(1-0.4\,\bar{n})$	$0.67\,(1-0.4\,\bar{n})$

NOTE — $\bar{n} = \dfrac{P}{P_e}$

where

P_e = elastic buckling load, and

P = applied load.

C-2 METHOD FOR DETERMINING EFFECTIVE LENGTH FOR STEPPED COLUMNS (*see* 13.2.2)

C-2.1 Single Stepped Columns

Effective length in the plane of stepping (bending about axis *z-z*) for bottom and top parts for single stepped column shall be taken as given in Table 36.

NOTE — The provisions of **C-2.1** are applicable to intermediate columns as well with stepping on either side, provided appropriate values of I_1 and I_2 are taken.

C-3 EFFECTIVE LENGTH FOR DOUBLE STEPPED COLUMNS

Effective lengths in the plane of steppings (bending about axis *z-z*) for bottom, middle and top parts for a double stepped column shall be taken as follows (*see also* Fig. 29):

Coefficient K_1 for effective length of bottom part of double stepped column shall be taken from the formula:

$$K_1 = \sqrt{\frac{t_1K_1^{\,2} + \left(t_2K_2^{\,2} + K_3^{\,2}\right)\times(1+n_2)^2 \times \dfrac{I_1}{I'_{av}}}{1+t_1+t_2}}$$

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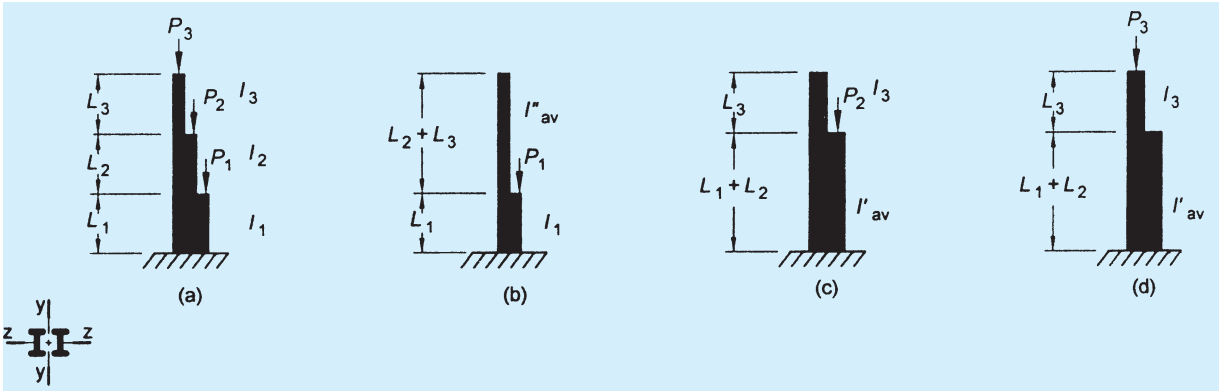
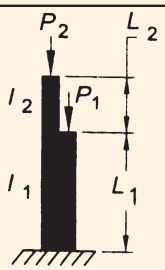


FIG. 29 EFFECTIVE LENGTH OF DOUBLE STEPPED COLUMNS

Table 36 Effective Length of Singled Stepped Columns

(*Clause* C-2.1)

Sl No. (1)	Degree of End Restraint	Sketch (2)	Effective Length Coefficients (3)	Column Parameters for all Cases (4)
i)	Effectively held in position and restrained against rotation at both ends		$K_1 = \sqrt{\frac{K_{12}^2 + K_{11}^2(\alpha - 1)}{\alpha}}$ $K_2 = \frac{K_1}{C_1} \leq 3$ where K_{12} and K_{11} are to be taken as per Table 37	
ii)	Effectively held in position at both ends and restrained against rotation at bottom end only		$K_1 = \sqrt{\frac{K_{12}^2 + K_{11}^2(\alpha - 1)}{\alpha}}$ $K_2 = \frac{K_1}{C_1} \leq 3$ where K_{12} and K_{11} are to be taken as per Table 38	$\alpha = \frac{P_1 + P_2}{P_2}$ $C_1 = \frac{L_2}{L_1}\sqrt{\frac{I_1}{I_2 \alpha}}$ $\frac{i_2}{i_1} = \frac{I_2}{L_2} \times \frac{L_1}{I_1}$
iii)	Effectively held in position and restrained against rotation at bottom end, and top end held against rotation but not held in position		K_1 to be taken as per Table 39 $K_2 = \frac{K_1}{C_1} \leq 3$	Effective length of bottom part of column in plane of stepping = $K_1 L_1$
iv)	Effectively held in position and restrained against rotation at bottom end, and top end neither held against rotation nor held in position		K_1 to be taken as per Table 40 $K_2 = \frac{K_1}{C_1} \leq 3$	Effective length of top part of column in plane of stepping = $K_2 L_2$

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Table 37 Coefficients of Effective Lengths K_{12} and K_{11} for Columns with Both Ends Effectively Held in Position and Restrained Against Rotation

(*Table* 36)

I_2/I_1	Coefficients K_{12} and K_{11} for L_2/L_1 Equal to														
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
	Coefficient K_{12} ($P_1 = 0$)														
0.05	0.74	0.94	1.38	1.60	1.87	2.07	2.23	2.39	2.52	2.67	3.03	3.44	3.85	4.34	4.77
0.1	0.67	0.76	1.00	1.20	1.42	1.61	1.78	1.92	2.04	2.20	2.40	2.60	2.86	3.18	3.41
0.2	0.64	0.70	0.79	0.93	1.07	1.23	1.41	1.50	1.60	1.72	1.92	2.11	2.28	2.45	2.64
0.3	0.62	0.68	0.74	0.85	0.95	1.06	1.18	1.28	1.39	1.48	1.67	1.82	1.96	2.12	2.20
0.4	0.60	0.66	0.71	0.77	0.82	0.93	0.99	1.08	1.17	1.23	1.39	1.53	1.66	1.79	1.92
0.5	0.59	0.65	0.70	0.77	0.82	0.93	0.99	1.08	1.17	1.23	1.39	1.53	1.66	1.79	1.92
1.0	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.10	1.20	1.30	1.40	1.50
	Coefficient K_{11} ($P_2 = 0$)														
0.05	0.65	0.67	0.71	0.85	1.01	1.17	1.31	1.41	1.50	1.57	1.67	1.74	1.78	1.82	1.86
0.1	0.64	0.65	0.65	0.65	0.78	0.92	1.05	1.15	1.25	1.33	1.45	1.55	1.62	1.68	1.71
0.2	0.62	0.64	0.65	0.65	0.66	0.73	0.83	0.92	1.01	1.09	1.23	1.33	1.41	1.48	1.54
0.3	0.60	0.63	0.64	0.65	0.66	0.67	0.73	0.81	0.89	0.94	1.09	1.20	1.28	1.35	1.41
0.4	0.58	0.63	0.63	0.64	0.64	0.66	0.68	0.75	0.82	0.88	1.01	1.10	1.19	1.26	1.32
0.5	0.57	0.61	0.63	0.64	0.64	0.65	0.68	0.72	0.77	0.83	0.94	1.04	1.12	1.19	1.25
1.0	0.55	0.58	0.60	0.61	0.62	0.63	0.65	0.67	0.70	0.73	0.80	0.88	0.93	1.01	1.05

NOTE — Intermediate value may be obtained by interpolation

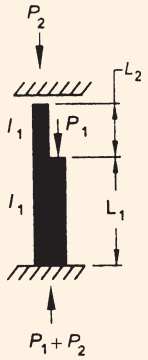


Table 38 Coefficients of Effective Lengths K_{12} and K_{11} for Columns with Both Ends Effectively Held in Position and Restrained Against Rotation at Bottom End Only

(*Table* 36)

I_2/I_1	Coefficients K_{12} and K_{11} for L_2/L_1 Equal to														
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
	Coefficient K_{12} ($P_1 = 0$)														
0.05	0.97	1.66	2.10	2.43	2.72	2.92	3.08	3.24	3.48	3.73	4.22	4.85	5.36	6.00	6.58
0.1	0.83	1.21	1.57	1.95	2.14	2.33	2.46	2.60	2.76	2.91	3.28	3.61	4.03	4.43	4.85
0.3	0.78	0.90	1.09	1.27	1.44	1.60	1.74	1.86	1.98	2.11	2.35	2.51	2.76	2.99	3.25
0.5	0.78	0.86	0.99	1.10	1.22	1.35	1.47	1.57	1.67	1.76	1.96	2.15	2.34	2.50	2.76
1.0	0.78	0.85	0.92	0.99	1.06	1.13	1.20	1.27	1.34	1.41	1.54	1.68	1.82	1.97	2.10
	Coefficient K_{11} ($P_2 = 0$)														
0.05	0.67	0.67	0.82	1.16	1.35	1.48	1.58	1.65	1.69	1.74	1.81	1.84	1.86	1.88	1.90
0.1	0.67	0.67	0.73	0.93	1.11	1.25	1.36	1.45	1.52	1.57	1.66	1.72	1.77	1.80	1.82
0.3	0.67	0.67	0.67	0.71	0.80	0.90	0.99	1.08	1.15	1.22	1.33	1.41	1.48	1.54	1.59
0.5	0.67	0.67	0.67	0.69	0.73	0.81	0.87	0.94	1.01	1.07	1.17	1.26	1.33	1.39	1.44
1.0	0.67	0.67	0.67	0.68	0.71	0.74	0.78	0.82	0.87	0.91	0.99	1.07	1.13	1.19	1.24

NOTE — Intermediate value may be obtained by interpolation

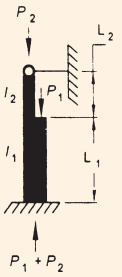
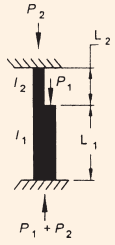


Table 39 Coefficients of Effective Lengths K_1 for Columns Effectively Held in Position and Restrained Against Rotation at Bottom End and Top End Held Against Rotation but not Held in Position

(*Table* 36)

C_1	Coefficients K_1 for I_2/I_1 Equal to														
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.2**	**1.4**	**1.6**	**1.8**	**2.0**
0	2.0	1.8	1.7	1.67	1.6	1.55	1.50	1.4	1.43	1.4	1.37	1.3	1.1	1.10	1.0
0.5	2.0	1.9	1.8	1.74	1.6	1.65	1.61	1.5	1.55	1.5	—	—	—	—	—
1.0	2.0	2.0	2.0	2.00	2.0	2.00	—	—	—	—	—	—	—	—	—
1.5	2.0	2.2	2.3	2.48	—	—	—	—	—	—	—	—	—	—	—
2.0	2.0	2.6	2.9	—	—	—	—	—	—	—	—	—	—	—	—
2.5	2.5	3.1	3.5	—	—	—	—	—	—	—	—	—	—	—	—
3.0	3.0	3.7	4.1	—	—	—	—	—	—	—	—	—	—	—	—

NOTE — Intermediate value may be obtained by interpolation

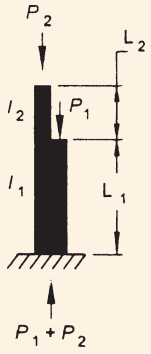


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Table 40 Coefficients of Effective Lengths K_1 for Columns with Top Ends Free and Bottom End Effectively Held in Position and Restrained Against Rotation

(*Table* 36)

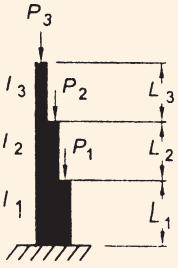
C_1	Coefficients K_1 for I_2/I_1 Equal to														
	0.1	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.5	5.0	10	20
0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
0.5	2.0	2.14	2.24	2.36	2.47	2.57	2.67	2.76	2.85	2.94	3.02	—	—	—	—
1.0	2.0	2.73	3.13	3.44	3.74	4.00	—	—	—	—	—	—	—	—	—
1.5	3.0	3.77	4.35	4.86	—	—	—	—	—	—	—	—	—	—	—
2.0	4.0	4.90	5.67	—	—	—	—	—	—	—	—	—	—	—	—
2.5	5.0	6.08	7.00	—	—	—	—	—	—	—	—	—	—	—	—
3.0	6.0	7.25	—	—	—	—	—	—	—	—	—	—	—	—	—



NOTE — Intermediate value may be obtained by interpolation

Table 41 Values of K_1, K_2 and K_3

(*Clause* C-3)

Sl No.	Degree of End Restraint	Sketch	K_1	K_2	K_3	Column Parameters for all Cases
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Effectively held in position and restrained against rotation at both ends		$K_1 = K_{11}$ where K_{11} is taken from Table 37	$K_2 = K_{11}$ where K_{11} is taken from Table 37	$K_3 = K_{12}$ where K_{12} is taken from Table 37	
ii)	Effectively held in position at both ends and restrained against rotation at bottom end only		$K_1 = K_{11}$ where K_{11} is taken from Table 38	$K_2 = K_{11}$ where K_{11} is taken from Table 38	$K_3 = K_{12}$ where K_{12} is taken from Table 38	
iii)	Effectively held in position and restrained against rotation at bottom end, and top end held against rotation but not held in position		$K_1 = K_1$ where K_1 is taken from Table 39 with C_1=0	$K_2 = K_1$ where K_1 is taken from Table 39 with C_1=0	$K_3 = K_1$ where K_1 is taken from Table 39 with $C_1 = \frac{L_3}{L_1 + L_2}\sqrt{\frac{I_{av}}{I_3}}$	
iv)	Effectively held in position and restrained against rotation at bottom end, and top end neither held against rotation nor against translation		$K_1 = 2$	$K_2 = 2$	$K_3 = K_1$ where K_1 is taken from Table 40 with $C_1 = \frac{L_3}{L_1 + L_2}\sqrt{\frac{I_{av}}{I_3}}$	

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where

K_1, K_2, and K_3 are taken from Table 41.

$$t_1 = \frac{P_1}{P_3},\ t_2 = \frac{P_2}{P_3},\ n_2 = \frac{L_2}{L_1}$$

I'_{av} = average value of moment of inertia for the lower and middle parts

$$= \frac{I_1L_1 + I_2L_2}{L_1 + L_2}$$

I''_{av} = average value of moment of inertia for the middle and top parts

$$= \frac{I_2L_2 + I_3L_3}{L_2 + L_3}$$

Value of coefficient K_2 for middle part of column is given by formula:

$$K_2 = \frac{K_1}{C_2}, \text{ and}$$

Value of coefficient K_3 for the top part of the column is given by:

$$K_3 = \frac{K_1}{C_3} \leq 3$$

where

$$C_2 = \frac{L_2}{L_1}\sqrt{\frac{I_1(P_2 + P_3)}{I_2(P_1 + P_2 + P_3)}},\ C_3 = \frac{L_3}{L_1}\sqrt{\frac{I_1P_3}{I_3(P_1 + P_2 + P_3)}}$$

NOTE — The provisions of **C-3.1** are applicable to intermediate columns as well with steppings on either side, provided appropriate values of I_1, I_2 and I_3 are taken.

ANNEX D

(*Clause* 14.2.2.1)

ELASTIC LATERAL TORSIONAL BUCKLING

D-1 ELASTIC CRITICAL MOMENT

D-1.1 General

The elastic critical moment is affected by the following:

a) Moment gradient in the unsupported length,
b) Boundary conditions at the lateral support points,
c) Non-symmetric and non-prismatic nature of the member, and
d) Location of transverse load with respect to shear centre.

The boundary conditions at the lateral supports have two components:

1) *Torsional restraint* — where the cross-section is prevented from rotation about the shear centre, and
2) *Warping restraint* — where the flanges are prevented from rotating in their own plane about an axis perpendicular to the flange.

The elastic critical moment corresponding to lateral torsional buckling of a doubly symmetric prismatic beam subjected to uniform moment in the unsupported length and torsionally restraining lateral supports is given by:

$$M_{cr} = \frac{\pi^2 EI_y}{(L_{LT})^2}\left[\frac{I_w}{I_y} + \frac{GI_t(L_{LT})^2}{\pi^2 E I_y}\right]^{0.5}$$

where

I_y, I_w, I_t = moment of inertia about the minor axis, warping constant and St.Venant's torsion constant of the cross-section, respectively (*see* Annex G for properties of sections);

G = modulus of rigidity; and

L_{LT} = effective length against lateral torsional buckling (*see* **14.3**).

This equation in simplified form for I-section has been presented in **14.2.2.1**.

While the simplified equation is generally on the safe side, there are many situations where this may be very conservative. More accurate calculation of the elastic critical moment for general case of unsymmetrical sections, loading away from shear centre and beams with moment gradient can be obtained from specialist literature, by using an appropriate computer program or equations given below.

D-1.2 Elastic Critical Moment of a Section Symmetrical About Minor Axis

In case of a beam which is symmetrical only about the minor axis, and bending about major axis, the elastic critical moment for lateral torsional buckling is given by the general equation below,

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$$M_{cr} = c_1 \frac{\pi^2 EI_y}{(L_{LT})^2}\left\{\left[\left(\frac{K}{K_w}\right)^2 \frac{I_w}{I_y} + \frac{GI_t (L_{LT})^2}{\pi^2 EI_y} + \left(c_2 y_g - c_3 y_j\right)^2\right]^{0.5} - \left(c_2 y_g - c_3 y_j\right)\right\}$$

where

c_1, c_2, c_3 = factors depending upon the loading and end restraint conditions (*see* Table 42);

K = effective length factors of the unsupported length accounting for boundary conditions at the end lateral supports. The effective length factor K varies from 0.5 for complete restraint against rotation about weak axis to 1.0 for free rotate about weak axis, with 0.7 for the case of one end fixed and other end free. It is analogous to the effective length factors for compression members with end rotational restraint;

K_w = warping restraint factor. Unless special provisions to restrain warping of the section at the end lateral supports are made, K_w should be taken as 1.0;

y_g = distance between the point of application of the load and the shear centre of the cross-section and is positive when the load is acting towards the shear centre from the point of application;

y_j = $y_s - 0.5\int_A \left(z^2 + y^2\right)^2 y \mathrm{d}A / I_z$

y_s = coordinate of the shear centre with respect to centroid, positive when the shear centre is on the compression side of the centroid; and

y, z = coordinates of the elemental area with respect to centroid of the section.

y_j can be calculated by using the following approximation:

a) *Plain flanges*:

$y_j = 0.8\ (2\beta_f - 1)\ h_y/2.0$ (when $\beta_f > 0.5$)

$y_j = 1.0\ (2\beta_f - 1)\ h_y/2.0$ (when $\beta_f \leq 0.5$)

b) *Lipped flanges*:

$y_j = 0.8\ (2\beta_f - 1)(1 + h_L/h)h_y/2$ (when $\beta_f > 0.5$)

$y_j = (2\beta_f - 1)\ (1 + h_L/h)\ h_y/2$ (when $\beta_f \leq 0.5$)

where

h_L = height of the lip,

h = overall height of the section,

h_y = distance between shear centre of the two flanges of the cross-section, and

β_f = $I_{fc}/(I_{fc} + I_{ft})$ where I_{fc}, I_{ft} are the moment of inertia of the compression and tension flanges, respectively, about the minor axis of the entire section.

I_t = St. Venant's Torsion constant, given by:

$I_t = \sum b_i t_i^3 / 3$ (for open section)

$= 4A_e^2 / \sum(b/t)$ (for hollow section)

where

A_e = area enclosed by the section, and

b, t = breadth and thickness of the elements of the section, respectively.

I_w = The warping constant, given by:

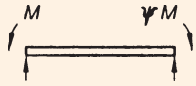
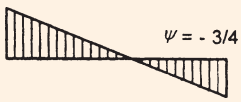
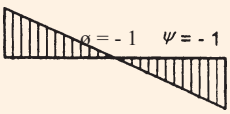
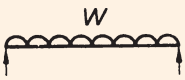
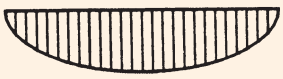
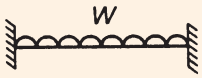
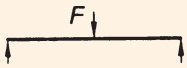
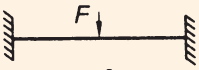
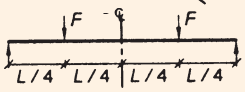
$(1-\beta_f)\ \beta_f\ I_y\ h_y^2$ (for I-sections mono-symmetric about weak axis)

= 0 (for angle, Tee, narrow rectangle section and approximately for hollow sections)

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Table 42 Constants c_1, c_2, and c_3

(*Clause* D-1.2)

Loading and Support Conditions (1)	Bending Moment Diagram (2)	Value of K (3)	Constants c_1 (4)	c_2 (5)	c_3 (6)
		1.0	1.000		1.000
		0.7	1.000	—	1.113
		0.5	1.000		1.144
		1.0	1.141		0.998
		0.7	1.270	—	1.565
		0.5	1.305		2.283
		1.0	1.323		0.992
		0.7	1.473	—	1.556
		0.5	1.514		2.271
		1.0	1.563		0.977
		0.7	1.739	—	1.531
		0.5	1.788		2.235
		1.0	1.879		0.939
		0.7	2.092	—	1.473
		0.5	2.150		2.150
		1.0	2.281		0.855
		0.7	2.538	—	1.340
		0.5	2.609		1.957
		1.0	2.704		0.676
		0.7	3.009	—	1.059
		0.5	3.093		1.546
		1.0	2.927		0.366
		0.7	3.009	—	0.575
		0.5	3.093		0.837
		1.0	2.752		0.000
		0.7	3.063	—	0.000
		0.5	3.149		0.000
		1.0	1.132	0.459	0.525
		0.5	0.972	0.304	0.980
		1.0	1.285	1.562	0.753
		0.5	0.712	0.652	1.070
		1.0	1.365	0.553	1.730
		0.5	1.070	0.432	3.050
		1.0	1.565	1.267	2.640
		0.5	0.938	0.715	4.800
		1.0	1.046	0.430	1.120
		0.5	1.010	0.410	1.890

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ANNEX E

(*Clause* 16.6.1)

CONNECTIONS

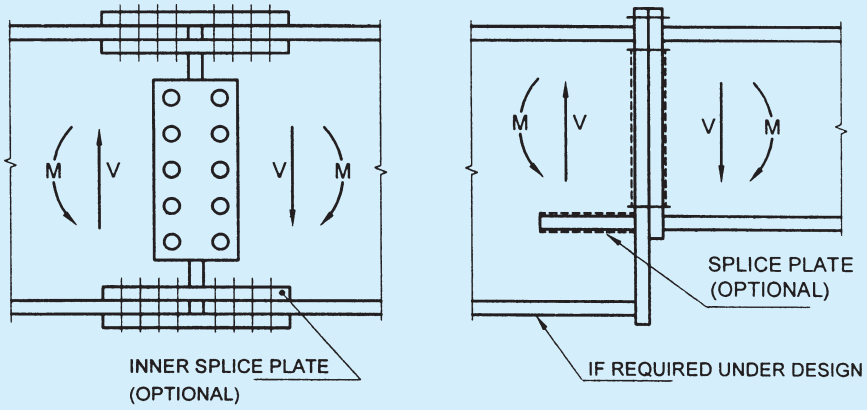
E-1 GENERAL

The requirement for the design of splice and beam to column connection as well as recommendation for their design shall be as given below.

E-2 BEAM SPLICES

E-2.1 For rolled section beam splices located away from the point of maximum moment, it may be assumed that the flange splice carries all the moment and the web splice carries the shear (*see* Fig. 30). However, in the case of a deep girder, the total moment may be divided between the flange and the web in accordance with the stress distribution. The web connection should then be designed to resist its share of moment and shear. Even web splice is designed to carry only shear force, the moment about the centroid of the bolt group on either side of the splice should be designed for moment due to eccentricity.

E-2.2 Flange joints should preferably not be located at points of maximum stress. Where splice plates are used, their area shall not be less than 5 percent in excess of the area of the flange element spliced; and their centre of gravity shall coincide, as nearly as possible with that of the element spliced. There shall be enough fasteners on each side of the splice to develop the load in the element spliced plus 5 percent but in no case should the strength developed be less than 50 percent of the effective strength of the material spliced. Wherever possible in welded construction, flange plates shall be joined by complete penetration butt welds. These butt welds shall develop the full strength of the plates. Whenever the flange width or thickness changes at the splice location, gradual transition shall be made in the width/thickness of the larger flange.



30A Conventional Splice (Typical) 30B End Plate Splice

FIG. 30 BEAM SPLICES

E-2.3 When beam splice is located at the point of inflection of a continuous beam, the flange splicing requirement given above may be relaxed appropriately.

E-3 COLUMN SPLICE

E-3.1 Where the ends of compression members are faced for bearing over the whole area, they shall be spliced to hold the connected parts aligned. The ends of compression members faced for bearing shall invariably be machined to ensure perfect contact of surfaces in bearing (*see* Fig. 31).

E-3.2 Where such members are not faced for complete bearing the splices shall be designed to transmit all the forces to which the members is subjected at the splice location.

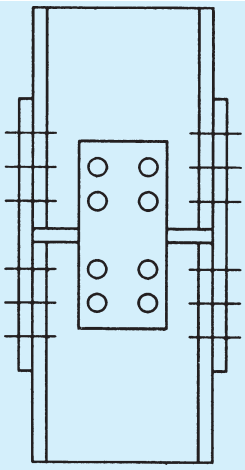


FIG. 31 COLUMN SPLICE (TYPICAL)

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E-3.3 Wherever possible, splices shall be proportioned and arranged so that centroidal axis of the splice coincides as nearly as possible with the centroidal axes of the members joined, in order to avoid eccentricity; but where eccentricity is present in the joint, the resulting stress considering eccentricity shall be provided for.

E-3.4 If a column flange is subjected to significant tension or if the faces are not prepared for bearing, or if full continuity is required without slip, only HSFG bolts shall be used.

E-4 BEAM-TO-COLUMN CONNECTIONS

E-4.1 Simple Connections

Simple connections are assumed to transfer only shear at some nominal eccentricity and typically used in frames up to about five stories in height, where strength rather than stiffness govern the design. In such frames separate lateral load resisting system is to be provided in the form of bracings or shear walls. The connections shown in Figs. 32A, 32B, 32C and 32D can be assumed as simple connections in framed analysis and need to be checked only for the transfer of shear from beam to column.

E-4.2 Rigid Connections

In high-rise and slender structures, stiffness requirements may warrant the use of rigid connections. Rigid connections transfer significant moments to the columns and are assumed to undergo negligible deformations at the joint. These are necessary in sway frames for stability and also contribute in resisting lateral loads. The connections shown in Figs. 32E, 32F, and 32G can be assumed as rigid connection in frame analysis and need to be checked for both shear and

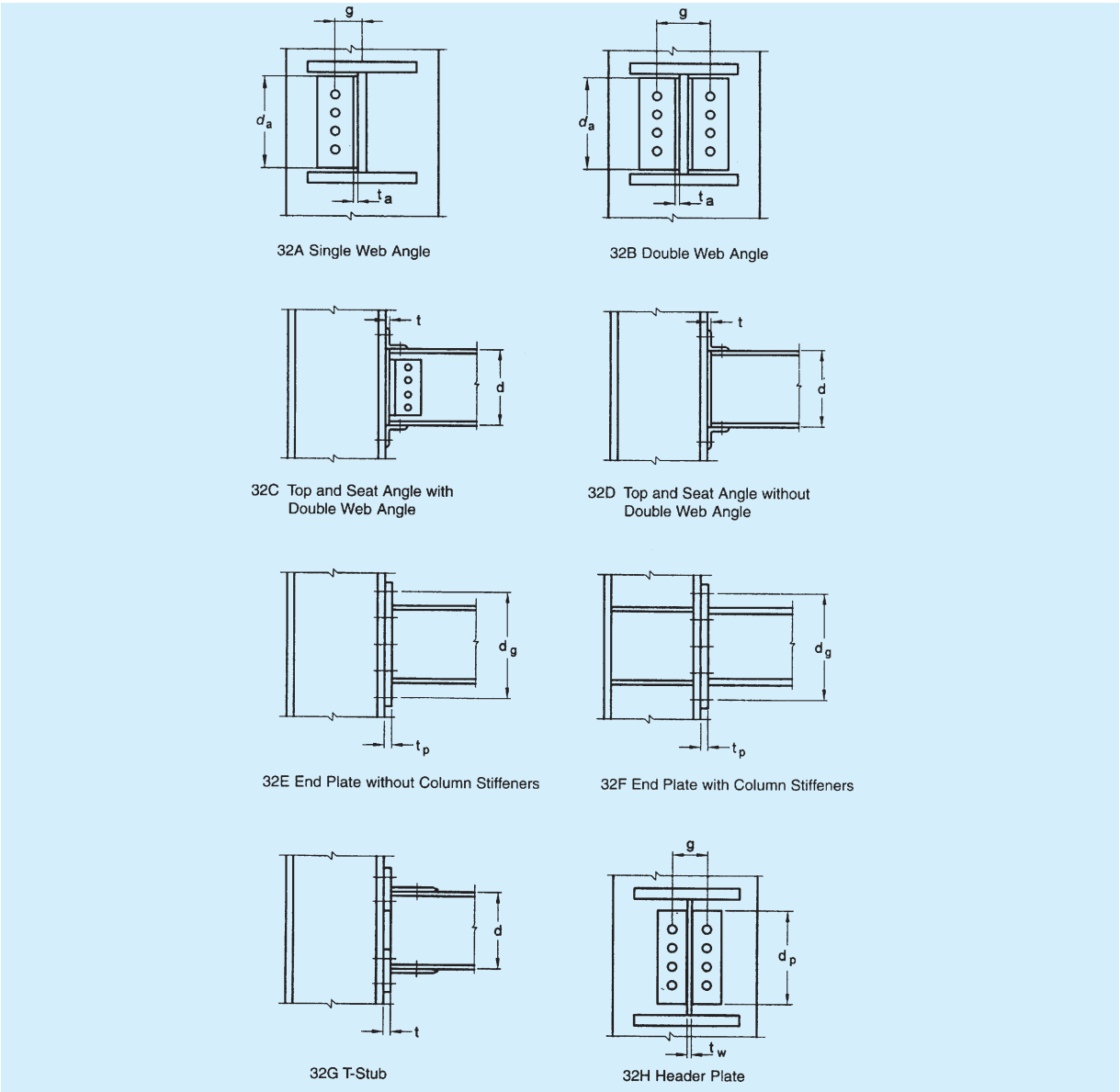


FIG. 32 SIZE PARAMETER FOR VARIOUS TYPES OF CONNECTION

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moment transfer from beam to the column. Fully welded connections can also be considered as rigid beam to column connections.

E-4.3 Semi-Rigid Connections

Semi-rigid connections fall between the two types mentioned above. The fact is that simple connections do have some degree of rotational rigidity as in the semi-rigid connections. Similarly rigid connections do experience some degree of joint deformation and this can be utilized to reduce the joint design moments.

The moment-rotation relationship of the connections have to be determined based on experiments conducted for the specific design or based on the relationship derived from tests, presented in specialist literature. The simplest method of analysis will be to idealize the connection as an equivalent rotational spring with either a bilinear or non-linear moment-rotation characteristics. The classification proposed by Bjorhovde combined with the Frye-Morris model can be used with convenience to model semi-rigid connections, as given in the next section.

E-4.3.1 *Connection Classification*

Connections are classified according to their ultimate strength or in terms of their initial elastic stiffness and Bjorhovde's classification. It is based on the non-dimensional moment parameter ($m^1 = M_u / M_{pb}$) and the non-dimensional rotation parameter ($\theta^1 = \theta_r/\theta_p$), where θ_p is the plastic rotation. The Bjorhovde's classification is based on a reference length of the beam equal to 5 times the depth of the beam. The limits used for connection classification are shown in Table 43 and are graphically represented in Fig. 33.

E-4.3.2 *Connection Models*

Frye-Morris has derived the following polynomial model for the moment curvature relationship of semi-rigid connections:

$$\theta_r = C_1(KM)^1 + C_2 (KM)^3 + C_3 (KM)^5$$

where

M = moment at the joint, in kN.m;

K = standardization parameter which depend on the connection type and geometry; and

C_1, C_2, C_3 = curve fitting constants.

Table 44 shows the curve fitting constants and standardization constants for Frye-Morris Model [All size parameters in the table are in mm (*see* Fig. 32)].

Table 43 Connection Classification Limits

(*Clause* E-4.3.1)

Sl No.	Nature of the Connection	In Terms of Strength	In Terms of Stiffness
(1)	(2)	(3)	(4)
i)	Rigid connection	$m^1 \geq 0.7$	$m^1 \geq 2.5\ \theta^1$
ii)	Semi-rigid connection	$0.7 > m^1 > 0.2$	$2.5\theta^1 > m^1 > 0.5\theta^1$
iii)	Flexible connection	$m^1 \leq 0.2$	$m^1 \leq 0.5\ \theta^1$

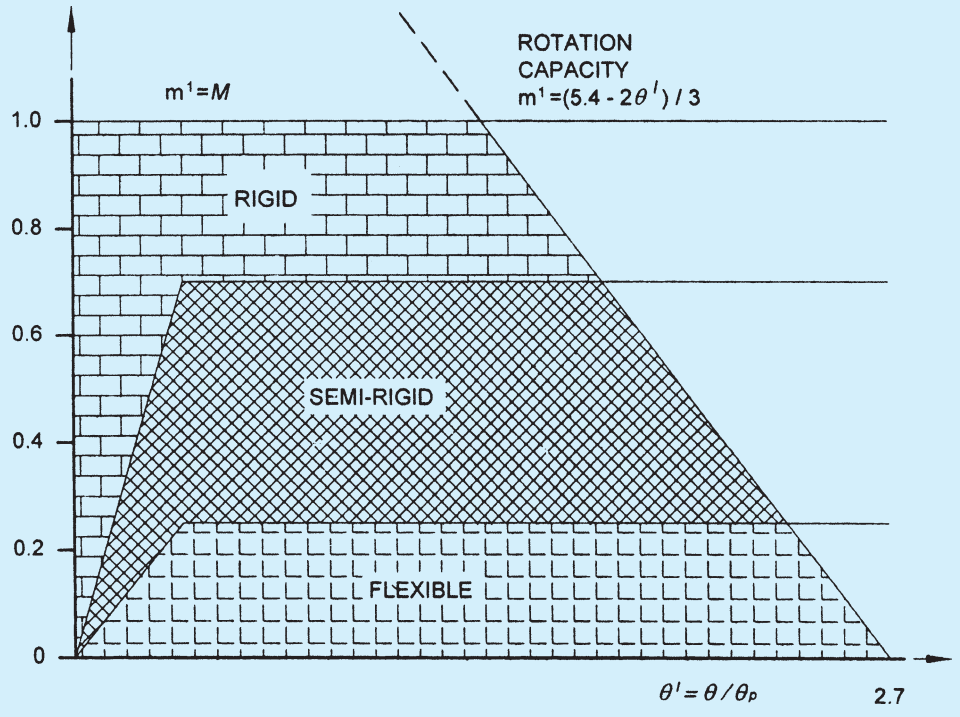


FIG. 33 CLASSIFICATION OF CONNECTIONS ACCORDING TO BJORHOVDE

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Table 44 Connection Constants in Frye-Morris Model

(*Clause* E-4.3.2 *and* Fig. 32)

Sl No. (1)	Type (2)	Connection Type (3)	Curve-Fitting Constants (4)	Standardization Constants (5)
i)	A	Single web angle connection	$C_1 = 1.91 \times 10^4$ $C_2 = 1.30 \times 10^{11}$ $C_3 = 2.70 \times 10^{17}$	$K = d_a^{-2.4} t_c^{-1.81} g^{0.15}$
ii)	B	Double web angle connection	$C_1 = 1.64 \times 10^3$ $C_2 = 1.03 \times 10^{14}$ $C_3 = 8.18 \times 10^{25}$	$K = d_a^{-2.4} t_c^{-1.81} g^{0.15}$
iii)	C	Top and seat angle connection with double web angle	$C_1 = 2.24 \times 10^{-1}$ $C_2 = 1.86 \times 10^4$ $C_3 = 3.23 \times 10^8$	$K = d^{-1.287} t_a^{-1.128} t_c^{-0.415}$ $l_a^{-0.694} (g - 0.5 d_b)^{1.35}$
iv)	D	Top and seat angle connection without double web angle	$C_1 = 1.63 \times 10^3$ $C_2 = 7.25 \times 10^{14}$ $C_3 = 3.31 \times 10^{23}$	$K = d^{-1.5} t_a^{-0.5} l_a^{-0.7} d_b^{-1.1}$
v)	E	End plate connection without column stiffeners	$C_1 = 1.78 \times 10^4$ $C_2 = -9.55 \times 10^{16}$ $C_3 = 5.54 \times 10^{29}$	$K = d_g^{-2.4} t_p^{-0.4} t_f^{-1.5}$
vi)	F	End plate connection with column stiffeners	$C_1 = 2.60 \times 10^2$ $C_2 = 5.37 \times 10^{11}$ $C_3 = 1.31 \times 10^{22}$	$K = d_g^{-2.4} t_p^{-0.6}$
vii)	G	T-stub connection	$C_1 = 4.05 \times 10^2$ $C_2 = 4.45 \times 10^{13}$ $C_3 = -2.03 \times 10^{23}$	$K = d^{-1.5} t_f^{-0.5} l_t^{-0.7} d_b^{-1.1}$
viii)	H	Header-plate connection	$C_1 = 3.87$ $C_2 = 2.71 \times 10^5$ $C_3 = 6.06 \times 10^{11}$	$K = t_p^{-1.6} g^{1.6} d_b^{-2.3} t_w^{-0.5}$

where

d = depth of beam, in mm.
d_a = depth of the angle, in mm.
d_b = diameter of the bolt, in mm.
d_g = center to center of the outermost bolt of the end plate connection, in mm.
g = gauge distance of bolt line, in mm.
t_a = thickness of the top angle, in mm.
t_c = thickness of the web angle, in mm.
t_f = thickness of flange T-stub connector, in mm.
t_w = thickness of web of the beam in the connection, in mm.
t_p = thickness of end plate, header plate, in mm.
l_a = length of the angle, in mm.
l_t = length of the T-stub connector, in mm.

NOTE — For preliminary analysis using a bilinear moment curvature relationship, the stiffness given in Table 45 may be assumed depending on the type of connection. The values are based on the secant stiffness at a rotation of 0.01 radian and typical dimension of connecting angle and other components as given in the table.

Table 45 Secant Stiffness

(*Table* 42)

Sl No. (1)	Type of Connection (2)	Dimension mm (3)	Secant Stiffness kNm/radian (4)
i)	Single web connection angle	$d_a = 250$, $t_a = 10$, $g = 35$	1 150
ii)	Double web-angle connection	$d_a = 250$, $t_a = 10$, $g = 77.5$	4 450
iii)	Top and seat angle connection without double web angle connection	d_a=300, t_a=10, l_a=140, d_b=20	2 730
iv)	Header plate	$d_p = 175$, $t_p = 10$, $g = 75$, $t_w = 7.5$	2 300

E-5 COLUMN BASES

E-5.1 Base Plates

Columns shall be provided with base plates capable of distributing the compressive forces in the compressed parts of the column over a bearing area such that the bearing pressure on the foundation does not exceed the design strength of the point. The design strength of the joint between the base plate and the foundation shall be determined taking account of the material properties and dimensions of both the grout and the concrete foundation.

E-5.2 Holding Down Bolts (Anchor Bolts)

E-5.2.1 Holding down bolts shall be provided, if

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necessary to resist the effects of the design loads. They shall be designed to resist tension due to uplift forces and tension due to bending moments as appropriate.

E-5.2.2 When calculating the tension forces due to bending moments, the lever arm shall not be taken as more than the distance between the centroid of the bearing area on the compression side and the centroid of the bolt group on the tension side, taking the tolerances on the positions of the holding down bolts into account.

E-5.2.3 Holding down bolts shall either be anchored into the foundation by a hook or by a washer plate or by some other appropriate load distributing member embedded in the concrete.

E-5.2.4 If no special elements for resisting the shear force are provided, such as block or bar shear connectors, it shall be demonstrated that sufficient resistance to transfer the shear force between the column and the foundation is provided by one of the following:

a) Frictional resistance of the joint between the base plate and the foundation.
b) Shear resistance of the holding down bolts.
c) Shear resistance of the surrounding part of the foundation.
d) Shear and bearing resistance of the shear key plates welded to the base plate and embedded in the pedestal/foundation.

ANNEX F

(*Clause* 23.16)

GENERAL RECOMMENDATIONS FOR STEELWORK TENDERS AND CONTRACTS

F-1 GENERAL

F-1.1 The recommendations given in this annex are in line with those generally adopted for steelwork construction and are meant for general information.

F-1.2 These recommendations do not form part of the requirements of the Section and compliance with these is not necessary for the purpose of complying with this Section.

F-1.3 The recommendations are unsuitable for inclusion as a block requirement in a contract, but in drawing up a contract the points mentioned should be given consideration.

F-2 EXCHANGE OF INFORMATION

Before the steelwork design is commenced, the building designer should be satisfied that the planning of the building, its dimensions and other principal factors meet the requirements of the building owner and comply with regulations of all authorities concerned. Collaboration of building designer and steelwork designer should begin at the outset of the project by joint consideration of the planning and of such questions as the stanchion spacing, materials to be used for the construction, and depth of basement.

F-3 INFORMATION REQUIRED BY THE STEELWORK DESIGNER

F-3.1 General

a) Site plans showing in plan and elevation of the proposed location and main dimensions of the building or structure;
b) Ground levels, existing and proposed;
c) Particulars of buildings or other constructions which may have to remain on the actual site of the new building or structure during the erection of the steelwork;
d) Particulars of adjacent buildings affecting, or affected by, the new work;
e) Stipulation regarding the erection sequence or time schedule;
f) Conditions affecting the position or continuity of members;
g) Limits of length and weight of steel members in transit and erection;
h) Drawings of the substructure, proposed or existing, showing:
    1) levels of stanchion foundations, if already determined;

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2) any details affecting the stanchion bases or anchor bolts;
3) permissible bearing pressure on the foundation; and
4) provisions for grouting.

NOTE— In the case of new work, the substructure should be designed in accordance with the relevant standards dealing with foundations and substructure.

j) The maximum wind velocity appropriate to the site (*see* Section 1 of Part 7 'Construction Management, Practices and Safety, of the Code); and

k) Environmental factors, such as proximity to sea coast, and corrosive atmosphere. Reference to bye-laws and regulations affecting the steelwork design and construction.

F-3.2 Further Information Relating to Buildings

a) Plans of the floors and roof with principal dimensions, elevations and cross-sections showing heights between floor levels.

b) The occupancy of the floors and the positions of any special loads should be given.

c) The building drawings, which should be fully dimensioned, should preferably be to the scale of 1 to 100 and should show all stairs, fire escapes, lifts, etc, suspended ceilings, flues and ducts for heating and ventilating. Doors and windows should be shown, as the openings may be taken into account in the computations of dead load.

Requirements should be given in respect of any maximum depth of beams or minimum head room.

Large-scale details should be given of any special features affecting the steelwork.

d) The inclusive weight per m^2 of walls, floors, roofs, suspended ceilings, stairs and partitions, or particulars of their construction and finish for the computation of dead load.

The plans should indicate the floors, which are to be designed to carry partitions. Where the layout of partitions is not known, or a given layout is liable to alteration, these facts should be specially noted so that allowance may be made for partitions in any position (*see* Part 6 'Structural Design, Section 1 Loads, Forces and Effects').

e) The superimposed loads on the floors appropriate to the occupancy, as given in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' or as otherwise required.

f) Details of special loads from cranes, runways, tips, lifts, bunkers, tanks, plant and equipment.

g) The grade of fire resistance appropriate to the occupancy as may be required.

F-4 INFORMATION REQUIRED BY TENDERER (IF NOT ALSO DESIGNER)

F-4.1 General

a) All information listed under **F-3.1**;

b) Climatic conditions at site-seasonal variations of temperature, humidity, wind velocity and direction;

c) Nature of soil. Results of the investigation of sub-soil at site of building or structure;

d) Accessibility of site and details of power supply;

e) Whether the steelwork contractor will be required to survey the site and set out or check the building or structure lines, foundations and levels;

f) Setting-out plan of foundations, stanchions and levels of bases;

g) Cross sections and elevations of the steel structure, as necessary, with large-scale details of special features;

h) Whether the connections are to be bolted, riveted or welded. Particular attention should be drawn to connections of a special nature, such as turned bolts, high strength friction grip bolts, long rivets and overhead welds;

j) Quality of steel, and provisions for identification;

k) Requirements in respect of protective paintings at works and on site, galvanizing or cement wash;

m) Approximate dates for commencement and completion of erection;

n) Details of any tests which have to be made during the course of erection or upon completion; and

p) Schedule of quantities. Where the tenderer is required to take off quantities, a list should be given of the principal items to be included in the schedule.

F-4.2 Additional Information Relating to Buildings

a) Schedule of stanchions giving sizes, lengths and typical details of brackets, joints, etc;

b) Plan of grillages showing sizes, lengths and levels of grillage beams and particulars of any stiffeners required;

c) Plans of floor beams showing sizes, lengths

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and levels eccentricities and end moments. The beam reactions and details of the type of connection required should be shown on the plans;

d) Plan of roof steelwork. For a flat roof, the plan should give particulars similar to those of a floor plan. Where the roof is pitched, details should be given of trusses, portals, purlins, bracing, etc;

e) The steelwork drawings should preferably be to a scale of 1 to 100 and should give identification marks against all members; and

f) Particulars of holes required for services, pipes, machinery fixings, etc. Such holes should preferably be drilled at works.

F-4.3 Information Relating to Execution of Building Work

a) Supply of materials;

b) Weight of steelwork for payment;

c) Wastage of steel;

d) Insurance, freight and transport from shop to site;

e) Site facilities for erection;

f) Tools and plants;

g) Mode and terms of payment;

h) Schedules;

j) *Force Majeure* (sections and provisions for liquidation and damages for delay in completion); and

k) Escalation sections.

F-5 DETAILING

In addition to the number of copies of the approved drawings or details required under the contract, dimensioned shop drawings or details should be submitted in duplicate to the engineer who should retain one copy and return the other to the steel supplier or fabricators with his comments, if any.

F-6 TIME SCHEDULE

As the dates on which subsequent trades can commence, depend on the progress of erection of the steel framing, the time schedule for the latter should be carefully drawn up and agreed to by the parties concerned at a joint meeting.

F-7 PROCEDURE ON SITE

The steelwork contractor should be responsible for the positioning and Ievelling of all steelwork. Any checking or approval of the setting out by the general contractor or the engineer should not relieve the steelwork contractor of his responsibilities in this respect.

F-8 INSPECTION

References may be made to the accepted standard [6-6(41)] for general guidance.

F-8.1 Access to Contractor's Works

The contractor should offer facilities for the inspection of the work at all stages.

F-8.2 Inspection of Fabrication

Unless otherwise, agreed, the inspection should be carried out at the place of fabrication. The contractor should be responsible for the accuracy of the work and for any error, which may be subsequently discovered.

F-8.3 Inspection on Site

To facilitate inspection, the contractor should during all working hours, have a foreman or properly accredited charge hand available on the site, together with a complete set of contract drawings and any further drawings and instructions which may have been issued from time to time.

F-9 MAINTENANCE

F-9.1 General

Where steelwork is to be encased in solid concrete, brickwork or masonry, the question of maintenance should not arise, but where steelwork is to be housed in hollow fire protection or is to be unprotected, particularly where the steelwork is exposed to a corroding agent, the question of painting or protective treatment of the steelwork should be given careful consideration at the construction stage, having regard to the special circumstances of the case.

F-9.2 Connections

Where connections are exposed to a corroding agent, they should be periodically inspected, and any corroded part should be thoroughly cleaned and painted.

F-9.2.1 Where bolted connections are not solidly encased and are subject to vibratory effects of machinery or plant, they should be periodically inspected and all bolts tightened.

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ANNEX G

(*Clause* D-1.1)

Table 44 Plastic Properties of Beams {*see also* accepted standard [6-6(35)]}

Designation	Weight per Metre	Sectional Area	Depth of Section	Width of Flange	Thickness of Flange	Thickness of Web	Radii of Gyration		Section Modulus	Plastic Modulus	Shape Factor
			(D)	(b_f)	(t_w)	(r_z)	(r_y)	(Z_{ez})	(t_f)	(Z_{pz})	(Z_{pz} / Z_{ez})
	kg/m	cm^2	mm	mm	mm(6)	mm	cm	cm	cm^3	cm^3	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ISWB 600	*145.1	184.86	600	250	23.6	11.8	25.01	5.35	3 854.2	4 341.63	1.126 5
ISWB 600	*133.7	170.38	600	250	21.3	11.2	24.97	5.25	3 540.0	3 986.66	1.126 2
ISMB 600	*122.6	156.21	600	210	20.8	12.0	24.24	4.12	3 060.4	3 510.63	1.147 1
ISWB 550	*112.5	143.34	550	250	17.6	10.5	22.86	5.11	2 723.9	3 066.29	1.125 7
ISLB 600	*99.5	126.07	600	210	15.5	10.5	23.98	3.79	2 428.9	2 798.56	1.152 2
ISMB 550	103.7	132.11	550	190	19.3	11.2	22.16	3.73	2 359.8	2 711.98	1.149 2
ISWB 500	*95.2	121.22	500	250	14.7	9.9	20.77	4.96	2 091.6	2 351.35	1.124 2
ISLB 550	*86.3	109.97	550	190	15.0	9.9	21.99	3.48	1 933.2	2 228.16	1.152 6
ISMB 500	86.9	110.74	500	180	17.2	10.2	20.21	3.52	1 808.7	2 074.67	1.147 1
ISHB 450	92.5	117.89	450	250	13.7	11.3	18.50	5.08	1 793.3	2 030.95	1.132 5
ISHB 450	87.2	111.14	450	250	13.7	9.8	18.78	5.18	1 742.7	1 955.03	1.121 8
ISLB 500	*75.0	95.50	500	180	14.1	9.2	20.10	3.34	1 543.2	1 773.67	1.149 3
ISWB 450	79.4	101.15	450	200	15.4	9.2	18.63	4.11	1 558.1	1 760.59	1.130 0
ISHB 400	82.2	104.66	400	250	12.7	10.6	16.61	5.16	1 444.2	1 626.36	1.126 1
ISHB 400	77.4	98.66	400	250	12.7	9.1	16.87	5.26	1 404.2	1 556.33	1.115 5
ISMB 450	*72.4	92.27	450	150	17.4	9.4	18.15	3.01	1 350.7	1 533.36	1.150 0
ISLB 450	*65.3	83.14	450	170	13.4	8.6	18.20	3.20	1 223.8	1 401.35	1.145 1
ISWB 400	66.7	85.01	400	200	13.0	8.6	16.60	4.04	1 171.3	1 290.19	1.127 1
ISHB 350	72.4	92.21	350	250	11.6	10.1	14.65	5.22	1 131.6	1 268.69	1.121 2
ISHB 350	67.4	85.91	350	250	11.6	8.3	14.93	5.34	1 094.8	1 213.53	1.108 5
ISMB 400	*61.5	78.40	400	140	16.0	8.9	16.05	2.84	1 020.0	1 176.18	1.149 8
ISLB 400	*56.9	72.43	400	165	12.5	8.0	16.33	3.15	965.3	1 099.45	1.139 0
ISWB 350	56.9	72.50	350	200	11.4	8.0	14.63	4.03	887.0	995.49	1.122 3
ISHB 300	63.0	80.25	300	250	10.6	9.4	12.70	5.29	863.3	962.18	1.114 5
ISHB 300	58.8	74.85	300	250	10.6	7.6	12.95	5.41	836.3	921.68	1.102 1
ISMC 400	*49.4	62.93	400	100	15.3	8.6	15.48	2.83	754.1	891.03	1.181 6
ISMB 350	52.4	66.70	350	140	14.2	8.1	14.32	2.84	779.0	889.57	1.142 1
ISLB 350	49.5	63.01	350	165	11.4	7.4	14.45	3.17	751.9	851.11	1.132 0
ISLC 400	*45.7	58.25	400	100	14.0	8.0	15.50	2.81	699.5	825.02	1.179 4
ISWB 300	48.1	61.33	300	200	10.0	7.4	12.66	4.02	654.8	731.21	1.116 7
ISHB 250	54.7	69.71	250	250	9.7	8.8	10.70	5.37	638.7	708.43	1.109 2
ISLB 325	*43.1	54.90	325	165	9.8	7.0	13.41	3.05	607.7	687.76	1.131 7
ISHB 250	51.0	64.96	250	250	9.7	6.9	10.91	5.49	618.9	678.73	1.096 7
ISMC 350	*42.1	53.66	350	100	13.5	8.1	13.66	2.83	571.9	672.19	1.175 4
ISMB 300	*44.2	56.26	300	140	12.4	7.5	12.37	2.84	573.6	651.74	1.136 2
ISLC 350	*38.8	49.47	350	100	12.5	7.4	13.72	2.82	532.1	622.95	1.170 7
ISLB 300	*37.7	48.08	300	150	9.4	6.7	12.35	2.80	488.9	554.32	1.133 8
ISHB 225	46.8	59.66	225	225	9.1	8.6	9.58	4.84	487.0	542.22	1.113 4
ISWB 250	40.9	52.05	250	200	9.0	6.7	10.69	4.06	475.4	527.57	1.109 7
ISHB 225	43.1	54.94	225	225	9.1	6.5	9.80	4.96	469.3	515.82	1.098 7
ISMC 300	*35.8	45.64	300	90	13.6	7.6	11.81	2.61	424.2	496.77	1.171 1
ISMB 250	37.3	47.55	250	125	12.5	6.9	10.39	2.65	410.5	465.71	1.134 5
ISLC 300	*33.1	42.11	300	100	11.6	6.7	11.98	2.87	403.2	466.73	1.157 6
ISLB 275	*33.0	42.02	275	140	8.8	6.4	11.31	2.61	392.4	443.09	1.130 5
ISHB 200	40.0	50.94	200	200	9.0	7.8	8.55	4.42	372.2	414.23	1.112 9
ISHB 200	37.3	47.54	200	200	9.0	6.1	8.71	4.51	360.8	397.23	1.101 0
ISWB 225	33.9	43.24	225	150	9.9	6.4	9.52	3.22	348.5	389.93	1.118 9
ISMC 250	*30.4	38.67	250	80	14.1	7.1	9.94	2.38	305.3	356.72	1.168 4
ISMB 225	31.2	39.72	225	110	11.8	6.5	9.31	2.34	305.9	348.27	1.138 5
ISLB 250	*27.9	35.53	250	125	8.2	6.1	10.23	2.33	297.4	338.69	1.138 8
ISLC 250	28.0	35.65	250	100	10.7	6.1	10.17	2.89	295.0	338.11	1.146 2
ISWB 200	28.8	36.71	200	140	9.0	6.1	8.46	2.99	262.5	293.99	1.120 0
ISMC 225	*25.9	33.01	225	80	12.4	6.4	9.03	2.38	239.5	277.93	1.160 5
ISLC 225	*24.0	30.53	225	90	10.2	5.8	9.14	2.62	226.5	260.13	1.148 5
ISLB 225	*23.5	29.92	225	100	8.6	5.8	9.15	1.94	222.4	254.72	1.145 3
ISMB 200	25.4	32.33	200	100	10.8	5.7	8.32	2.15	223.5	253.86	1.135 8

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Table 44 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
ISHB 150	34.6	44.08	150	150	9.0	11.8	6.09	3.35	218.1	251.64	1.153 8
ISHB 150	30.6	38.98	150	150	9.0	8.4	6.29	3.44	205.3	232.52	1.132 6
ISHB 150	27.1	34.48	150	150	9.0	5.4	6.50	3.54	194.1	215.64	1.111 0
ISMC 200	*22.1	28.21	200	75	11.4	6.1	8.03	2.23	181.9	211.25	1.161 4
ISLC 200	*20.6	26.22	200	75	10.8	5.5	8.11	2.37	172.6	198.77	1.151 6
ISWB 175	22.1	28.11	175	125	7.4	5.8	7.33	2.59	172.5	194.20	1.125 8
ISLB 200	*19.8	25.27	200	100	7.3	5.4	8.19	2.13	169.7	184.34	1.137 0
ISMB 175	*19.3	24.62	175	90	8.6	5.5	7.19	1.86	145.4	166.08	1.142 2
ISMC 175	*19.1	24.38	175	75	10.2	5.7	7.08	2.23	139.8	161.65	1.156 3
ISLC 175	*17.6	22.40	175	75	9.5	5.1	7.16	2.38	131.3	150.36	1.145 2
ISLB 175	*16.7	21.30	175	90	6.9	5.1	7.17	1.93	125.3	143.30	1.143 7
ISJB 225	*12.8	16.28	225	80	5.0	3.7	8.97	1.58	116.3	134.15	1.153 5
ISJC 200	13.9	17.80	200	70	7.1	4.1	8.08	2.18	116.1	133.12	1.146 5
ISWB 150	17.0	21.67	150	100	7.0	5.4	6.22	2.09	111.9	126.86	1.133 7
ISMC 150	16.4	20.88	150	75	9.0	5.4	6.11	2.21	103.9	119.82	1.153 3
ISMB 150	14.9	19.00	150	80	7.6	4.8	6.18	1.66	96.9	110.48	1.140 1
ISLC 150	14.4	18.36	150	75	7.8	4.8	6.16	2.37	93.0	106.17	1.141 6
ISLB 150	14.2	18.08	150	80	6.8	4.8	6.17	1.75	91.8	104.50	1.138 4
ISJC 175	*11.2	14.24	175	60	6.9	3.6	7.11	1.88	82.3	94.22	1.144 9
ISJB 200	*9.9	12.64	200	60	5.0	3.4	7.86	1.17	78.1	90.89	1.163 9
ISMB 125	13.0	16.60	125	75	7.6	4.4	5.20	1.62	71.8	81.85	1.139 9
ISMC 125	12.7	16.19	125	65	8.1	5.0	5.07	1.92	66.6	77.15	1.158 5
ISLB 125	11.9	15.12	125	75	6.5	4.4	5.19	1.69	65.1	73.93	1.135 6
ISJC 150	9.9	12.65	150	55	6.9	3.6	6.90	1.73	62.8	72.04	1.147 2
ISLC 125	10.7	13.67	125	65	6.6	4.4	5.11	2.05	57.1	65.45	1.146 2
ISJB 175	*8.1	10.28	175	50	4.6	3.0	6.83	0.97	54.8	64.22	1.179 9
ISMB 100	11.5	14.60	100	75	7.2	4.0	4.20	1.05	36.6	41.68	1.138 9
ISJB 150	*7.1	9.01	150	50	4.6	3.0	5.98	1.01	42.9	49.57	1.155 6
ISJC 125	7.9	10.07	125	50	6.6	3.0	5.18	1.60	43.2	49.08	1.136 2
ISMC 100	9.2	11.70	100	50	7.5	4.7	4.00	1.49	37.3	43.83	1.175 0
ISLB 100	8.0	10.21	100	50	6.4	4.0	4.06	1.12	33.6	38.89	1.157 3
ISLC 100	7.9	10.02	100	50	6.4	4.0	4.06	1.57	32.9	38.09	1.157 6
ISJC 100	*5.8	7.41	100	45	5.1	3.0	4.09	1.42	24.8	28.38	1.144 2
ISMC 75	6.8	8.67	75	40	7.3	4.4	2.96	1.21	20.8	24.17	1.190 4
ISLB 75	6.1	7.71	75	50	5.0	3.7	3.07	1.14	19.4	22.35	1.152 2
ISLC 75	*5.7	7.26	75	40	6.0	3.7	3.02	1.26	17.6	20.61	1.171 0

NOTE — Sections having 'weight per metre' marked with an asterisk (*) may be chosen as the section is lighter having high Z_p as compared to sections below it.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section:

	IS No.	*Title*
(1)	786 : 1967	Conversion factors and conversion tables (*first revision*)
(2)	808 : 1989	Dimensions for hot-rolled steel beam, column, channel and angle sections (*third revision*)
	1852 : 1985	Rolling and cutting tolerance for hot rolled steel products (*fourth revision)*
(3)	IS 8000	Geometrical tolerancing on technical drawings (*second revision*)

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IS No.	*Title*
(Part 1) : 1985	Tolerances of form, orientation, location and run-out, and appropriate geometrical definitions (*first revision*)
(Part 2) : 1992	Maximum material principles (*first revision*)
(Part 3) : 1992	Dimensioning and tolerancing of profiles (*second revision*)
(Part 4) : 1976	Practical examples of indications on drawings
8976 : 1978	Guide for preparation and arrangement of sets of drawings and parts list
962 : 1989	Code of practice for architectural and building drawings (*second revision*)
(4) 962 : 1989	Code of practice for architectural and building drawings (*second revision*)
(5) 813 : 1986	Scheme of symbols for welding (*first revision*)
(6) 2062 : 2011	Hot rolled low, medium and high tensile structural steel (*seventh revision*)
(7) 1608 : 2005/ ISO 6892 : 1998	Metallic materials — Tensile testing at ambient temperatures (*third revision*)
(8) 1161 : 2014	Steel tubes for structural purposes (*fifth revision*)
(9) 814 : 2004	Specification for covered electrodes for manual metal arc welding of carbon and carbon manganese steel *(sixth revision)*
(10) 7557 : 1982	Specification for steel wire (up to 20 mm) for the manufacture of cold-forged rivets (*first revision*)
(11) 1148 : 2009	Steel rivet bars (medium and high tensile) — For structural purposes (*fourth revision*)
(12) 1929 : 1982	Specification for hot forged steel rivets for hot closing (12 to 36 mm diameter) (*first revision*)
2155 : 1982	Specification for cold forged solid steel rivets for hot closing (6 to 16 mm diameter) (*first revision*)
(13) 1148 : 2009	Steel rivet bars (medium and high tensile) — For structural purposes (*fourth revision*)
(14) 1363	Hexagon head bolts, screws and nuts of product grade C:
(Part 1) : 2002/ ISO 4016 : 1999	Hexagon head bolts (size range M5 to M64) (*fourth revision*)
(Part 2) : 2002/ ISO 4018 : 1999	Hexagon head screws (size range M5 to M64) (*fourth revision*)
(Part 3) : 2002/ ISO 4034 : 1999	Hexagon nuts (size range M5 to M64) (*fourth revision*)
1364	Hexagon head bolts, screws and nuts of product grades A and B:
(Part 1) : 2014/ ISO 4014 : 2005	Hexagon head bolts (size range M1.6 to M64) (*fourth revision*)
(Part 2) : 2002/ ISO 4017 : 1999	Hexagon head screws (size range M1.6 to M64) (*fourth revision*)
(Part 3) : 2002/ ISO 4032 : 1999	Hexagon nuts, Style 1(size range M1.6 to M64) (*fourth revision*)
(Part 4) : 2003/ ISO 4035 : 1999	Hexagon thin nuts (chamfered) (size range M1.6 to M64) (*fourth revision*)
(Part 5) : 2002/ ISO 4036 : 1999	Hexagon thin nuts – Product grade B (unchamfered) (size range M1.6 to M10) (*fourth revision*)
1367	Technical supply conditions for threaded steel fasteners:
(Part 1) : 2014/ ISO 8992 : 2005	General requirements for bolts, screws and studs (*fourth revision*)
(Part 2) : 2002/ ISO4759-1 : 2000	Tolerance for fasteners — Bolts, screws, studs and nuts — Product grades A, B and C (*third revision*)
(Part 3) : 2002/ ISO 898-1 : 1999	Mechanical properties of fasteners made of carbon steel and alloy steel — bolts, screws and studs (*fourth revision*)
(Part 5) : 2002/ ISO898-5 : 1998	Mechanical properties of fasteners made of carbon steel and alloy steel — set screws and similar threaded fasteners not under tensile stresses (*third revision*)

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IS No.	*Title*
(Part 6) : 1994/ ISO 898-2 : 1992	Mechanical properties and test methods for nuts with specified (*third revision*)
(Part 7) : 1980	Mechanical properties and test methods for nuts without specified proof loads (*second revision*)
(Part 8) : 2014/ ISO 2320 : 2008	Prevailing torque type steel hexagon nuts — Mechanical and performance properties (*fourth revision*)
(Part 9)	Surface discontinuities
Sec 1 : 1993/ ISO 6157-1 : 1988	Bolts, screws and studs for general application (*third revision)*
Sec 2 : 1993/ ISO 6157-3 : 1988	Bolts, screws and studs for special applications (*third revision*)
(Part 10) : 2002/ ISO 6157-2 : 1995	Surface discontinuities — Nuts (*third revision*)
(Part 11) : 2002/ ISO 4042 : 1999	Electroplated coatings (*third revision*)
(Part 12) : 1981	Phosphate coatings on threaded fasteners (*second revision*)
(Part 13) : 1983	Hot dip galvanized coatings on threaded fasteners (*second revision*)
(Part 14) : 1984	Stainless steel threaded fasteners (*second revision*)
(Part 14)	Mechanical properties of corrosion-resistant stainless-steel fasteners
Sec 1 : 2002/ ISO 3506-1 : 1997	Bolts, screws and studs (*third revision*)
Sec 2 : 2002/ ISO 3506-2 : 1997	Nuts (*third revision*)
Sec 3 : 2002/ ISO 3506-3 : 1997	Set screws and similar fasteners not under tensile stress (*third revision*)
(Part 16) : 2002/ ISO 8991 : 1986	Designation system for fasteners (*third revision*)
(Part 17) : 2005/ ISO 3269 : 2000	Inspection, sampling and acceptance procedure (*fourth revision*)
(Part 18) : 1996	Packaging (*third revision*)
(Part 19) : 1997/ ISO 3800 : 1993	Axial load fatigue testing of bolts, screws and studs
(Part 20) : 1996/ ISO 898-7 : 1992	Torsional test and minimum torques for bolts and screws
	with nominal diameters 1 mm to 10 mm
3640 : 1982	Specification for hexagon fit bolts (*first revision*)
3757 : 1985	Specification for high strength structural bolts (*second revision*)
5369 : 1975	General requirements for plain washers and lock washers (*first revision*)
5370 : 1969	Specification for plain washers with outside diameter 3 × inside diameter
5372 : 1975	Taper washer for channels (ISMC) (*first revision*)
5374 : 1975	Taper washers for I-beams (ISMB) (*first revision*)
5624 : 1993	Specification for foundation bolts (*first revision*)
6610 : 1972	Specification for heavy washers for steel structures
6623 : 2004	Specification for high strength structural nuts (*second revision*)
6639 : 1972	Specification for hexagon bolts for steel structures
649 : 1997	Specification for hardened and tempered washers for high strength structural bolts and nuts (*second revision*)
(15) 4000 : 1992	Code of practice for high strength bolts in steel structures (*first revision*)
(16) 1030 : 1998	Carbon steel castings for general engineering purposes (*fifth revision*)
(17) 2708 : 1993	1.5 percent manganese steel castings for general engineering purpose (*third revision*)
(18) 814 : 2004	Specification for covered electrodes for manual metal arc welding of carbon and carbon manganese steel (*fifth revision*)
(19) 1395 : 1982	Low and medium alloy steel covered electrodes for manual metal arc welding (*third revision*)
(20) 1278 : 1972	Specification for filler rods and wires for gas welding (*second revision*)

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IS No.	*Title*
(21) 1387 : 1993	General requirements for the supply of metallurgical materials (*second revision*)
(22) 15977 : 2013	Specification for classification and acceptance tests for bare solid wire electrodes and wire flux combination for submerged are welding of structural steel
(23) 6419 : 1996	Welding rods and bare electrodes for gas shielded arc welding of structural steel (*first revision*)
6560 : 1996	Molybdenum and chromium-molybdenum low alloy steel welding rods and bare electrodes for gas shielded arc welding (*first revision*)
(24) 513 : 2008	Cold reduced low carbon steel sheets and strips (*fifth revision*)
(25) 1079 : 2009	Specification for hot rolled carbon steel sheets and strips (*sixth revision*)
(26) 1367 (Part 3) : 2002/ISO 898-1 : 1999	Technical supply conditions for threaded steel fasteners : Part 3 Mechanical properties of fasteners made of carbon steel and alloy steel – bolts, screws and studs (*fourth revision*)
(27) 1875 : 1992	Specification for carbon steel billets, blooms, slabs and bars for forgings (*fifth revision*)
(28) 1990 : 2009	Steel rivet and stay bars for boilers (*second revision*)
(29) 2002 : 2009	Steel plates for pressure vessels for intermediate and high temperature service including boilers (*third revision*)
(30) 3039 : 1988	Structural steel for construction of hulls of ships (*second revision*)
(31) 6240 : 2008	Hot rolled steel plate (up to 6 mm) sheet and strip for the manufacture of low pressure liquefiable gas cylinders (*fourth revision*)
(32) 9295 : 1983	Steel tubes for idlers for belt conveyors (*first revision*)
(33) 10748 : 2004	Hot rolled steel strip for welded tubes and pipes — Specification (*second revision*)
(34) 801 : 1975	Code of practice for use of cold-formed light gauge steel structural members in general building construction (*first revision*)
(35) 808 : 1989	Dimensions for hot-rolled steel beam, column, channel and angle sections (*third revision*)
(36) 4326 : 2013	Code of practice for earthquake resistance design and construction of buildings (*third revision*)
(37) 3757 : 1985	Specification for high strength structural bolts (*second revision*)
(38) 1367	Technical supply conditions for threaded steel fasteners:
(Part 1) : 2014/ ISO 8992 : 2005	General requirements for bolts, screws and studs (*fourth revision*)
(Part 2) : 2002 / ISO 4759-1 : 2000	Tolerance for fasteners — Bolts, screws, studs and nuts — Product grades A, B and C (*third revision*)
(Part 3) : 2002/ ISO 898-1 : 1999	Mechanical properties of fasteners made of carbon steel and alloy steel – bolts, screws and studs (*fourth revision*)
(Part 5) : 2002/ ISO 898-5 : 1998	Mechanical properties of fasteners made of carbon steel and alloy steel – set screws and similar threaded fasteners not under tensile stresses (*third* revision)
(Part 6) : 1994/ ISO 898-2 : 1992	Mechanical properties and test methods for nuts with specified (*third revision*)
(Part 7) : 1980	Mechanical properties and test methods for nuts without specified proof loads (*third revision*)
(Part 8) : 2014/ ISO 2320:2008	Prevailing torque type steel hexagon nuts – Mechanical and performance properties (*fourth revision*)
(Part 9)	Surface discontinuities

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IS No.	*Title*
Sec 1 : 1993/	Bolts, screws and studs for general application (*third revision*)
Sec 2 : 1993/ ISO 6157-3 : 1988	Bolts, screws and studs for special applications (*third revision*)
(Part 10) : 2002/ ISO 6157-2 : 1995	Surface discontinuities – Nuts (*third revision*)
(Part 11) : 2002/ ISO 4042 : 1999	Electroplated coatings (*third revision*)
(Part 12) : 1981	Phosphate coatings on threaded fasteners (*second revision*)
(Part 13) : 1983	Hot dip galvanized coatings on threaded fasteners (*second revision*)
(Part 14) : 1984	Stainless steel threaded fasteners (*second revision*)
(Part 14)	Mechanical properties of corrosion-resistant stainless-steel fasteners
Sec 1 : 2002/ ISO 3506-1 : 1997	Bolts, screws and studs (*third revision*)
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Sec 3 : 2002/ ISO 3506-3 : 1997	Set screws and similar fasteners not under tensile stress (*third revision*)
(Part 16) : 2002/ ISO 8991 : 1986	Designation system for fasteners (*third revision*)
(Part 17) : 2005/ ISO 3269 : 2000	Inspection, sampling and acceptance procedure (*third revision*)
(Part 18) : 1996	Packaging (*third revision*)
(Part 19) : 1997/ ISO 3800 : 1993	Axial load fatigue testing of bolts, screws and studs
(Part 20) : 1996/ ISO 898-7 : 1992	Torsional test and minimum torques for bolts and screws with nominal diameters 1 mm to 10 mm
(39) 816 : 1969	Code of practice for use of metal arc welding for general construction in mild steel (*first revision*)
9595 : 1996	Metal arc welding of carbon and carbon manganese steels-Recommendations (*first revision*)
(40) 9077 : 1979	Code of practice for corrosion protection of steel reinforcement in RB and RCC construction
9172 : 1979	Recommended design practice for corrosion prevention of steel structures
(41) 7215 : 1974	Tolerances for fabrication of steel structures
(42) 12843 : 1989	Tolerances for erection of steel structures
(43) 9595 : 1996	Metal arc welding of carbon and carbon manganese steels-Recommendations (*first revision*)
(44) 919	ISO systems of limits and fits:
(Part 1) : 2014/ ISO 286-1 : 2010	Bases of tolerance, deviations and fits (*third revision*)
(Part 2) : 2014/ ISO 286-2 : 2010	Tables of standard tolerance grades and limit deviations for holes and shafts (*second revision*)
(45) 816 : 1969	Code of practice for use of metal arc welding for general construction in mild steel (*first revision*)
819 : 1957	Code of practice for resistance spot welding for light assemblies in mild steel
1024 : 1999	Code of practice for use of welding in bridges and structures subject to dynamic loading (*second revision*)
1261 : 1959	Code of practice for seam welding in mild steel
1323 : 1982	Code of practice for oxy-acetylene welding for structural work in mild steels (*second revision*)
9595 : 1996	Metal arc welding of carbon and carbon manganese steels — Recommendations (*first revision*)
(46) 817	Code of Practice for training of welders
(Part 1) : 1966	Manual metal arc welding (*second revision*)
(Part 2) : 1996	Oxyfuel welding (*second revision*)
1393 : 1961	Code of practice for training and testing of oxy-acetylene welders

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IS No.	*Title*
7307 (Part 1) : 1974	Approval tests for welding procedures: Part 1 Fusion welding of steel
7310 (Part 1) : 1974	Approval tests for welders working to approved welding procedures: Part 1 Fusion welding of steel
7318 (Part 1) : 1974	Approval tests for welders when welding procedure approval is not required: Part 1 Fusion welding of steel
(47) 1477	Code of practice for painting of ferrous metals in buildings:
(Part 1) : 2000	Pre-treatment (*second revision*)
(Part 2) : 1971	Painting (*first revision*)
(48) 7205 : 1974	Safety code for erection of structural steelwork
(49) 456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7A Prefabricated Concrete

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 7A) gives recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transport and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

Prefabrication, though desirable for large scale building activities, is now gaining importance for use in the country. Two aspects of prefabrication, specifically to be borne in mind, are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular coordination is of value and its use is recommended.

Advantages of recent trends in prefabrication have been taken note of and also the hazards attended to such construction. Recommendations on the need to avoid progressive collapse of the structure are covered to make a structure reasonably safe against such a collapse.

Prefabricated constructions being comparatively a new technique, some of the essential requirements for the manufacture of the prefabricated components and elements are also included in this Subsection.

Since the aim of prefabrication is to effect economy and improve quality and speed of construction, the selection of proper materials for prefabrication is also an important factor in the popularization of this technique. The use of locally available materials with required characteristics and the materials which, due to their innate characteristics such as lightweight, easy workability, thermal insulation, non-combustibility, etc, that effect economy and improve quality, may also be tried. However, this Subsection pertains to prefabricated elements with cementitious materials.

The design of prefabricated buildings shall include provision for installations of all services and required piping, wiring and accessories to be installed in the building.

This Section was first published in 1970 and was subsequently revised in 1983. In the first revision, the main changes made included: inclusion of brief provision regarding importance of architectural treatment and finishes as applicable to prefabricated buildings; addition of a brief clause on the requirements of materials for use in prefabrication; elaboration of the clause on prefabricating systems and structural elements; revision of the clause on testing of components to include testing of structure or part of structure; and addition of a brief clause on the manufacture of cellular concrete.l:

In the second revision, this Section 7, earlier named as Prefabrication and Systems Building was renamed and restructured as follows:

Section 7 Prefabrication, Systems Buildings and Mixed/Composite Construction
- 7A Prefabricated Concrete
- 7B Systems Buildings and Mixed/Composite Construction

This Subsection, 7A covers prefabricated concrete, in the second revision of which the following main changes were made:

a) Modular coordination and modular dimension of the components were revised to have more flexibility for planning.
b) The provisions on tolerance were revised to include different types of prefabricated components.
c) A detailed clause on design requirements for safety of prefabricated buildings against progressive collapse was included.
d) A clause on sampling procedure was added for testing of components.

In the third, revision, in this Subsection, the following major modifications have been incorporated:

a) Definitions of some new terms have been added and existing terminologies modified, wherever required.

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b) Provisions relating to prefab systems have been updated.
c) Detailed provisions on diaphragm action of floor systems have been included.
d) Emulative system has been categorized and detailed with respect to its definition, analysis, design, detailing, etc.
e) Design considerations have been updated where accidental impact due to vehicles has been included.
f) Provisions and testing procedures for water tightness of joints have been included.
g) Some of the typical precast joint details have been illustrated.
h) Provisions relating to fire resistance testing of prototypes under sustained load has been provided for.
j) Connection between adjacent prefabricated members only through frictional resistance has been removed and suggestions for resistance using shear has been included.
k) Provisions on site prefabrication have been updated.
m) Guidelines (restriction on the number of components) on vertical stacking on ground have been included.
n) The time for which a chosen component of a lot to be loaded as per the load test has been modified.
p) Provisions for tolerances in erection and associated design considerations have been included.
q) An annex has been included on common defects, their causes and remedies which cover dimensional deviations, cracks, honeycombing, damages, strand slippage, alignment, etc.

The information contained in this Subsection is largely based on IS 15916 : 2010 'Building design and erection using prefabricated concrete — Code of practice'. Annex A provides information relating to common defects and remedies related prefabricated concrete construction.

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7A Prefabricated Concrete

1 SCOPE

This Code (Part 6/Subsection 7A) gives recommendations regarding modular planning, component sizes, prefabrication systems, design considerations, joints and manufacture, storage, transportation and erection of prefabricated concrete elements for use in buildings and such related requirements for prefabricated concrete.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply.

2.1 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.2 Basic Module — The fundamental module used in modular coordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

2.3 Cellular Concrete — The material consisting of an inorganic binder (such as lime or cement or both) in combination with a finely ground material containing siliceous material (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and/or steam cured under high pressure in autoclaves.

2.4 Components — A building product formed as a distinct unit having specified sizes in three dimensions.

2.5 Composite Members — Structural members comprising prefabricated structural units of steel, prestressed concrete or reinforced concrete and cast *in-situ* concrete connected together in such a manner that they act monolithically.

2.6 Diaphragm — It is a horizontal or nearly horizontal structural system (for example, reinforced concrete floors and horizontal bracing systems), which transmits lateral forces to vertical elements that resist earthquake-induced inertia effects.

2.7 Increments — Difference between two homologous dimensions of components of successive sizes.

2.8 Light-Weight Concrete — Concrete of substantially lower unit weight than that made from gravel or crushed stone.

2.9 Module — A unit of size used in dimensional coordination.

2.10 Modular Coordination — Dimensional coordination employing the basic module or a multimodule.

NOTE — The purposes of modular co-ordination are,

a) to reduce the variety of component sizes produced, and

b) to allow the building designer greater flexibility in the arrangement of components.

2.11 Modular Grid — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multimodule. This multimodule may differ for each of the two dimensions of the grid.

2.12 Multimodule — A module whose size is a selected multiple of the basic module.

2.13 Prefabricate — To fabricate components or assembled units prior to erection or installation in a building.

2.14 Prefabricated Building — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

2.15 Sandwich Concrete Panels — Panels made by sandwiching an insulation material between two layers of reinforced/prestressed concrete to act as insulation for concrete panels.

2.16 Self Compacting Concrete — Concrete that is able to flow under its own weight and completely fill the voids within the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

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2.17 Shear Connectors — Structural elements, such as anchors, studs, channels, loops and spirals, intended to transmit the shear between the prefabricated member and the cast *in-situ* concrete and also to prevent separation at the interface.

2.18 System — It is a particular method of construction of buildings with certain order and discipline using the prefabricated components which are inter-related in functions and are produced based on a set of instructions.

2.19 Unit — Building material formed as a simple article with all three dimensions specified, complete in itself but intended to be part of a compound unit or complete building. Examples are brick, block, floor panel, wall panel, etc.

2.20 Emulative Detailing System — A connection detailing system for precast concrete structures that has structural performance equivalent to that of a conventionally designed, *cast-in-situ*, monolithic concrete structure

2.21 Jointed Detailing System — A connection detailing system for precast concrete structures that has individual precast components separated from each other but connected using special connections such as welded or bolted plates.

3 MATERIALS, PLANS AND SPECIFICATIONS

3.1 Materials

Use of materials for plain, reinforced concrete and prestressed concrete shall satisfy the requirements of Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete and Subsection 5B Prestressed Concrete' of the Code. Connections and jointing materials shall be in accordance with **8.3**.

3.1.1 While selecting the materials for prefabrication, the following characteristics shall be considered:

a) Easy availability;
b) Light weight for easy handling and transport;
c) Strength;
d) Thermal insulation property;
e) Easy workability;
f) Water absorption;
g) Serviceability along with durability;
h) Non-combustibility/fire resistance rating;
j) Sound insulation;
k) Easy assembly and compatibility to form a complete unit;
m) Economy; and
n) Any other special requirement in a particular application.

3.2 Plans and Specifications

The detailed plans and specifications shall cover the following:

a) Such drawings shall describe the elements and the structure and assembly including all required data of physical properties of component materials, material specification, strength of concrete for demoulding, casting/ erection tolerance and type of curing to be followed.
b) Details of connecting joints of prefabricates shall be given to an enlarged scale.
c) Site or shop location of services, such as installation of piping, wiring or other accessories integral with the total scheme shall be shown separately.
d) Data sheet indicating the location of the inserts and acceptable tolerances for supporting the prefabricate during erection, location and position of doors/windows/ventilators, etc, if any.
e) The drawings shall also clearly indicate location of handling arrangements for lifting and handling the prefabricated elements. Sequence of erection with critical check points and measures to avoid stability failure during construction stage of the building.

4 MODULAR COORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

4.1 Modular Coordination

The basic module shall be adopted. After adopting this, further work is necessary to outline suitable range of multimodules with greater increments, often referred to as preferred increments. A set of rules as detailed below would be adequate for meeting the requirements of conventional and prefabricated construction.

These rules relate to the following basic elements:

a) The planning grid in both directions of the horizontal plan shall be:
   1) 15 *M* for industrial buildings, and
   2) 3 *M* for other buildings.

   The centre lines of load bearing walls should preferably coincide with the gridlines.
b) The planning module in the vertical direction shall be 2 *M for* industrial buildings and 1 *M* for other buildings.

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c) Preferred increments for sill heights, doors, windows and other fenestration shall be 1 *M*.

d) In the case of internal columns, the grid lines shall coincide with the centre lines of columns. In case of external columns and columns near the lift and stair wells, the grid lines shall coincide with centre lines of the column in the topmost storey.

4.2 Architectural Treatment and Finishes

In general, prefabricated systems provide better opportunity to achieve superior finishes leading to an array of aesthetically pleasing options. The architectural elevational treatments, form and features can also be effectively incorporated in the structures with careful advanced planning. In addition, detailed coordination between the architectural and structural design team during the planning stage for panel joints and false joints is necessary. The purpose of finishes and architectural treatment is not only to give prefabricated buildings an individual character but also to effect better performance and greater user satisfaction.

Treatment and finishes have to be specified keeping in view the requirements of protection, function and aesthetics of internal and external spaces and surfaces.

While deciding the type of architectural treatment and finishes for prefabricated buildings, the following points should be kept in view:

a) Suitability for mass production techniques;

b) Recognition of the constraints imposed by the level of workmanship available;

c) Possibility of using different types of finishes;

d) Use of finishes and architectural treatment for the creation of a particular architectural character in individual buildings and in groups of buildings by the use of colour, texture, projections and recesses on surfaces, etc;

e) Incorporation of structural elements like joists, columns, beams, etc, as architectural features and the treatment of these for better overall performance and appearance;

f) Satisfactory finishing of surfaces; and

g) Use of light weight materials to effect economy in the structural system.

Some of the acceptable methods of finishes integral with the precasting are:

1) Concrete surface moulded to design/shape;

2) Laid-on finishing tiles fixed during casting;

3) Finishes obtained by washing, tooling, grinding, grooving of hardened concrete;

4) Exposed aggregates; and

5) Other integral finishes.

5 COMPONENTS

5.1 The dimensions of precast elements shall meet the design requirements. However, the actual dimensions shall be the preferred dimensions as follows:

a) *Flooring and roofing scheme* — Precast slabs or other precast *s*tructural flooring units:

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.5 *M*; and

3) *Overall Thickness* — Overall thickness shall be in multiples of 0.1 *M*.

b) *Beams*:

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and

3) *Overall Depth* — Overall depth of the floor zone shall be in multiples of 0.1 *M*.

c) *Columns*:

1) *Height* — Height of columns for industrial building and other buildings shall be in multiples of 1 *M; and*

2) *Lateral Dimensions* — Overall lateral dimension or diameter of columns shall be in multiples of 0.1 *M*.

d) *Walls*:

Thickness — The nominal thickness of walls shall be in multiples of 0.1 *M*.

e) *Staircase:*

Width — Nominal width shall be in multiples of 1 *M*.

f) *Lintels*:

1) *Length* — Nominal length shall be in multiples of 1 *M*;

2) *Width* — Nominal width shall be in multiples of 0.1 *M*; and

3) *Depth* — Nominal depth shall be in multiples of 0.1 *M*.

g) *Sunshades/Chajja Projections*:

1) *Length* — Nominal length shall be in multiples of 1 *M*.

2) *Projection* — Nominal length shall be in multiples of 0.5 *M*.

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5.2 Casting Tolerances of Precast Components

Sl No.	*Product Tolerances*	*Product (see Key No.)*
(1)	(2)	(3)
i)	Length:	
	a) ± 5 mm	1, 7
	b) ± 5 mm or ± 0.1 percent, whichever is greater	2, 3, 8
	c) ± 0.1 percent subject to maximum of $^{+5}_{-10}$ mm	4
	d) 1) ± 2 mm for length below and up to 500 mm 2) ± 5 mm for length over 500 mm	5
	e) ±10 mm	6, 9,10
ii)	Thickness/cross-sectional dimensions:	
	a) ± 3 mm	1
	b) ± 3 mm or 0.1 percent, whichever is greater	2, 8
	c) 1) ± 2 mm up to 300 mm wide 2) ± 3 mm greater than 300 mm wide	4, 5
	d) ± 2 mm	3, 7
	e) ± 4 mm	6, 9, 10
iii)	Straightness/Bow:	
	a) ± 5 mm or 1/750 of length, whichever is greater	2, 4, 8
	b) ± 3 mm	1, 5
	c) ± 2 mm	7
iv)	*Squareness* — When considering the squareness of the corner, the longer of two adjacent sides being checked shall be taken as the base line, and the following tolerances shall apply:	
	a) The longer side shall not vary in length from the perpendicular by more than 5 mm	2, 5, 8
	b) The shorter side shall not vary in length from the perpendicular by more than 3 mm	1, 7
	c) The shorter side shall not be out of square line for more than $^{+2}_{-5}$ mm	4
v)	*Twist* — Any corner shall not be more than the tolerance given below from the plane containing the other three corners:	
	a) 1) Up to 600 mm in width and up to 6 m in length — 5 mm 2) Over 600 mm in width and for any length — 10 mm	2, 8
	b) ± 1/1 500 of dimension or ± 5 mm. whichever is less	4
	c) ± 3 mm	1
	d) ± 1 mm	7
vi)	*Flatness* — The maximum deviation from 1.5 m straight edge placed in any position on a nominal plane surface shall not exceed:	
	a) ± 5 mm	2, 8
	b) ± 3 mm	4
	c) ± 2 mm	1, 7
	d) ± 4 mm or maximum of 0.1 percent length	5

Key No. for product reference:

1 Channel unit.
2 Ribbed slab unit/hollow slab.
3 Waffle unit.
4 Large panel prefabrication.
5 Cellular concrete floor/roof slabs.
6 Prefabricated brick panel.
7 Precast planks.
8 Ribbed/plain wall panel.

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6 PREFABRICATION SYSTEMS AND STRUCTURAL SCHEMES

6.1 The word 'system' refers to a particular method of construction of buildings using the prefabricated components which are inter-related in functions and are produced to a set of instructions. With certain constraints, several plans are possible, using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

6.2 The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low rise and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection;
n) Effective utilization of available equipment, plant and machinery; and
p) Simple jointing system.

6.3 Prefabrication Systems

The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

6.3.1 *Types of Prefabrication Components*

The prefabricated concrete components such as those given below may be used which shall be in accordance with relevant Indian Standards (*see* Part 5 'Building Materials' of the Code) and the accepted standards [6-7A(1)], where available:

a) Reinforced/prestressed concrete channel unit,
b) Reinforced/prestressed concrete slab unit,
c) Reinforced/prestressed concrete beams,
d) Reinforced/prestressed concrete columns,
e) Reinforced/prestressed concrete hollow core slab,
f) Reinforced concrete waffle slab/shells,
g) Reinforced/prestressed concrete wall elements,
h) Hollow/solid concrete blocks and battens,
j) Precast planks and joists for flooring and roofing,
k) Precast joists and trussed girders,
m) Light weight/cellular concrete slabs/wall panels,
n) Precast lintel and *Chajjas*,
p) Large panel prefabricates,
q) Reinforced/prestressed concrete trusses,
r) Reinforced/prestressed roof purlins,
s) Precast concrete L-panel unit,
t) Prefabricated concrete double-T unit,
u) Prefabricated brick panel unit,
w) Prefabricated sandwich concrete panels,
y) Precast concrete foundation, and
z) Precast concrete staircase.

There may be other types of components which may be used with the approval of the Authority.

NOTE — The elements may be cast at the site or off the site.

6.3.2 *Open Prefabrication System*

There are two categories of open prefab system depending on the extent of prefabrication used in the construction as given in **6.3.2.1** and **6.3.2.2**.

6.3.2.1 *Partial prefabrication system*

This system basically uses precast roofing and flooring components and other minor elements like lintels, *Chajjas*, kitchen sills in conventional building construction. The structural system could be in the form of *in-situ* framework or load bearing walls.

6.3.2.2 *Full prefabrication system*

In this system almost all the structural components are prefabricated. The filler walls may be of brick/block masonry or of any other locally available material.

6.3.3 *Large Panel Prefabrication System*

This system is based on the use of large prefab components. The components used are precast concrete large panels for walls, floors, roofs, balconies, staircases, etc. The casting of the components could be at the site or off the site.

Depending upon the extent of prefabrication, this system can also lend itself to partial prefab system and full prefab system.

Structural scheme with precast large panel walls can be classified as given in **6.3.3.1** to **6.3.3.3**.

6.3.3.1 *Precast Walls*

6.3.3.1.1 Based on the structural functions of the walls, the precast walls may be classified as:

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a) Load bearing walls,
b) Non-load bearing walls, and
c) Shear walls.

6.3.3.1.2 Based on construction, the precast walls may be classified as:

a) *Homogeneous walls* — which could be solid, hollow or ribbed; and

b) *Non-homogeneous walls* — these could be composite or sandwich panels.

6.3.3.1.3 Based on their locations and functional requirements the precast walls may also be classified as:

a) External walls, which may be load bearing or non-load bearing depending upon the lay-out; these are usually non-homogeneous walls of sandwiched type to impart better thermal comfort; they can also act as shear walls to resist horizontal loads with appropriate design and

b) Internal walls providing resistance against vertical loads, horizontal loads, fire, etc; these are normally homogeneous walls.

6.3.3.2 *Precast floors*

6.3.3.2.1 Depending upon the composition of units, precast flooring units may be classified as:

a) *Homogeneous floors* — which may be of solid slabs, cored slabs, ribbed or waffle slabs and precast slabs with structural topping (60-75 mm thick) designed as a composite system; and

b) *Non-homogeneous floors* — which may be of multi-layered units with combinations of light weight concrete or reinforced/prestressed concrete, with filler blocks.

6.3.3.2.2 Depending upon the way the loads are transferred, the precast floors may be classified as one way, two way or cantilever systems:

a) One way system transfers loads to supporting members in one direction only. The precast elements which come under this category are channel slabs, hollow core slabs, channels and ties system, light weight/cellular concrete slabs, etc.
b) Two way systems transfers loads in both the directions imparting loads on the four edges. The precast elements under this category are room sized panels, two way ribbed or waffle slab systems, etc.
c) Cantilever components are supported on one edge or two adjacent edges and other ends without supports.

6.3.3.3 *Staircase systems*

Staircase system may consist of single flights with in-built risers and treads in the element. The flights are normally unidirectional transferring the loads to supporting landing slabs or load bearing walls.

6.3.4 *Box Type Construction*

In this system, room size units are prefabricated and erected at site. Toilet and kitchen blocks may also be similarly prefabricated and erected at site.

NOTE — This system derives its stability and stiffness from the box units which are formed by four adjacent walls. Walls are jointed to make rigid connections among themselves. The box unit rests on foundation - conventional or precast.

7 DESIGN CONSIDERATIONS AND REQUIREMENTS

7.1 Design Considerations

7.1.1 Precast structures could be analyzed either as an emulative systems or as a jointed system. However, emulative analysis is typically preferred where the structure is detailed such that the overall behaviour of the building in its service life will be similar to a RCC building constructed *in-situ*. In emulative approach, the precast structure is analyzed as a monolithic one and the joints in them designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by having appropriate moment and shear resisting joints or placing shear walls (in diaphragm braced frame type of construction) in two directions at right angles or otherwise. No account is to be taken of rotational stiffness, if any, of the floor-wall joint in case of precast bearing wall buildings. The individual components shall be designed, taking into consideration the appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads and reactions in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. In addition, members shall be designed for handling, erection and impact loads that might be expected during handling and erection.

NOTE — Rotational stiffness can be accounted for long/short term deflection calculations provided that the approach is mutually agreed by the design team and approved by the Authority.

7.1.2 In some conventional forms of construction, experience has shown that structures are capable of safely sustaining abnormal conditions of loading and remaining stable after the removal of primary structural members. It has been shown that some forms of building structure and particularly some industrialized large

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panel systems have little reserve strength to resist forces not specifically catered for in the design. In light of this, therefore, recommendations made in **7.1.3** to **7.1.10** should be kept in mind for ensuring stability of such structure.

7.1.3 Adequate buttressing of external wall panels is important since these elements are not fully restrained on both sides by floor panels. Adequate design precautions may be taken by the designer. External wall panel connections are likely to be the weakest points of a precast panel building, if not designed properly.

7.1.4 It is equally important to provide restraint to all load bearing elements at the corners of the building. These elements and the external ends of cross-wall units should be stiffened either by introducing columns as connecting units or by jointing them to non-structural wall units which in emergency may support the load. Jointing of these units should be done bearing in mind the need for load support in an emergency.

7.1.5 In prefabricated construction, the possibility of gas or other explosions which can remove primary structural elements leading to progressive collapse of the structure shall be taken into account. It is, therefore, necessary to consider the possibility of progressive collapse in which the failure or displacement of one element of a structure causes the failure or displacement of another element and results in the partial or total collapse of the building.

7.1.6 Provision in the design to reduce the probability of progressive collapse is essential in buildings of over six storeys and is of relatively higher priority than for buildings of lower height.

7.1.7 It is necessary to ensure that any local damage to a structure does not spread to other parts of the structure remote from the point of mishap and that the overall stability is not impaired, but it may not be necessary to stiffen all parts of the structure against local damage or collapse in the immediate vicinity of a mishap, unless the design briefs specifically requires this to be done. The requirements as specified at **7.2** shall be followed to prevent progressive collapse of the structure.

7.1.8 Additional protection may be required in respect of damage from vehicles; further, it is necessary to consider the effect of damage to or displacement of a load-bearing member by an uncontrolled vehicle. It is strongly recommended that important structural members are adequately protected by concrete kerbs or similar method.

In areas with possibility of passenger vehicular impact, the precast components should be designed for a horizontal load of 27 kN, in any direction, acting at heights between 450 mm and 700 mm on an area not larger than 300 mm × 300 mm to produce maximum load effect. This load is not required to act concurrently with any handrail or guard rail system loads.

7.1.9 In all aspects of erection that affect structural design, it is essential that the designer should maintain a close liaison with the builder/contractor regarding the erection procedures to be followed.

7.1.10 Failures that have occurred during construction appear to be of two types. The first of these is the pack-of-cards type of collapse in which the absence of restraining elements, such as partitions, cladding or shear walls, means that the structure is not stable during the construction period. The second is the situation in which one element falls during erection and lands on an element below. The connections of the lower element then give way under the loading, both static and dynamic, and a chain reaction of further collapse is set up.

7.1.10.1 A precaution against the first form of failure is that the overall stability of a building shall be considered in all its erection stages as well as in its completed state. All joints that may be required to resist moments and shears during the erection stage only, shall be designed with these in mind. Temporary works required to provide stability during construction shall be designed carefully.

7.1.10.2 To guard against the second form of failure, that is, the dropping of a unit during erection, particular attention shall be given to the details of all pre-formed units and their to ensure that they are sufficiently robust to withstand the maximum stresses that can arise from site conditions. Precast concrete construction generally shall be capable of withstanding the impact forces that can arise from bad workmanship on site.

7.1.11 The design shall take care of requirements owing to erection given at **10.11**.

7.1.12 In case of buildings whose floors are capable of providing rigid horizontal diaphragm action, the total shear in any horizontal plane shall be distributed to the various vertical elements of lateral forces resisting system, assuming the floors to be infinitely rigid in the horizontal plane.

In case of building whose floor diaphragms cannot be treated as infinitely rigid in their own plane, the lateral shear at each floor shall be distributed to the vertical elements resisting the lateral forces, considering the in-plane flexibility of the diaphragms.

NOTES

1 A floor diaphragm shall be considered to be flexible, if it deforms such that the maximum lateral displacement measured from the chord of the deformed shape at any point of the diaphragm is more than 1.5 times the average displacement of the entire diaphragm.

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2 Reinforced concrete monolithic slab-beam floors or those consisting of prefabricated/precast elements with topping reinforced screed can be taken as a rigid diaphragm.

7.1.12.1 Floor systems play a key role in the lateral resistance of building structures by providing diaphragm action. Diaphragm action serves to,

a) transfer lateral loads at each level to the lateral load-resisting elements (walls, frames); and
b) unite individual lateral load-resisting elements into a single lateral load-resisting system.

These actions are crucial in allowing the lateral (load-resisting) system to perform as intended. Diaphragm action occurs by virtue of the in-plane stiffness inherent in the floor system. Accordingly, significant in-plane forces may develop in the diaphragm during lateral loading. In this regard, the panelled nature of floor systems in precast concrete construction can present challenges in the seismic design of diaphragms. These design challenges may pertain to providing adequate strength, stiffness and in cases, ductility in the diaphragm and diaphragm connections.

7.1.12.2 *Standard analysis methods for diaphragm design*

The magnitude of the inertia force at each floor level is estimated using a capacity design approach or a diaphragm design force distribution based on equivalent lateral loads. A key design step is to transform the diaphragm design forces into internal actions. For regular floor plans, a 'horizontal plate girder' analogy is typically used in design. In this approach, diaphragm design forces are typically applied at each level as a distributed in-plane load along the length of the diaphragm. The resulting girder internal forces are used to determine the amount of flexural reinforcement (chord steel), shear (web) reinforcement, and lateral system reaction load path reinforcement (collector steel). An irregular mass distribution in plan may require the design forces to take on a smeared load configuration as the mass distribution with respect to diaphragm depth has relevance in determining the proper web reinforcement.

For more complex diaphragm configurations, a strut-and-tie method can be used. However, there is compelling evidence that the strut-and-tie method accurately predicts the behaviour of floor diaphragms in general and may become the preferred method of diaphragm analysis. *See* Fig. 1 and Fig. 2.

7.2 Design Requirements for Safety Against Progressive Collapse

7.2.1 Prefabricated buildings shall be designed with proper structural integrity to avoid situations where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure.

The following precaution may generally provide adequate structural integrity:

a) All buildings should be capable of safely resisting the minimum horizontal load of 1.5 percent of characteristic dead load applied at each floor or roof level simultaneously (*see* Fig. 3).
b) All buildings shall be provided with effective horizontal ties,
   1) around the periphery;
   2) internally (in both directions); and
   3) to columns and walls.
c) All buildings of five or more storeys shall be provided with vertical ties.

In proportioning the ties, it may be assumed that no other forces are acting and the reinforcement is acting at its characteristic strength (that is, the material factor of safety is not applicable).

Normal procedure may be to design the structure for the usual loads and then carry out a check for the tie forces.

7.2.2 *Continuity and Anchorage of Ties*

Bars shall be lapped, welded or mechanically joined as in accordance with Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

7.2.3 *Design of Ties*

7.2.3.1 *Peripheral ties*

At each floor and roof level an effectively continuous tie should be provided within 1.2 m of the edge of the building or within the perimeter wall (*see* Fig. 4).

The tie should be capable to resist a tensile force of F_t equal to 60 kN or $(20 + 4N)$ kN whichever is less, where N is the number of storeys (including basement).

7.2.3.2 *Internal ties*

These are to be provided at each floor and roof level in two directions approximately at right angles. Ties should be effectively continuous throughout their length and be anchored to the peripheral tie at both ends, unless continuing as horizontal ties to columns or walls (*see* Fig. 5). The tensile strength, in kN per metre width shall be the greater of,

$$\frac{(g_k + q_k)}{7.5} \cdot \frac{l_r F_t}{5} \text{ and } 1.5\, F_t$$

where $(g_k + q_k)$ is the sum of average characteristic dead and imposed floor loads, in kN/m^2, and l_r is the

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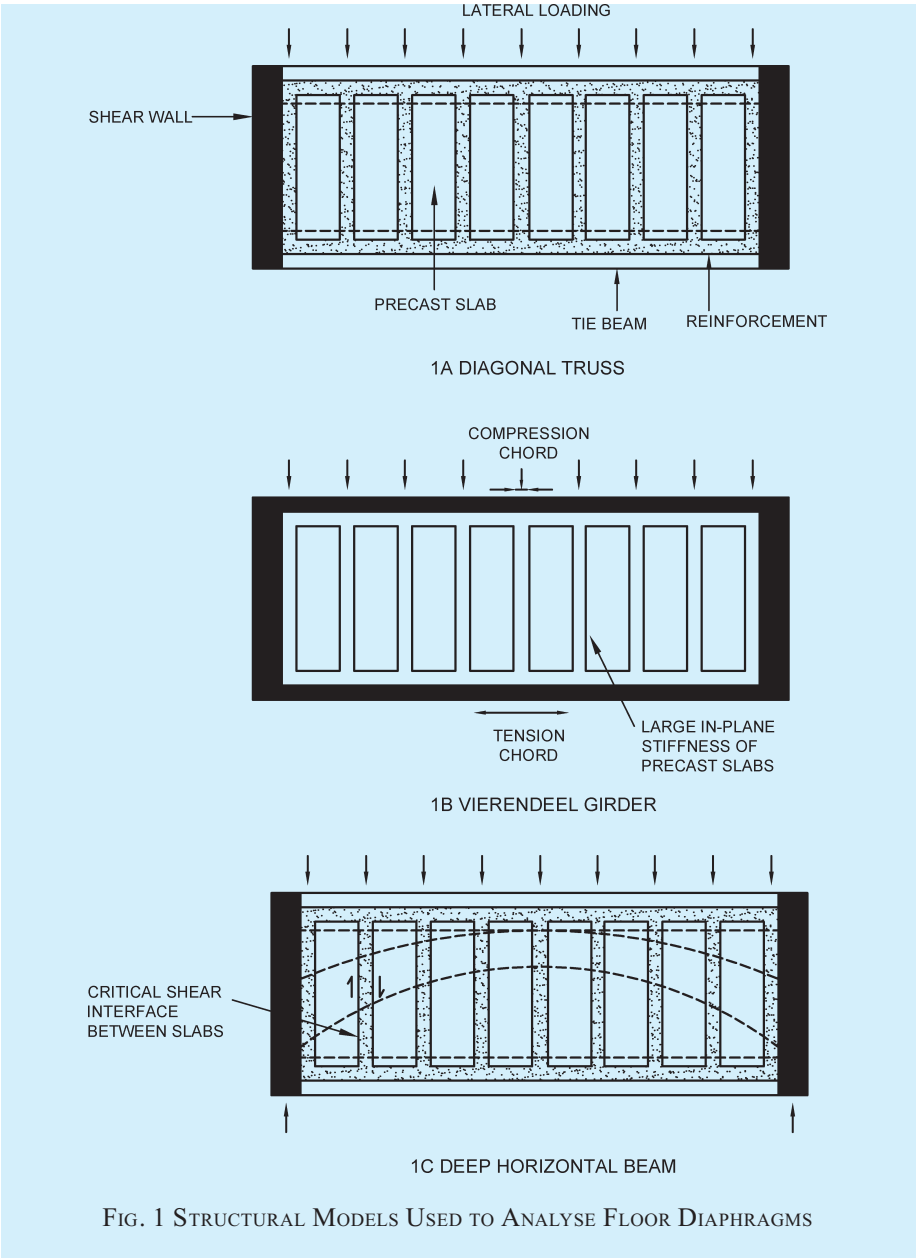


FIG. 1 STRUCTURAL MODELS USED TO ANALYSE FLOOR DIAPHRAGMS

greater of the distance between the centre of columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration.

The bars providing these ties may be distributed evenly in the slabs (*see* Fig. 6) or may be grouped at or in the beams, walls or other appropriate positions but at spacings generally not greater than 1.5 l_r.

7.2.3.3 *Horizontal ties to column and wall*

All external load-bearing members such as columns and walls should be anchored or tied horizontally into the structure at each floor and roof level. The design force for the tie is to be greater of,

a) $2F_t$ kN or $l_s \times F_t/2.5$ kN, whichever is less for a column or for each metre length if there is a wall (l_s is the floor to ceiling height in metre).

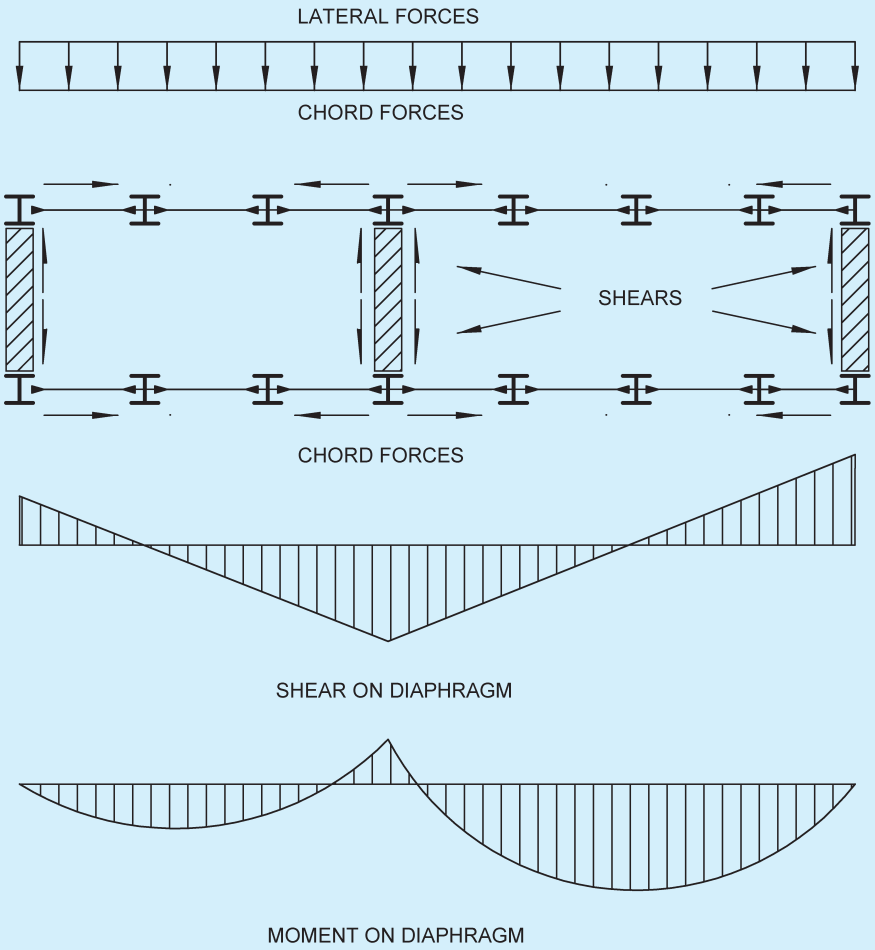
b) 3 percent of the total ultimate vertical load in the column or wall at that level.

For corner columns, this tie force should be provided in each of two directions approximately at right angles.

7.2.3.4 *Vertical ties (for buildings of five or more storeys)*

Each column and each wall carrying vertical load should be tied continuously from the foundation to the roof level. The reinforcement provided is required only to resist a tensile force equal to the maximum design ultimate load (dead and imposed) received from any one storey.

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NOTE — The floor deck is assumed to act as the web of the continuous beam and the beams at the floor periphery are assumed to act as the flanges of the continuous beam

FIG. 2 DESIGN FORCES ON A DIAPHRAGM

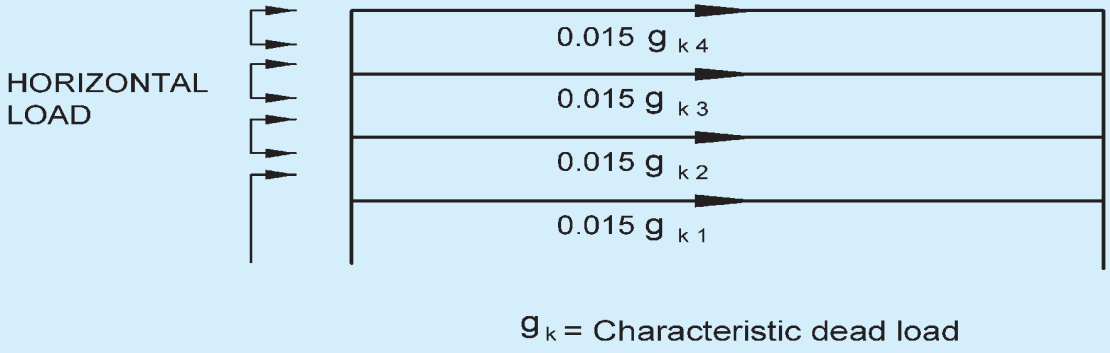


FIG. 3 HORIZONTAL LOADS

In situation where provision of vertical ties cannot be done, the element should be considered to be removed and the surrounding members designed to bridge the gap.

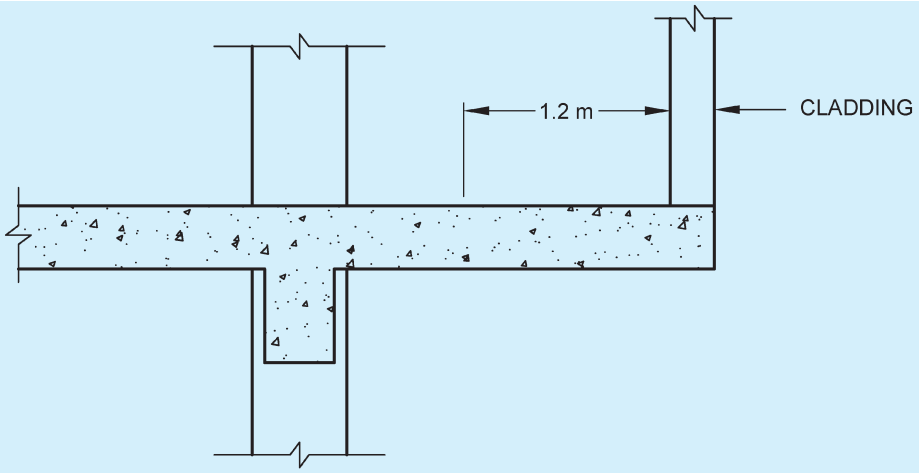
7.2.4 *Key Elements*

For buildings of five or more storeys, the layout should be checked to identify key elements. A key element is such that its failure would cause the collapse of more than a limited area close to it.

The limited area defined above may be taken equal to 70 m^2 or 15 percent of the area of the storey, whichever is lesser.

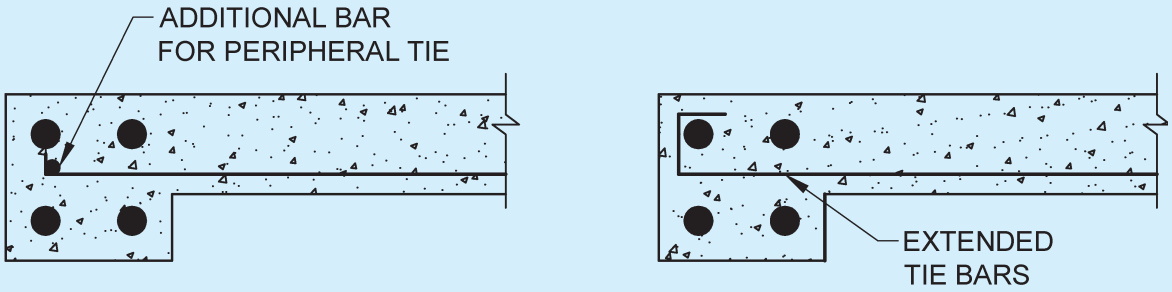
If key elements exists, it is preferable to modify the layout so that the key element is avoided.

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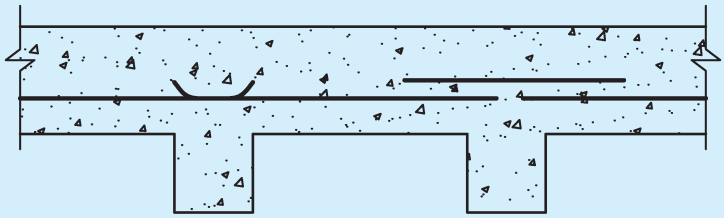
NOTE — If there are cantilever slabs, supporting external cladding, projecting in front of the columns and these are more than 1.2 m, than peripheral tie shall go in the slab.

FIG. 4 POSITION FOR PERIPHERAL TIE



NOTE — If the peripheral tie consists of bars in an edge beam, then the bottom bars in the slabs will not be at the same level as the peripheral tie bars. It is suggested that either an additional bar be used for the peripheral tie or the internal tie bars be extended and anchored around the top bar in the beam.

FIG. 5 ANCHORING OF TIES IN SLABS



NOTE — For continuity in continuous slabs, bars are distributed evenly in a floor slab by means of lapping some bottom steel at supports, either by extending existing bars or by the addition of splice bars.

FIG. 6 CONTINUITY REQUIREMENT FOR SLAB

7.3 Bearing for Precast Units

7.3.1 *Jointed Precast Detailing*

The precast units shall have a bearing of at least of 100 mm on masonry supports and of 75 mm at least on steel or concrete. Steel angle shelf bearings shall have a 100 mm horizontal leg to allow for a 50 mm bearing exclusive of fixing clearance. When deciding to what extent, if any, the bearing width may be reduced in special circumstances, factors, such as loading, span, height of wall and provision of continuity, shall be taken into consideration.

7.3.2 *Emulative Precast Detailing*

In emulative precast detailing, the structure under service conditions behaves similar to a cast-in-situ structure and inherits the redundancy due to continuity. Typically, the components are tied together with appropriate steel ties and connected using a *cast-in-situ* 'stitch' concrete pour for near monolithic continuity. The bearing for the building components thus becomes a critical concern only during the erection stages. The precast members, in emulative detailing system, shall have a bearing of at

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least 40 mm on concrete support components. In cases, where the supports are in steel or masonry system where emulative detailing is not followed in local limited areas, bearing of at least 75 mm for steel support and 100 mm for masonry support should be provided. Otherwise, for both systems, bearing of at least 40 mm should be provided at the structural engineer's discretion. In special circumstances, where additional temporary supports/ shoring is provided during erection, bearing of at least 25 mm should be acceptable at the structural engineer's discretion. Such temporary supports shall be kept in place until the 'stitch' concrete pour gains at least 70 percent of the final design strength.

8 JOINTS

8.1 The design of joints shall be made in the light of their assessment with respect to the following considerations:

a) *Feasibility* — The feasibility of a joint shall be determined by its load carrying capacity in the particular situation in which the joint is to function.

b) *Practicability* — Practicability of joint shall be determined by the amount and type of material required in construction; cost of material, fabrication and erection and the time for fabrication and erection.

c) *Serviceability* — Serviceability shall be determined by the joints/expected behaviour to repeated or possible overloading and exposure to climatic or chemical conditions.

d) *Fire rating* — The fire rating for joints of precast components shall be higher or at least equal to connecting members.

NOTE — Fire resistance testing under sustained loading may also be carried out on a prototype, as mutually agreed to between the parties concerned.

e) *Appearance* — The appearance of precast components' joints shall merge with architectural aesthetic appearance and shall not be physically prominent compared to other parts of structural components.

f) *Water tightness of joints* — In buildings, the external joints between precast elements should be water tight to ensure the durability requirements. If the joints are not water tight, it may lead to corrosion of reinforcing steel due to exposure to moisture thereby impacting the structural integrity. Also, water can enter inside the building and impact the functionality in service life of the building. In case of precast reinforced concrete wall buildings, joints of external walls, in addition to their structural efficiency, shall be watertight. For non-load bearing/façade walls the connections shall allow free movement of the walls due to temperature changes. This can be achieved by suitably shaping the joint or by sealing compounds. In load bearing external walls, the horizontal and vertical joints shall be filled with non-shrink non-metallic high strength cementitious grout followed by backer rod (bond breaker such as polyethylene film also can be used in place of backer rod) with sealant at the external side. The sealing compound shall be approved by the Engineer-in-Charge and shall have a long life to avoid frequent repair of the joints. It should be noted that the sealant is provided as an additional line of defense against water entry. In cases of moderate water exposure, the joints could be detailed with cement grout only with appropriate additional water proofing treatment instead of sealant (*see* **9.4**).

8.2 The following are the requirements of a structural joint:

a) It shall be capable of being designed to transfer the imposed load and moments with a known margin of safety;

b) It shall occur at logical locations in the structure and at points which may be most readily analyzed and easily reinforced;

c) It shall accept the loads without marked displacement or rotation and avoid high local stresses;

d) It shall accommodate tolerances in elements;

e) It shall require little temporary support, permit adjustment and demand only a few distinct operation to make;

f) It shall permit effective inspection and rectification;

g) It shall be reliable in service with other parts of the building; and

h) It shall enable the structure to absorb sufficient energy during earthquakes so as to avoid sudden failure of the structure (*see* Note). The joint should be ductile.

NOTE — If required, tests may be carried out on prototypes to assess against the above requirement.

8.2.1 Precast structures may have continuous or hinged connections subject to providing sufficient rigidity to withstand horizontal loading. When only compressive forces are to be taken, hinged joints may be adopted. In case of prefabricated concrete elements, load is transmitted *via* the concrete. When both compressive force and bending moment are to be taken, rigid or welded joints may be adopted; the shearing force is usually small in the column and can be taken up by the friction resistance of the joint. Here load transmission is accomplished by steel inserted parts together with concrete. In precast structures, it is critical to minimize

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relative movements of precast components under loads. Hence, connection details that rely solely on the frictional resistance under gravity loads are not permitted. The connections shall be designed using either the pure shear capacity of the connection element or based on the shear friction theory that takes the advantage of the frictional resistance of concrete components under gravity loads.

8.2.2 When considering thermal shrinkage and heat effects, provision of freedom of movement or introduction of restraint may be considered.

8.3 Following connections and jointing techniques/ materials may be employed:

a) Welding of cleats or projecting steel,

b) Overlapping reinforcement, loops and linking steel grouted by concrete,

c) Reinforced concrete ties all round a slab,

d) Prestressing,

e) Epoxy grouting,

f) Cement/lime grout with non-shrink additive,

g) Polymer slurry grouting at dowel cast bolts and nuts connection,

h) Rebar fastener, chemical fastener and expansion fastener,

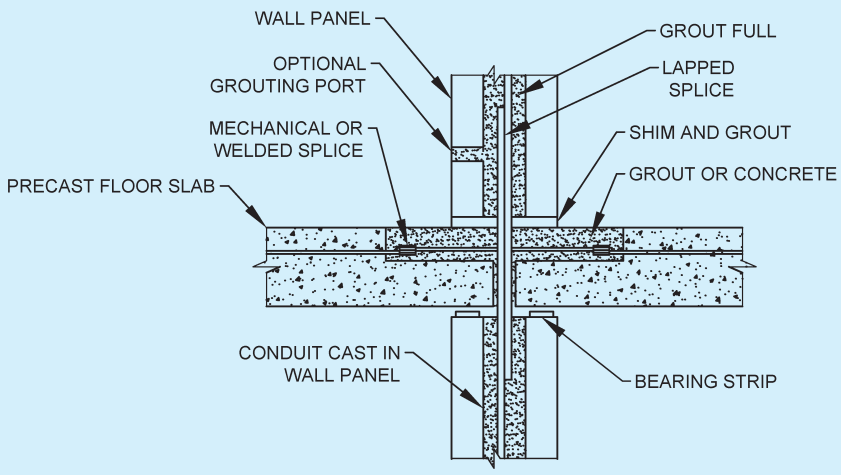
j) Reinforcement coupler,

k) Combination of the above, and

m) Any other method proven by test.

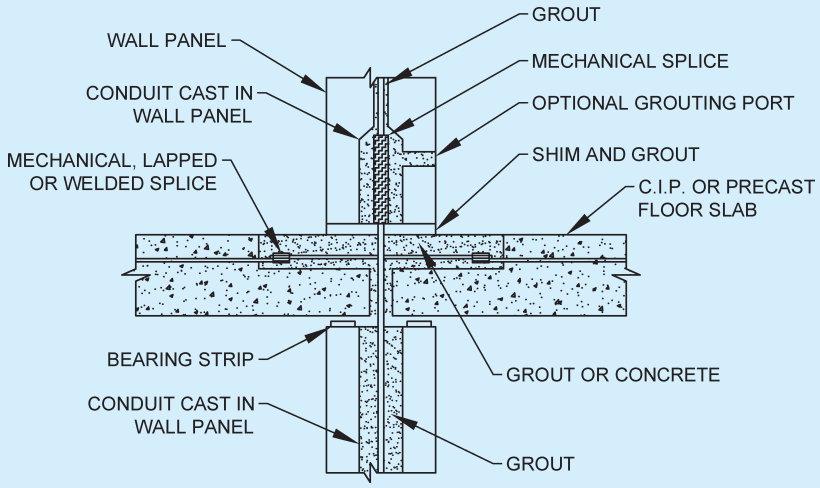
8.4 Precast Joint details

Some of the typical precast joint details have been illustrated in Fig. 7 to Fig. 24.



NOTE — Overlapping bars in grout-filled conduit are extended full-height through the structural element.

FIG. 7 LAPPED SPLICES IN LARGE CONDUIT



NOTE — Vertical bars in conduit are spliced and the system is grouted.

FIG. 8 MECHANICAL CONNECTION IN CONDUIT

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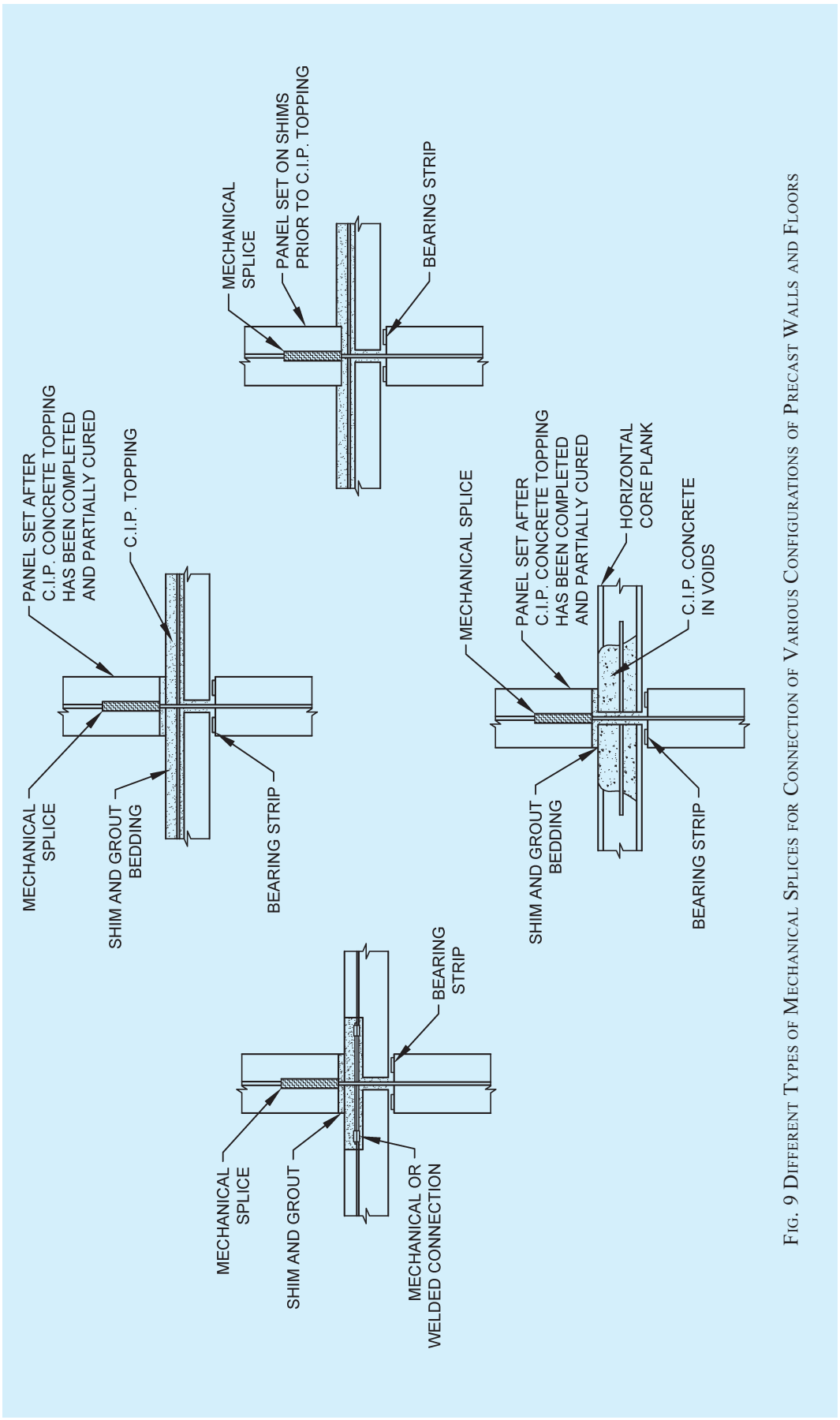


FIG. 9 DIFFERENT TYPES OF MECHANICAL SPLICES FOR CONNECTION OF VARIOUS CONFIGURATIONS OF PRECAST WALLS AND FLOORS

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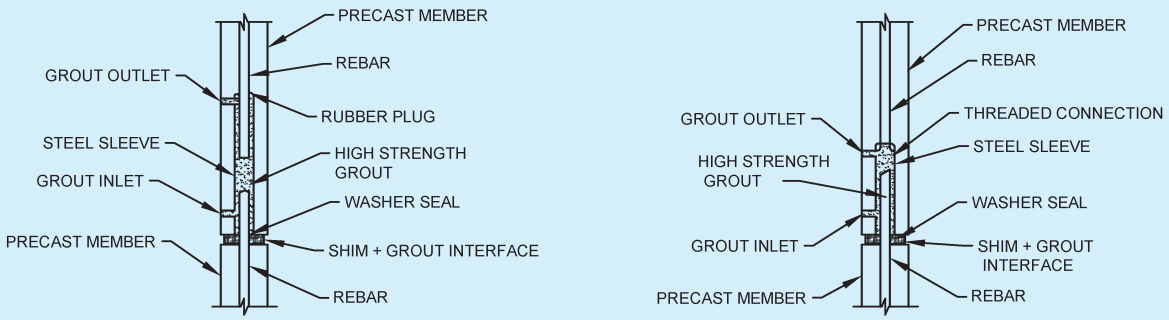


FIG. 10 SOME MECHANICAL SPLICES USING HIGH-STRENGTH NON-SHRINK GROUT

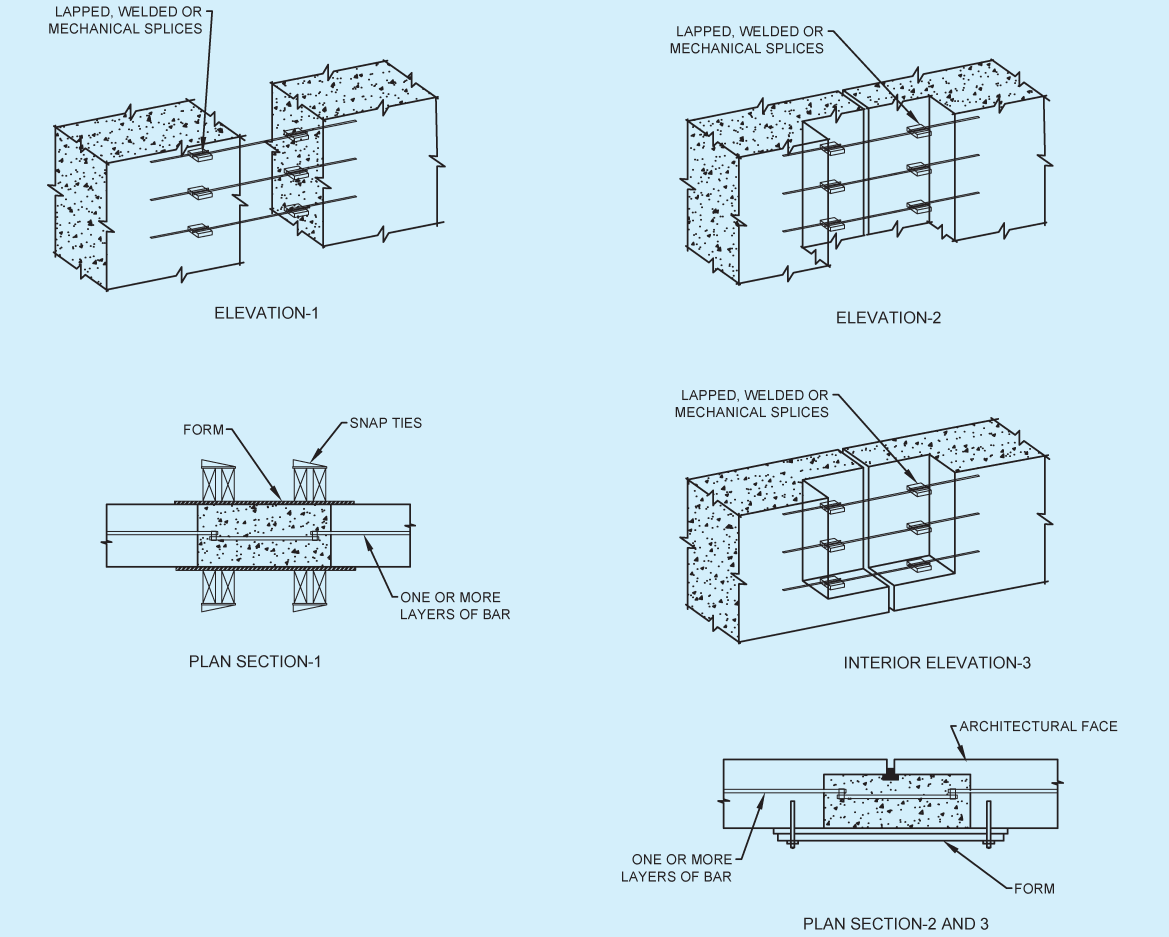


FIG. 11 VARIATIONS OF SPLICES AND CAST-IN-PLACE CLOSURE PLACEMENTS TO CREATE VERTICAL JOINTS BETWEEN PRECAST CONCRETE ELEMENTS

9 TESTS FOR COMPONENTS/STRUCTURES

9.1 Sampling Procedure

9.1.1 *Lot*

All the precast units of the same size, manufactured from the same material under similar conditions of production shall be grouped together to constitute a lot.

The number of units to be selected from each lot for dimensional requirements shall depend upon the size of the lot and shall be in accordance with col 2 and col 3 of Table 1.

The units shall be selected from the lot at random. In order to ensure the randomness of selection, reference may be made to good practice [6-7A(2)].

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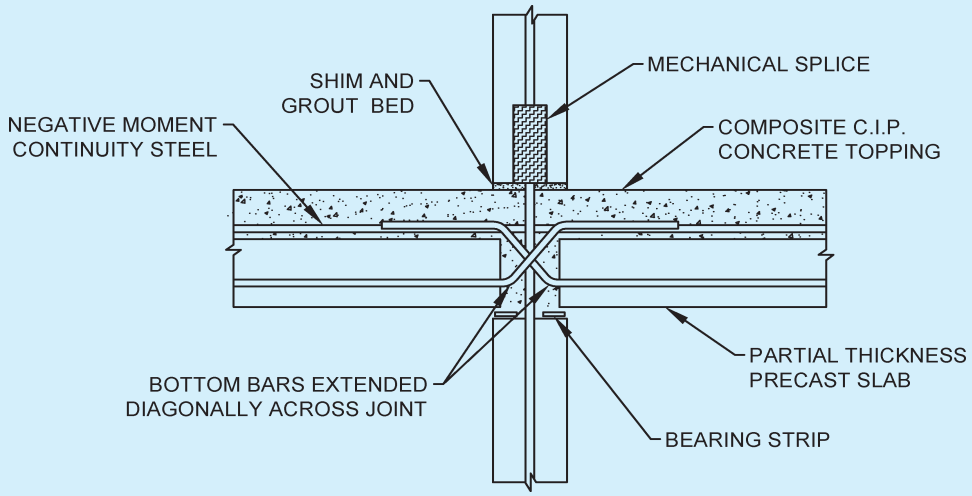


FIG. 12 FLOOR SLAB-TO-WALL DETAIL WHERE DIAGONAL DOWELS CROSS THE WALL JOINT INTO THE OPPOSITE FLOOR

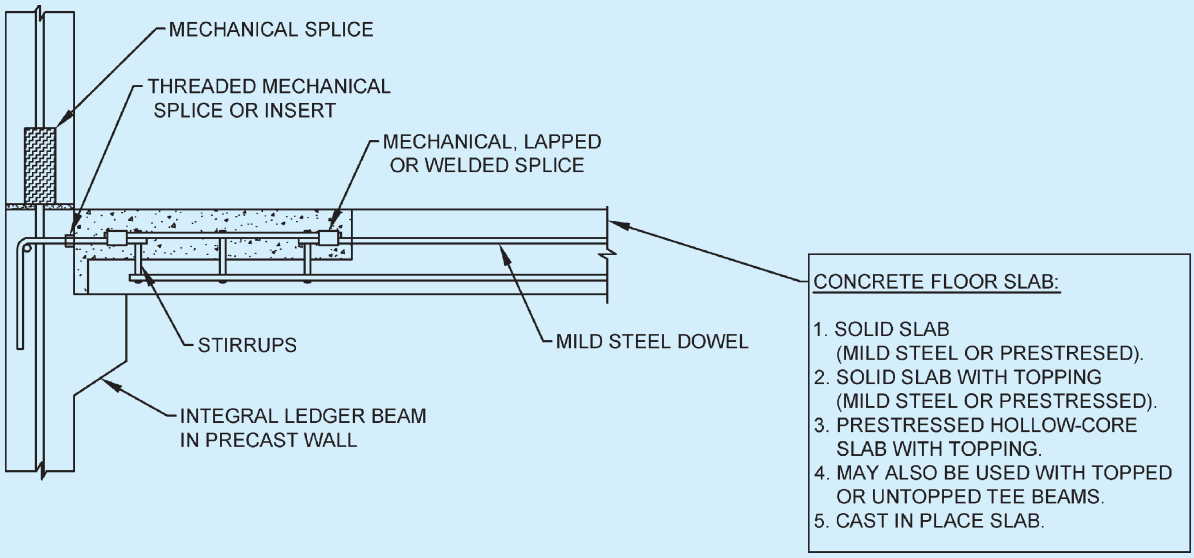


FIG. 13 END DETAIL OF A MONOLITHIC CONNECTION BETWEEN PRECAST CONCRETE FLOOR ELEMENT AND A PRECAST CONCRETE WALL

Table 1 Sample Size and Rejection Number
(*Clauses* 9.1.1 *and* 9.1.2)

Sl No.	Lot Size	First Sample Size	Second Sample Size	First Rejection Number	Second Rejection Number
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 100	5	5	2	2
ii)	101 to 300	8	8	2	2
iii)	301 to 500	13	13	2	2
iv)	500 and above	20	20	3	4

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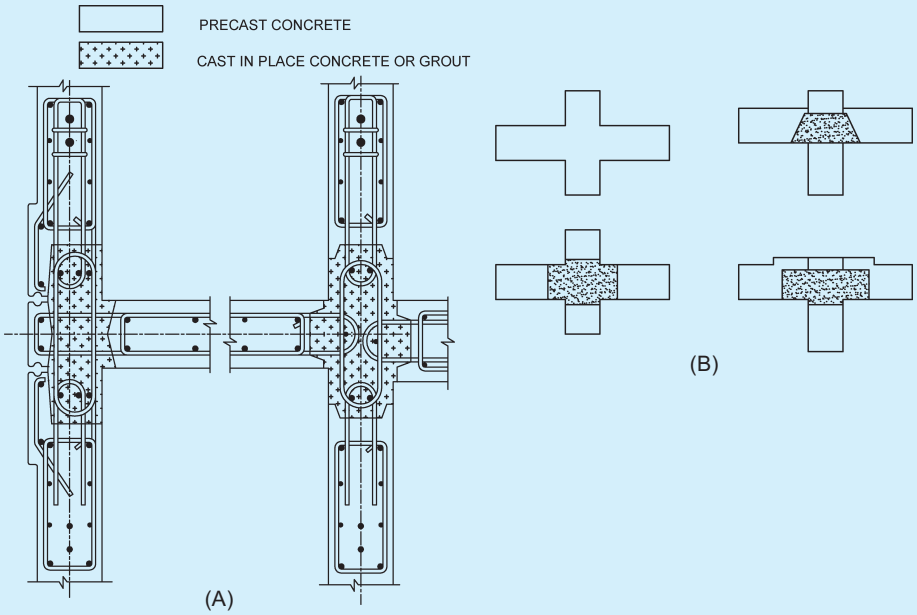
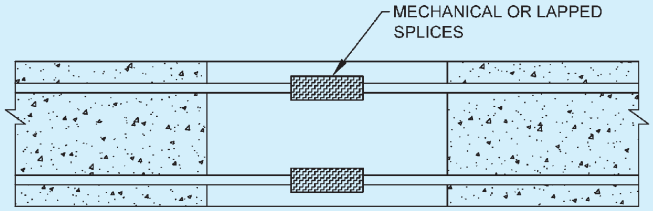
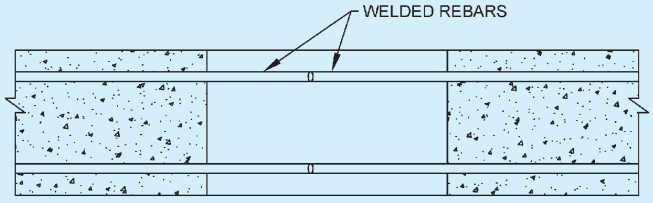


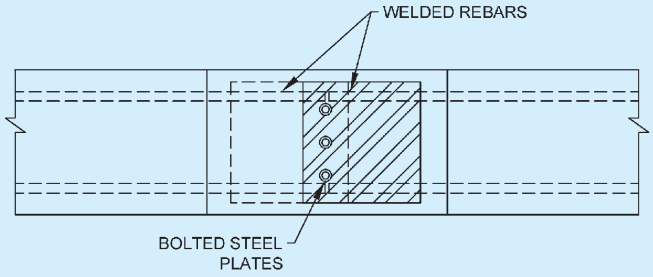
FIG. 14 (A) PLAN VIEW OF TYPICAL GROUTED OR CAST-IN-PLACE VERTICAL JOINTS IN SHEAR-WALL PANELS REINFORCED FOR HIGH SEISMIC LOADING (REFER TO ADJACENT PLAN VIEW FOR DIFFERENT CONFIGURATIONS); AND (B) VARIATIONS OF VERTICAL WALL-TO-WALL CONNECTIONS (PLAN VIEW)



15A USING MECHANICAL OR LAPPED SPLICES



15B BUTT-WELDED REINFORCEMENT (SPECIAL PROCESS)



15C COMBINATION OF BOLTED PLATES AND WELDED REBARS

FIG. 15 HORIZONTAL CONNECTIONS BETWEEN BEAM OR GIRDER ENDS AT LOCATIONS OTHER THAN COLUMN FACES

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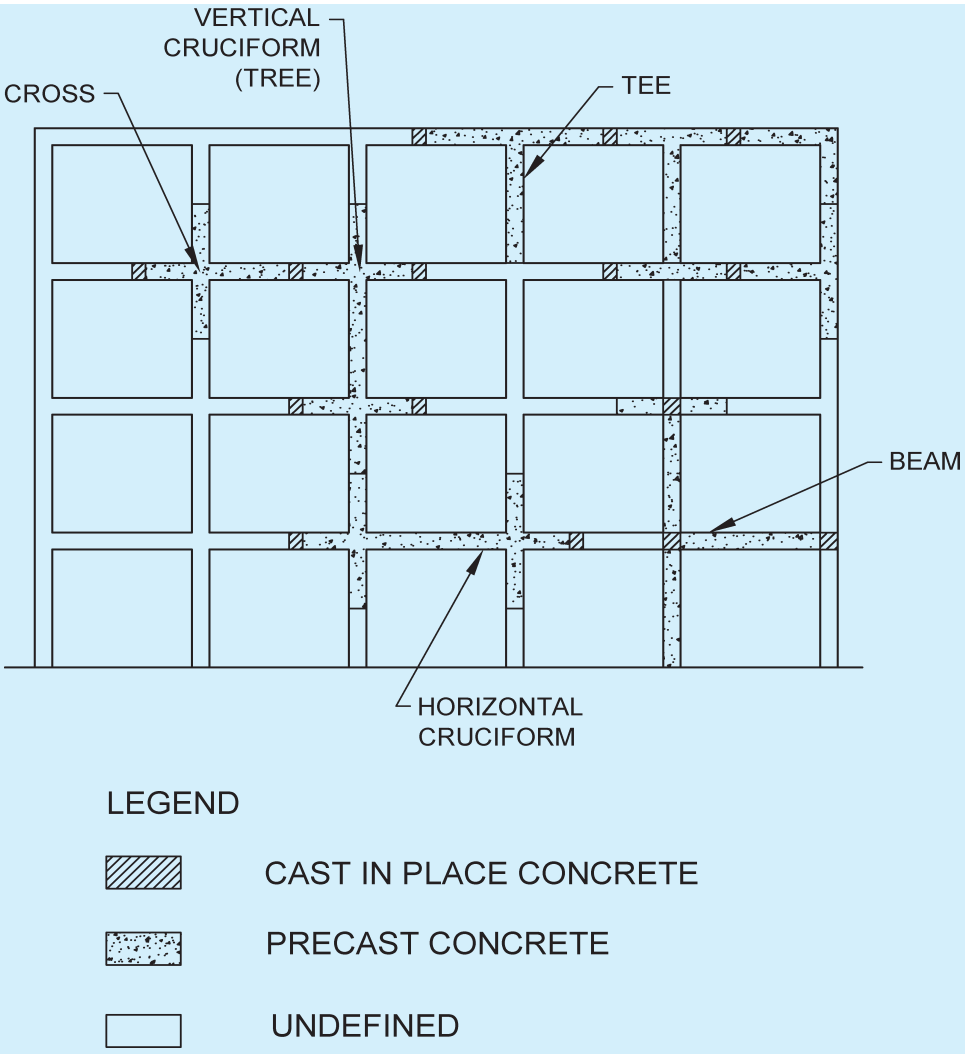


FIG. 16 VARIOUS CONFIGURATIONS OF PRECAST FRAME ELEMENTS

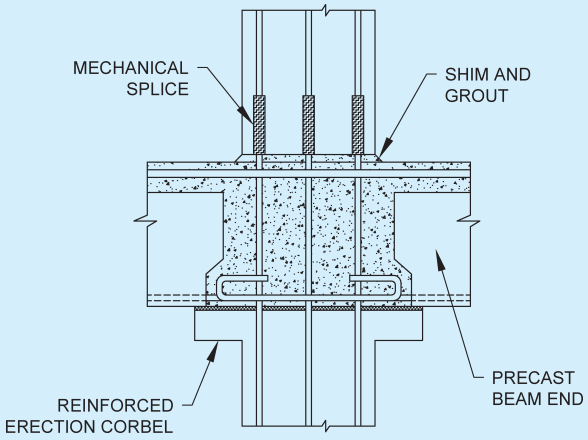
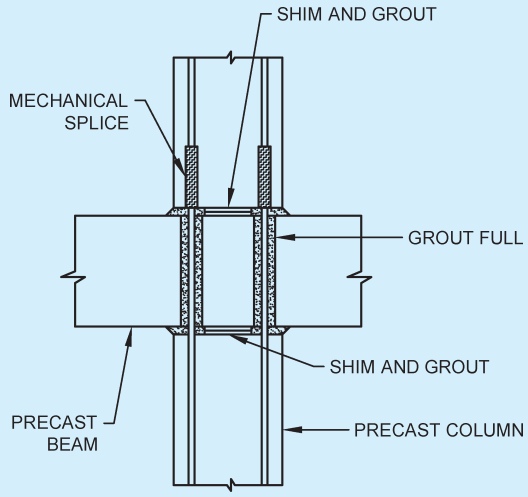


FIG. 17 CONNECTION AT BEAMS AND COLUMNS WITH CAST-IN PLACE CLOSURE



NOTE — Conduit diameter should be two to four times the bar diameter for tolerance in field erection.

FIG. 18 COLUMN-TO-COLUMN CONNECTION THROUGH CONDUITS INSTALLED IN A BEAM

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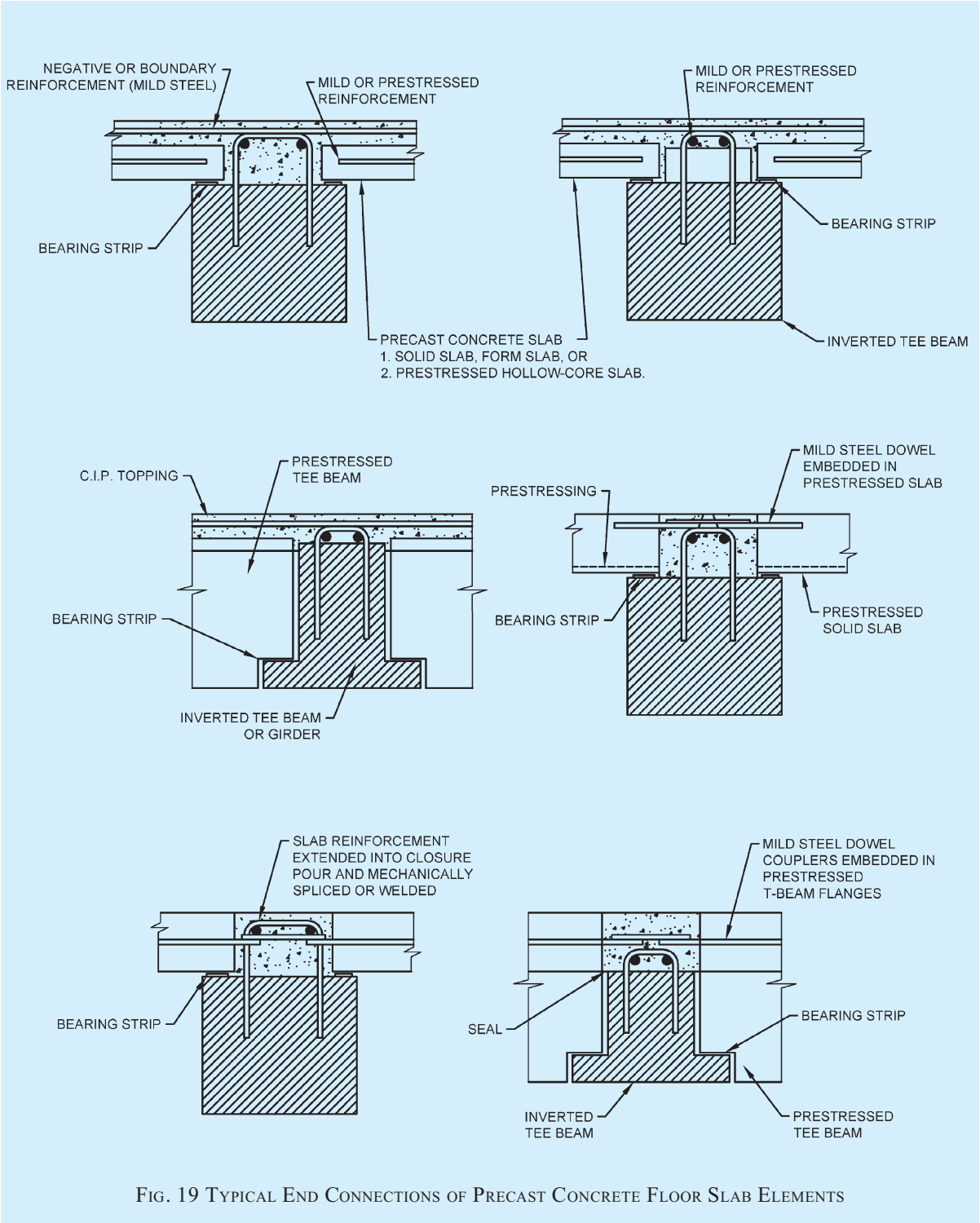


FIG. 19 TYPICAL END CONNECTIONS OF PRECAST CONCRETE FLOOR SLAB ELEMENTS

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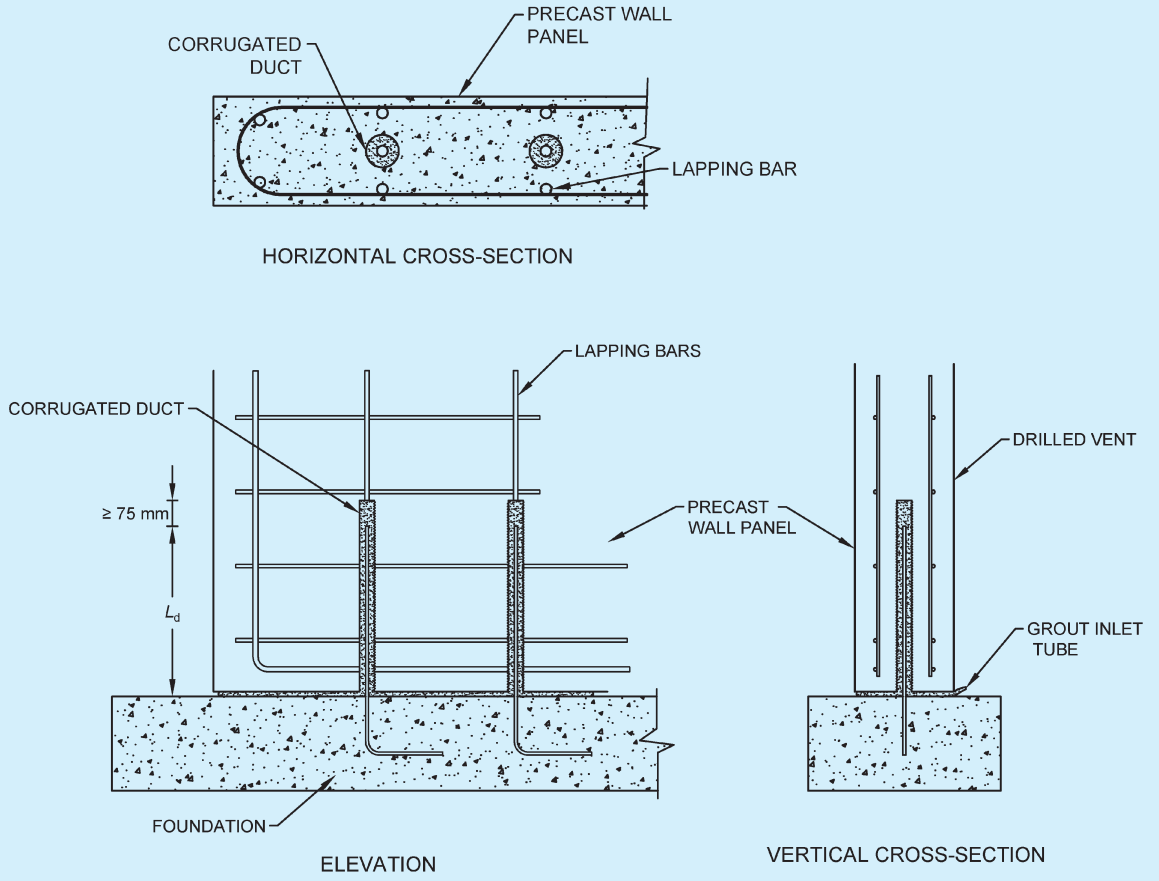


FIG. 20 WALL-FOUNDATION BEAM CONNECTION THROUGH GROUTED DUCTING

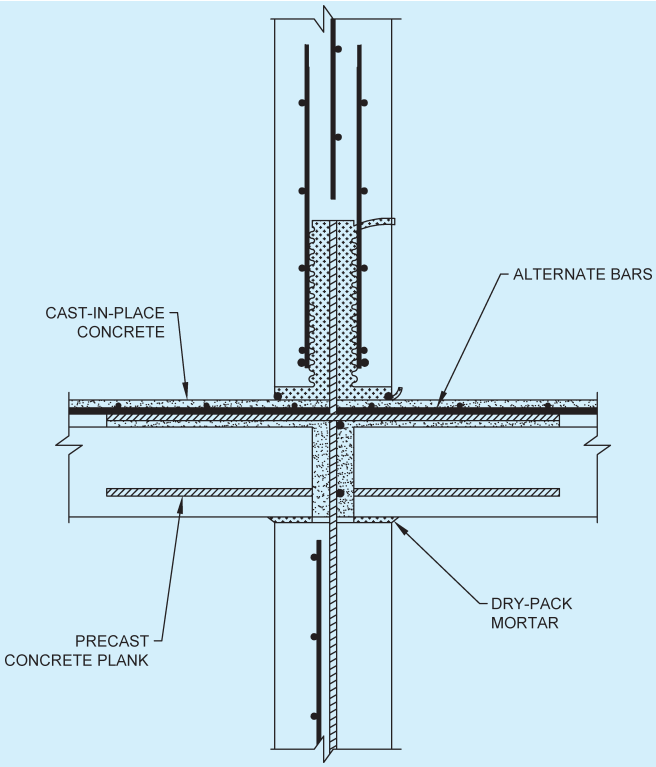


FIG. 21 INTERIOR WALL-FLOOR SLAB CONNECTION DETAIL: CONTINUOUS WALL

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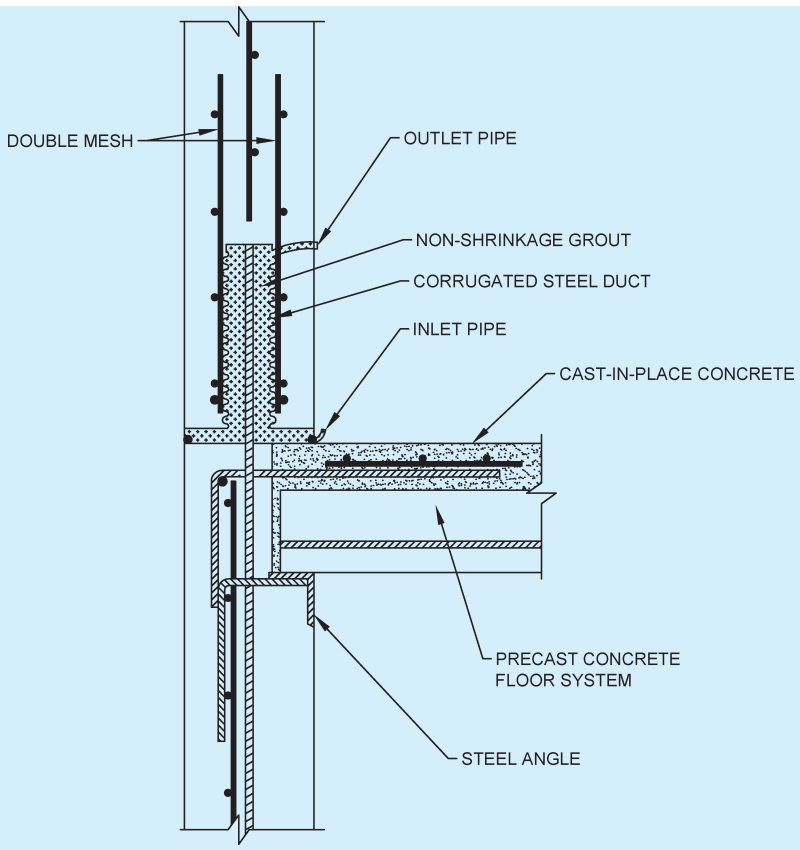


FIG. 22 EXTERIOR WALL-FLOOR SLAB CONNECTION DETAIL: PARTITIONED WALL WITH HORIZONTAL JOINT

9.1.2 *Number of Tests and Criteria for Conformity*

All the units selected at random in accordance with col 2 and col 3 of Table 1 shall be subjected to the dimensional requirements. A unit failing to satisfy any of the dimensional requirements shall be termed as defective. The lot shall be considered as conforming to the dimensional requirements if no defective is found in the sample, and shall be rejected if the number of defectives is greater than or equal to the first rejection number. If the number of defectives is less than the first rejection number the second sample of the same size as taken in the first stage shall be selected from the lot at random and subjected to the dimensional requirements. The number of defectives in the first sample and the second sample shall be combined and if the combined number of defectives is less than the second rejection number, the lot shall be considered as conforming to the dimensional requirements; otherwise not.

The lot which has been found as satisfactory with respect to the dimensional requirements shall then be tested for load test. For this purpose one unit shall be selected for every 300 units or part thereof. The lot shall be considered as conforming to the strength requirement if all the units meet the requirement; otherwise not.

9.2 Testing on Individual Components

The component should be loaded for 24 h at its full span with a total load (including its own self weight) of 1.25 times F_{lt}. At the end of this time it should not show any sign of weakness, faulty construction or excessive deflection. Its recovery 24 h after the removal of the test load, should not be less than 75 percent of the maximum deflection recorded during the test. If prestressed, it should not show any visible cracks up to working load and should have a recovery of not less than 85 percent in 1 h.

9.3 Load Testing of Structure or Part of Structure

Loading test on a completed structure should be made if required by the specification or if there is a reasonable doubt as to the adequacy of the strength of the structure.

9.3.1 In such tests, the structure should be subjected to full dead load of the structure plus an imposed load equal to 1.25 times the specified imposed load used in design, for a period of 24 h and then the imposed load shall be removed. During the tests, vertical struts equal

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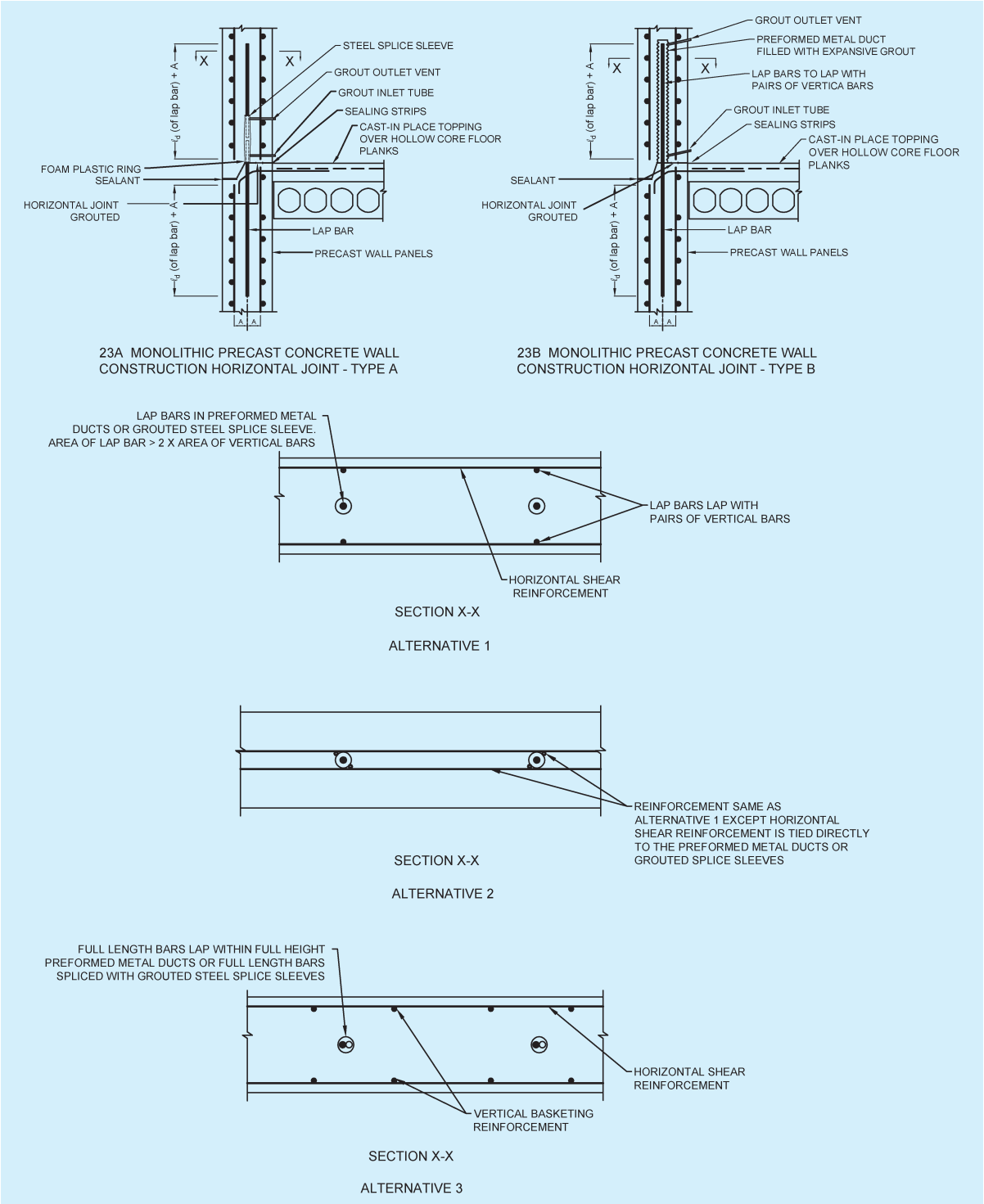


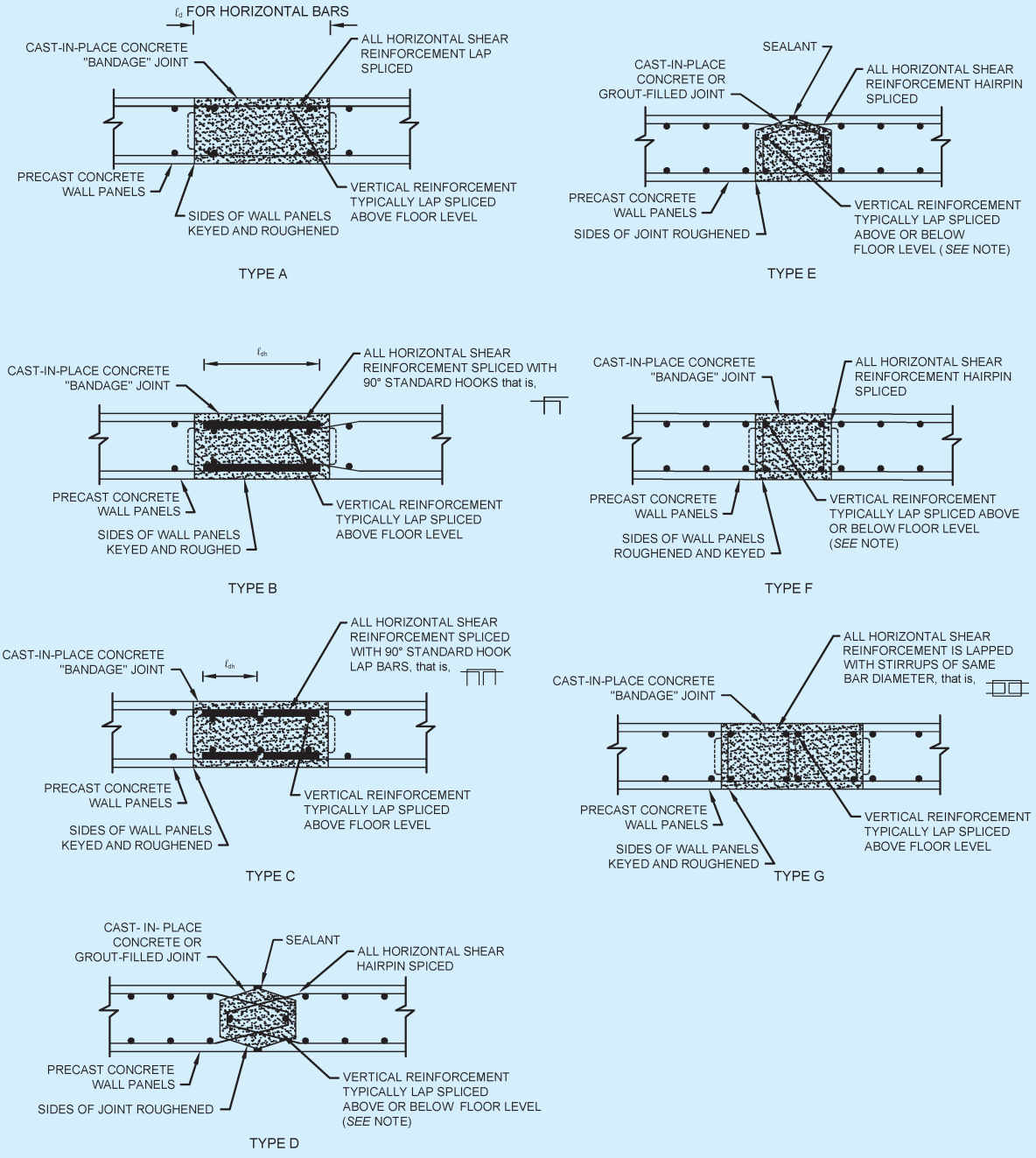
FIG. 23 MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION

in strength to take the whole load should be placed in position leaving a gap under the member.

NOTE — Dead load includes self weight of the structural members plus weight of finishes and walls or partitions, if any, as considered in the design.

9.3.1.1 If within 24 h of the removal of the load, a reinforced concrete structure does not show a recovery of at least 75 percent of the maximum deflection shown during the 24 h under load, test loading should be repeated after a lapse of 72 h. If the recovery is less than 80 percent in second test, the structure shall be deemed to be unacceptable.

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NOTE — Vertical joints shown as Types D, E and F need to be detailed with extreme care. Once the lapping bars have been overlapped the ability for lowering the wall panels over starter bars is very restricted. These details will typically work only when grouted steel splice sleeves are used to splice the vertical flexural reinforcement and when the laps of the vertical bars in the 'bandage' joints are made below floor level. Type D is not preferred because joint reinforcement and concrete infill cannot be inspected.

FIG. 24 MONOLITHIC PRECAST CONCRETE WALL CONSTRUCTION VERTICAL JOINTS

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9.3.1.2 If within 24 h of the removal of the load, prestressed concrete structure does not show a recovery of at least 85 percent of the maximum deflection shown during the 24 h under load, the test loading should be repeated. The structure should be considered to have failed, if the recovery after the second test is not at least 85 percent of the maximum deflection shown during the second test.

9.3.1.3 If the maximum deflection, in mm, shown during 24 h under load is less than 40 l^2/D, where l is the effective span in m; and D, the overall depth of the section in mm, it is not necessary for the recovery to be measured and the recovery provisions of **9.3.1.1** and **9.3.1.2** shall not apply.

9.4 Testing of External Precast Wall/Facade Panels for Water Tightness

Any of the testing procedures given in **9.4.1** and **9.4.2** may be followed for testing of external wall/façade panel joints for water tightness.

9.4.1 *Testing Procedure 1*

9.4.1.1 *General*

If it is deemed necessary to demonstrate that the precast façade joints are adequate to resist water penetration, a water penetration test on a full scale panel including joint mock-ups could be undertaken.

9.4.1.2 *Test procedures*

Mock-up panels to be tested for water tightness should be subjected to both static and cyclic pressure in accordance with standard accepted procedures. Available international testing procedures are to be modified for local conditions as follows:

a) Differential test pressure shall be 20 percent of the maximum inward design wind load but not less than 0.77 kPa; and
b) The test shall be performed with water flow rate of 3.4 litre/min/m² for 15 min.

9.4.1.3 *Sampling for water penetration test*

Full scale water tightness testing on precast façade panels and joints should be carried out at the rate of 0.5 percent for each type of joint and combination of panels or one for each type of joint and precast unit, whichever is the greater.

9.4.1.4 *Failure criterion*

The façade units or joints are deemed to have failed if signs of water seepage through the joints or through the façade unit, including signs of damp patches, are observed during the test or within the subsequent 2 h after the test.

9.4.1.5 *Remedial action on failure*

Upon failure of a water penetration test on a precast façade system the cause of failure should be identified and the system revised and re-tested until a satisfactory test result is achieved. Modifications must be realistic in terms of job conditions and must maintain standards of quality and durability.

9.4.2 *Testing Procedure 2*

9.4.2.1 For external walls, a continuous jet of water shall be sprayed on the joint corresponding to 600 litre/h from a water hose having nozzle velocity of 2 m/s and a cone scatter of approximately 60° held at a distance of 1.2 m from the wall surface under test. The duration of the test shall not be less than 2 h. The hose shall be placed with the nozzle in line with the vertical joint and at a level of horizontal joints so that the jet cone will cover a vertical and two horizontal joints as shown in the drawings.

For external walls, the following tests shall be conducted for each building block:

Building Height	*Frequency of Tests*
Up to 10 storeys	5 tests each for vertical joints and horizontal joints
Up to 20 storeys	10 tests each for vertical joints and horizontal joints
Up to 30 storeys	15 tests each for vertical joints and horizontal joints
Up to 40 storeys	20 tests each for vertical joints and horizontal joints
Up to 50 storeys	25 tests each for vertical joints and horizontal joints

These tests shall be carried out at any location as instructed by the Engineer-in-Charge.

9.4.2.2 *Acceptance criterion*

Water shall not seep into any part of the building during the test.

9.4.2.3 *Remedial action on failure*

For each test which fails, two additional tests shall be carried out at joint locations as instructed by the Engineer-in-Charge, all at the contractor's cost and expense.

10 MANUFACTURE, STORAGE, TRANSPORT AND ERECTION OF PRECAST ELEMENTS

10.1 Manufacture of Precast Concrete Elements

10.1.1 A judicious location of precasting yard with concreting, initial curing (required for demoulding), storage facilities, suitable transporting and erection equipments and availability of raw materials are the crucial factors which should be carefully planned and

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provided for effective and economic use of precast concrete components in constructions.

10.1.2 *Manufacture*

The manufacture of the components can be done in a factory for the commercial production established at the focal point based on the market potential or in a site precasting yard set up at or near the site of work.

10.1.2.1 *Factory prefabrication*

Factory prefabrication is resorted to in a factory for the commercial production for the manufacture of standardized components on a long term basis. It is a capital intensive production where work is done throughout the year preferably under a closed shed to avoid effects of seasonal variations. High level of mechanization can always be introduced in this system where the work can be organized in a factory-like manner with the help of a constant team of workmen.

10.1.2.2 *Site prefabrication*

In this scheme, prefabricated components are produced at site or near the site of work as possible.

This system is normally adopted for a specific job order of large scale that will continue over a long period. This option provides definite economy with respect to cost of transportation thereby improving productivity. Even though temporary, the factory established should be comparable to high capacity permanent factory with equivalent state-of-the-art degree of mechanization and quality control. Under this category there are two types, that is, semi-mechanized and fully-mechanized.

10.1.2.2.1 *Semi-mechanized*

The work is normally carried out in open space with locally available labour force or skilled labour force depending on project complexity. The equipment machinery used may be minor in nature and moulds are of mobile or stationary in nature.

10.1.2.2.2 *Fully-mechanized*

The work is carried out under a shed with skilled labour. The equipments used are similar to one of factory production. This type of precast yards will be set up for the production of precast components of high quality, high rate of production.

10.1.3 The various processes involved in the manufacture of precast elements may be classified as follows.

10.1.3.1 *Main process*

a) Providing and assembling the moulds, placing reinforcement cage in position for reinforced concrete work, and stressing the wires in the case of prestressed elements;
b) Putting concealed service conduits/pipes;
c) Fixing of inserts and tubes, where necessary (for handling);
d) Pouring the concrete (designed properly under strict quality control) into the moulds;
e) Vibrating the concrete and finishing;
f) Curing (steam curing, if necessary); and
g) Demoulding the forms and stacking the precast products.

10.1.3.2 *Auxiliary process*

Process, such as the following, necessary for the successful completion of the processes covered by the main process:

a) Mixing and manufacture of fresh concrete (done in a mixing station or by a batching plant);
b) Prefabrication of reinforcement cage (done in a steel yard or workshop);
c) Manufacture of inserts and other finishing items to be incorporated in the main precast products;
d) Finishing the precast products; and
e) Testing of products.

10.1.3.3 *Subsidiary process*

All other work such as the following, involved in keeping the main production work to a cyclic working:

a) Storage of materials;
b) Transport of cement and aggregates;
c) Transport of green concrete and reinforcement cages;
d) Transport of and stacking the precast elements;
e) Repairs and maintenance of tools, shackles and machines;
f) Repairs and maintenance of moulds;
g) Maintenance of curing yards; and
h) Generation of steam, etc.

10.1.4 For the manufacture of precast elements all the above processes shall be planned in a systematic way to achieve the following:

a) A cyclic technological method of working to bring in speed and economy in manufacture;
b) Mechanization of the process to increase productivity and to improve quality;
c) The optimum production satisfying the quality control requirements and to keep up the expected speed of construction aimed;
d) Better working conditions for the people on the job; and

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e) Minimizing the effect of weather on the manufacturing schedule.

10.1.5 The various stages of precasting can be classified as in Table 2 on the basis of the equipment required for the various stages. This permits mechanization and rationalization of work in the various stages. In the precasting, stages 6 and 7 given in Table 2 form the main process in the manufacture of precast concrete elements. For these precasting stages there are many technological processes to suit the concrete product under consideration which have been proved rational, economical and time saving. The technological line or process is the theoretical solution for the method of planning the work involved by using machine complexes. Figure 25 illustrates diagrammatically the various stages involved in a plant process.

10.1.6 The various accepted methods of manufacture of precast units can be broadly classified into two methods:

a) The 'Stand Method' where the moulds remain stationary at places, when the various processes involved are carried out in a cyclic order at the same place, and

b) The 'Flow Method' where the precast unit under consideration is in movement according to the various processes involved in the work which are carried out in an assembly-line method.

The various accepted precasting methods are listed in Table 3 with details regarding the elements that can be manufactured by these methods.

10.2 Preparation and Storage of Materials

Storage of materials is of considerable importance in

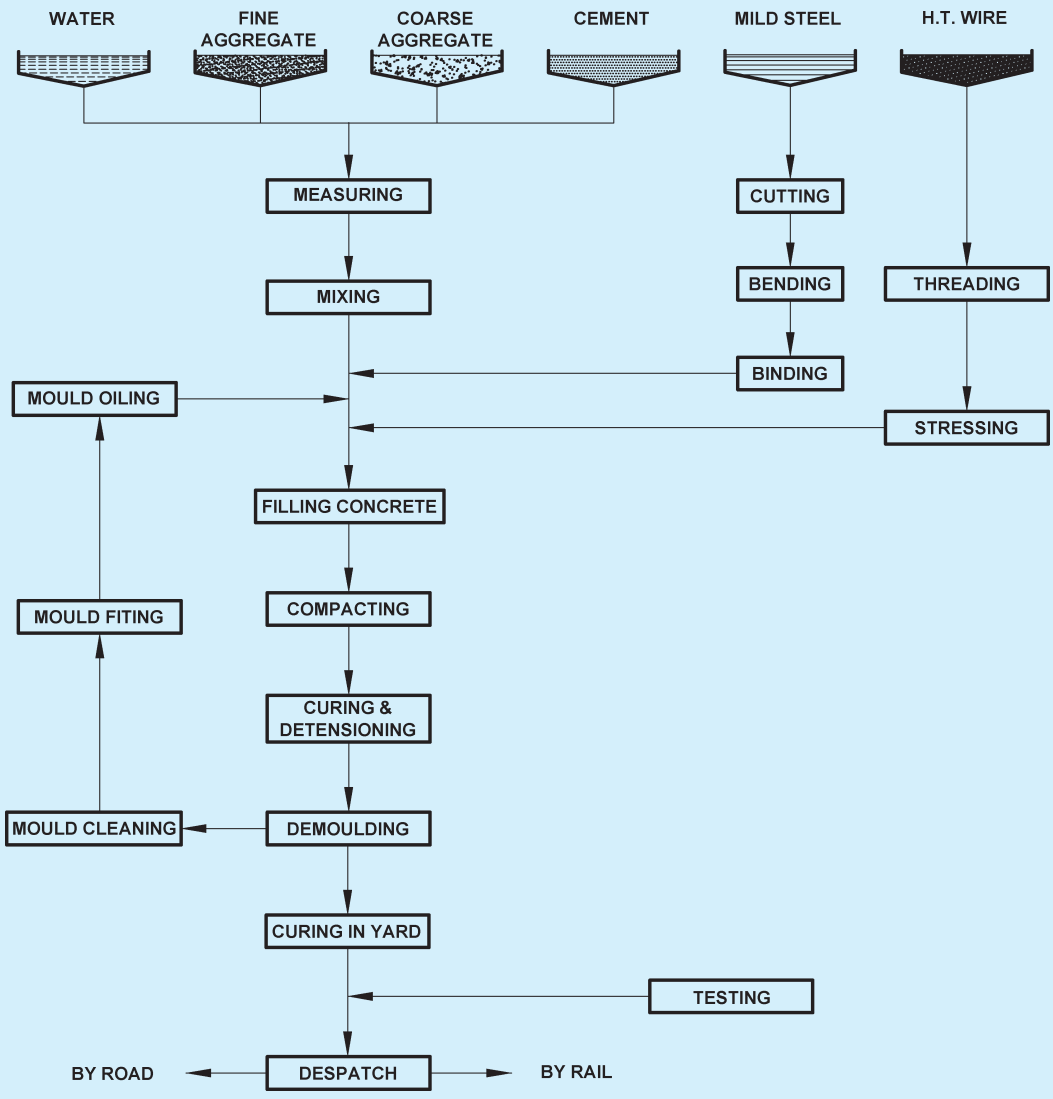


FIG. 25 PLANT PROCESS

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Table 2 Stages of Precasting of Concrete Products
(*Clause* 10.1.5)

Sl No.	Precasting Stage No.	Name of Process	Operations Involved
(1)	(2)	(3)	(4)
i)	1	Procurement and storage of construction materials	Unloading and transport of cement, coarse and fine aggregates and steel, and storing them in bins, silos or storage sheds
ii)	2	Testing of materials	Testing of all materials including steel
iii)	3	Design of concrete mix	Testing of raw materials, plotting of grading curves and trial of mixes in laboratory
iv)	4	Making of reinforcement cages	Unloading of reinforcement bars from wagons or lorries and stacking them in the steel yard, cutting, bending, tying or welding the reinforcements and making in the form of a cage, which can be directly introduced into the mould
v)	5	Applying form release agent and laying of moulds in position	Moulds are cleaned, applied with form release agent and assembled and placed at the right place
vi)	6	Placing of reinforcement cages, inserts and fixtures	The reinforcement cages are placed in the moulds with spacers, etc as per data sheet prepared for the particular prefabricate
vii)	7	Preparation of green concrete	Taking out aggregates and cement from bins, silos, etc, batching and mixing
viii)	8	Transport of green concrete	Transport of green concrete from the mixer to the moulds. In the case of precast method involving direct transfer of concrete from mixer to the mould or a concrete hopper attached to the mould this prefabrication stage is not necessary
ix)	9	Pouring and consolidation of concrete	Concrete is poured and vibrated to a good finish
x)	10	Curing of concrete and demoulding	Either a natural curing with water or an accelerated curing using steam curing and other techniques. In the case of steam curing using trenches or autoclaves, this stage involves transport of moulds with the green concrete into the trench or autoclave and taking them out after the curing and demoulding elements. Cutting of protruding wires also falls in this stage In certain cases the moulds have to be partly removed and inserts, have to be removed after initial set. The total demoulding is done after a certain period and the components are then allowed to be cured. All these fall in this operation
xi)	11	Stacking of precast elements	Lifting of precast elements from the mould and transporting to the stacking yard for further transport by trailer or rail is part of this stage
xii)	12	Testing of finished components	Tests are carried out on the components individually and in combination to ensure the adequacy of their strength
xiii)	13	Miscellaneous	a) Generation of steam involving storing of coal or oil necessary for generation of steam and providing insulated steam pipe connection up to the various technological lines b) Repair of machines used in the production

the precasting industry, as a mistake in planning in this aspect can greatly influence the economics of production. From experience in construction, it is clear that there will be very high percentages of loss of materials as well as poor quality due to improper storage and transport. So, in a precast factory where everything is produced with special emphasis on quality, proper storage and preservation of building materials, especially cement, coarse and fine aggregates, is of prime importance. Storage of materials shall be done in accordance with Part 7 'Construction Management, Practices and Safety' of the Code. Also, precast elements be subjected to 'first-in first-out' to minimize and or avoid issues relating to shrinkage, creep, etc.

10.3 Moulds

10.3.1 Moulds for the manufacture of precast elements may be of steel, timber, concrete and plastic or a combination thereof. For the design of moulds for the various elements, special importance should be given to easy demoulding and assembly of the various parts. At the same time rigidity, strength and water-tightness of the mould, taking into consideration forces due to pouring of green concrete and vibrating, are also important.

10.3.2 *Tolerances*

The moulds have to be designed in such a way to take into consideration the tolerances given in **5.2**.

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Table 3 Precasting Methods
(*Clauses* 10.1.6 *and* 10.9.1)

Sl No.	Precasting Method	Where Used	Recommended Dimensions and Weights	Advantages and Remarks
(1)	(2)	(3)	(4)	(5)
i)	*Individual mould method* — Precasting method using mould which may be easily assembled out of bottom and sides, transportable, if necessary. This may be either in timber or in steel using needle or mould vibrators and capable of taking prestressing forces	a) Ribbed slabs, beams, girders, window panels, box type units and special elements b) Prestressed railway sleepers, parts of pre-stressed girders, etc	No limit in size and weight. Depends on the equipment used for demoulding, transporting and placing	a) Strengthening of the cross-section possible b) Openings are possible in two planes
ii)	*Battery form method* − The shuttering panels may be adjusted into the form of a battery at the required distances equal to the thickness of the concrete member	Interior wall panels, shell elements, reinforced concrete battens, rafters, purlins and, roof and floor slabs	a) Length : 18 m b) Breadth : 3 m c) Mass : 5 t	Specially suitable for mass production of wall panels where shuttering cost is reduced to a large extent and autoclave or trench steam curing may be adopted by taking the steam pipes through the shuttering panels.
iii)	*Stack method*	Floor and roof slab panels	a) Length : Any desired length b) Breadth : 1 to 4 m c) Mass : 5 t	For casting identical reinforced or prestressed panels one over the other with separating media interposed in between.
iv)	*Tilting mould method* − This method is capable of being skipped vertically using hydraulic jacks	Exterior wall panels where special finishes are required on one face or for sandwich panel	a) Length : 6 m b) Breadth : 4 m c) Mass : 5 t	Suitable for manufacturing the external wall panels
v)	*Long line prestressing bed method*	Double tees, ribbed slabs, purlins, piles and beams	a) Length : Any desired b) Breadth : 2 m c) Height : 2 m d) Mass : Up to 10 t	Ideally suited for pretension members
vi)	*Extrusion method* − Long concrete mould with constant cross section where concreting and vibration are done automatically just as in hollow code slab casting	Roof slabs, foam concrete wall panels and beams cross-section where concreting and vibration are done automatically just as in hollow cored slab casting	a) Length : Any desired b) Breadth : Less than 2 m c) Height : Less than 3 m	May be used with advantage in the case of un-reinforced blocks, foam concrete panels

10.3.3 *Slopes of the Mould Walls*

For easy demoulding of the elements from the mould with fixed sides, the required slopes have to be maintained. Otherwise there is a possibility of the elements getting stuck up with the mould at the time of demoulding.

10.4 Accelerated Hardening

In most of the precasting factories, it is economical to use faster curing methods or artificial curing methods, which in turn will allow the elements to be demoulded much earlier permitting early re-use of the forms. Any of the following methods may be adopted:

a) *By heating the aggregates and water before mixing the concrete* — By heating of the aggregates as well as water to about 70°C to 80°C before making the concrete mix and placing the same in the moulds, sufficiently high earlier strengths are developed to allow the elements to be stripped and transported.

b) *Steam curing* — Steam curing may be done under high pressure and high temperature in an autoclave. This technique is more suited to smaller elements. Alternatively, this could be done using low pressure steam having temperature around 80°C. This type of curing shall be done as specified in **10.5.2**. For light weight concrete products when steam cured under high pressure, the drying shrinkage is reduced considerably. Due to this reason, high pressure steam curing in autoclave is specified for light weight low densities ranging from 300 to 1 000 kg/m^3. For normal (heavy) concretes as well as light weight concretes of higher densities, low pressure steam curing

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may be desirable as it does not involve using high pressures and temperatures requiring high investment in an autoclave (*see also* **10.5.2**).

c) *Steam injection during mixing of concrete* — In this method low pressure saturated steam is injected into the mixer while the aggregates are being mixed. This enables the heating up of concrete to approximately 60°C. Such a concrete after being placed in the moulds attains high early strength.

d) *Heated air method* — In this method, the concrete elements are kept in contact with hot air with a relative humidity not less than 80 percent. This method is specially useful for light weight concrete products using porous coarse aggregates.

e) *Hot water method* — In this method, the concrete elements are kept in a bath of hot water around 50°C to 80°C. The general principles of this type of curing are not much different from steam curing.

f) *Electrical method* — The passage of current through the concrete panels generates heat through its electro-resistivity and accelerates curing. In this method, the concrete is heated up by an alternating current ranging from 50 V for a plastic concrete and gradually increasing to 230 V for the set concrete. This method is normally used for massive concrete products.

10.4.1 After the accelerated hardening of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

10.4.2 Accelerated hardening may also be achieved by the following techniques:

a) *Construction chemicals* — Suitable construction chemicals may be used.

b) *Consolidation by spinning* — Such a method is generally used in the centrifugal moulding of pipes and such units. The spinning motion removes excess water, effects consolidation and permits earlier demoulding.

c) *Pressed concrete* — This method is suitable for fabrication of small or large products at high speed of production. A 100 to 200 t press compresses the wet concrete in rigid moulds and expels water. Early handling and a dense wear resistant concrete is obtained.

d) *Vacuum treatment* — This method removes the surplus air and water from the newly placed concrete as in slabs and similar elements. A suction up to about 70 percent of an atmosphere is applied for 20 to 30 min/cm thickness of the units.

e) *Consolidation by shock* — This method is suitable for small concrete units dropped repeatedly from a height in strong moulds. The number of shocks required to remove excess water and air may vary from 6 to 20 and the height of lift may be up to as much as half the depth of the mould.

10.4.3 After the accelerated curing of the above products by any of the above accepted methods, the elements shall be cured further by normal curing methods to attain full final strength.

10.5 Curing

10.5.1 The curing of the prefabricated elements can be effected by the normal methods of curing by sprinkling water and keeping the elements moist. This can also be done in the case of smaller elements by immersing them in a specially made water tanks.

10.5.2 *Steam Curing*

10.5.2.1 The steam curing of concrete products shall take place under tarpaulin in tents, under hoods, under chambers, in tunnels or in special autoclaves. The steam shall have a uniform quality throughout the length of the member. The precast elements shall be so stacked, with sufficient clearance between each other and the bounding enclosure, so as to allow proper circulation of steam.

Before the concrete products are subjected to any accelerated method of curing, the cement to be used shall be tested in accordance with accepted standards (*see* Part 5 'Building Materials' of the Code) especially for soundness, setting time and suitability for steam curing.

In the case of elements manufactured by accelerated curing methods, concrete admixtures to reduce the water content may be allowed to be used. The normal aeration agents used to increase the workability of concrete should not be allowed to be used. Use of calcium chloride based admixtures should not be used for reinforced concrete elements so as to meet the chloride limits prescribed in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code.

10.5.2.2 The surrounding walls, the top cover and the floor of steam curing chamber or tunnel or hood shall be so designed as not to allow more than 1 kcal/m^2/h°C.

10.5.2.3 The inside face of the steam curing chamber, tunnel or hood shall have a damp-proof layer to maintain the humidity of steam. Moreover, proper slope shall be given to the floor and the roof to allow the condensed water to be easily drained away. At first, when steam is let into the curing chambers, the air inside shall be allowed to go out through openings provided in the hoods or side walls which shall be closed soon after moist steam is seen jetting out.

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10.5.2.4 It is preferable to let in steam at the top of the chamber through perforated pipelines to allow uniform entry of steam throughout the chamber.

10.5.2.5 The fresh concrete in the moulds should be allowed to get the initial set before allowing the concrete to come into contact with steam. The regular heating up of fresh concrete product from about 20°C to 35°C should start only after a waiting period ranging from 2 h to 5 h depending on the setting time of cement used. It may be further noted that steam can be let in earlier than this waiting period provided the temperature of the concrete product does not rise beyond 35°C within this waiting period.

10.5.2.6 The second stage in steam curing process is to heat up the concrete elements, moulds and the surroundings in the chamber,

a) in the low pressure steam curing the airspace around the member is heated up to a temperature of 75°C to 80°C at a gradual rate, usually not faster than 30°C/h (this process takes around 1 h to 1½ h depending upon outside temperature); and

b) in the case of curing under high pressure steam in autoclaves, the temperature and pressure are gradually built up during a period of about 4 h.

10.5.2.7 The third stage of steam curing is to maintain the uniform temperature and pressure for a duration depending upon thickness of the section. This may vary from 3 h to 5½ h in the case of low pressure steam curing and 4 h to 7 h in the case of high pressure steam curing.

10.5.2.8 The fourth stage of steam curing is the gradual cooling down of concrete products and surroundings in the chamber and normalization of the pressure to bring it at par with outside air. The maximum cooling rate, which is dependent on the thickness of the member, should normally not exceed 30°C/h.

10.5.3 In all these cases, the difference between the temperature of the concrete product and the outside temperature should not be more than 60°C for concretes up to M 30 and 75°C for concretes greater than M 45. In the case of light weight concrete, the difference in temperature should not be more than 60°C for concretes less than M 25. For concretes greater than M 50, the temperature differences can go up to 75°C.

10.6 Stacking During Transport and Storage

Every precaution shall be taken against overstress or damage, by the provision of suitable packings at agreed points of support. Particular attention is directed to the inherent dangers of breakage and damage caused by supporting other than at two positions, and also by the careless placing of packings (for example, not vertically one above the other). Ribs, corners and intricate projections from solid section should be adequately protected. Packing pieces shall not discolour, disfigure or otherwise permanently cause mark on units or members. Stacking shall be arranged or the precast units should be protected, so as to prevent the accumulation of trapped water or rubbish, and if necessary to reduce the risk of efflorescence.

10.6.1 The following points shall be kept in view during stacking:

a) Care should be taken to ensure that the flat elements are stacked with right side up. For identification, top surfaces should be clearly marked.

b) Stacking should be done on a hard and suitable ground to avoid any sinking of support when elements are stacked.

c) In case of horizontal stacking, packing materials shall be at specified locations and shall be exactly one over the other to avoid cantilever stress in panels.

d) Components should be packed in a uniform way to avoid any undue projection of elements in the stack which normally is a source of accident.

e) In general, vertical stacking should be limited to 6-10 components. Where the ground is only compacted, the maximum ground load at support should be restricted to 15 t/m^2 and the stacking should be restricted to 6 panels. Where PCC layer is poured, the maximum ground load at support should be restricted to 30 t/m^2 and the stacking should be restricted to 10 panels. In both cases, the ground should be fairly levelled and the supports should be continuous along the width of the panels.

10.7 Handling Arrangements

10.7.1 Lifting and handling positions shall be clearly defined particularly where these sections are critical. Where necessary special facilities, such as bolt holes or projecting loops, shall be provided in the units and full instructions supplied for handling. For the purpose of testing the bolts/hooks, bond strength shall be the criteria for embedded bolts and bearing strength for through bolts. For bond strength, pull out test of concrete shall be carried out. *See* **10.11** for additional design considerations.

10.7.2 For precast prestressed concrete members, the residual prestress at the age of particular operation of handling and erection shall be considered in

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conjunction with any stresses caused by the handling or erection of member. The compressive stress thus computed shall not exceed 50 percent of the cube strength of the concrete at the time of handling and erection. Tensile stresses up to a limit of 50 percent above those specified in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code shall be permissible.

10.8 Identification and Marking

All precast units shall bear an indelible identification, location and orientation marks as and where necessary. The date of manufacture shall also be marked on the units.

10.8.1 The identification markings on the drawings shall be the same as that indicated in the manufacturer's literature and shall be shown in a table on the setting schedule together with the length, type, size of the unit and the sizes and arrangement of all reinforcement.

10.9 Transport

Transport of precast elements inside the factory and to the site of erection is of considerable importance not only from the point of view of economy but also from the point of view of design and efficient management. Transport of precast elements must be carried out with extreme care to avoid any jerk and distress in elements and handled as far as possible in the same orientation as it is to be placed in final position. *See* **10.11** for additional design considerations.

10.9.1 *Transport Inside the Factory*

Transport of precast elements moulded inside the factory depends on the method of production, selected for the manufacture as given in Table 3.

10.9.2 *Transport from Stacking Yard Inside the Factory to the Site of Erection*

Transport of precast concrete elements from the factory to the site of erection should be planned in such a way so as to be in conformity with the traffic rules and regulations as stipulated by the Authorities. The size of the elements is often restricted by the availability of suitable transport equipment, such as tractor-cum-trailers, to suit the load and dimensions of the member in addition to the opening dimensions under the bridge and load carrying capacity while transporting the elements over the bridge.

10.9.2.1 While transporting elements in various systems, that is, wagons, trucks, bullock carts, etc, care should be taken to avoid excessive cantilever actions and desired supports are maintained. Transportation of prefabricated element should be done with safety ties and vibrations to the elements in transit should be minimum. Special care should be taken at location of sharp bends and on uneven or slushy roads to avoid undesirable stresses in elements.

10.9.2.2 Before loading the elements in the transporting media, care should be taken to ensure that the base packing for supporting the elements are located at specified positions only. Subsequent packings shall be kept strictly one over the other.

10.10 Erection

In the erection of precast elements, all the following items of work are meant to be included:

a) Slinging of the precast element;
b) Tying up of erection ropes connecting to the erection hooks;
c) Cleaning of the elements and the site of erection;
d) Cleaning of the steel inserts before incorporation in the joints, lifting up of the elements, setting them down into the correct envisaged position;
e) Adjustment to get the stipulated level, line and plumb;
f) Welding of cleats;
g) Changing of the erection tackles;
h) Putting up and removing of the necessary scaffolding or supports;
j) Welding of the inserts, laying of reinforcements in joints and grouting the joints; and
k) Finishing the joints to bring the whole work to a workmanlike finished product.

See **10.11** for additional design considerations.

10.10.1 In view of the fact that the erection work in various construction jobs using prefabricated concrete elements differs from place to place depending on the site conditions, safety precautions in the work are of utmost importance. Hence only those skilled foremen, trained workers and fitters who have been properly instructed about the safety precautions to be taken should be employed on the job. For additional information, *see* Part 7 'Construction Management, Practices and Safety' of the Code.

10.10.2 Transport of people, workers or visitors, by using cranes and hoists should be strictly prohibited on an erection site.

10.10.3 In the case of tower rail mounted cranes running on rails, the track shall not have a slope more than 0.2 percent in the longitudinal direction. In the transverse direction the rails shall lie in a horizontal plane.

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10.10.4 The track of the crane should be checked daily to see that all fish plates and bolts connecting them to the sleepers are in place and in good condition.

10.10.5 The operation of all equipment used for handling and erection shall follow the operations manual provided by the manufacturer. All safety precautions shall be taken in the operations of handling and erection.

10.10.6 *Erection Tolerances*

For the erection tolerances, reference shall be made to good practice [6-7A(3)] for large panel prefabricates .

10.11 Design Considerations

Based on the design intent, production environment and aesthetic requirements of the prefabricated panels, the resultant stresses should be controlled to minimize cracking in precast and/or prestressed panels. Precast (non-prestressed) components are generally designed as 'cracked' unless cracking is an aesthetic concern. Where the panels are to be designed 'without cracking' the extreme fibre tensile stresses during various stages of handling, storage and erection should be kept under the tensile strength of the concrete (modulus of rupture) at that stage with a factor of safety of 1.5 or more. Structural design requirements of minimum spacing, skin reinforcement and crack width criteria as specified in Part 6 'Structural Design, Section 5 Concrete, Subsection 5A Plain and Reinforced Concrete' of the Code are applicable.

Resultant extreme fibre tensile stresses $\leq 0.7\sqrt{f_{ck}}$ /1.5

In addition, extra static load multipliers should be used to account for impact, and demoulding forces as per the following:

Sl No.	*Prefabricated Panel Type*	*Static Load Multiplier*
i)	Demoulding:	
	a) Structural components	1.3
	b) Architectural components	1.4
ii)	Yard handling and erection:	
	All components	1.2
iii)	Transportation:	
	All components	1.2

The static load multipliers are to be used in addition to the factor of safety of 1.5 used in the tensile stress limit. Also, the load multipliers are only needed for the flexural design and are not applicable for the lifting devices.

11 EQUIPMENT

11.1 General

The equipment used in the precast concrete industry/ construction may be classified into the following categories:

a) Machinery required for quarrying of coarse and fine aggregates;
b) Conveying equipment, such as belt conveyors, chain conveyors, screw conveyors, bucket elevators, hoists, etc;
c) Concrete mixing machines;
d) Concrete vibrating machines;
e) Erection equipment, such as cranes, derricks, hoists, chain pulley blocks, etc;
f) Transport machinery, such as tractor-cum-trailers, dumpers, lorries, locomotives, motor boats and rarely even helicopters;
g) Workshop machinery for making and repairing steel and timber moulds;
h) Bar straightening, bending and welding machines to make reinforcement cages;
j) Minor tools and tackles, such as wheel barrows, concrete buckets, etc; and
k) Steam generation plant for accelerated curing.

In addition to the above, pumps and soil compacting machinery are required at the building site for the execution of civil engineering projects involving prefabricated components.

Each of the above groups may further be classified into various categories of machines and further to various other types depending on the source of power and capacity.

11.2 Mechanization of the Construction and Erection Processes

The various processes can be mechanized as in any other industry for attaining the advantages of mass production of identical elements which in turn will increase productivity and reduce the cost of production in the long run, at the same time guaranteeing quality for the end-product. On the basis of the degree of mechanization used, the various precasting factories can be divided into three categories:

a) With simple mechanization;
b) With partial mechanization; and
c) With complex mechanization leading to automation.

11.2.1 In simple mechanization, simple mechanically operated implements are used to reduce the manual labour and increase the speed.

11.2.2 In partial mechanization, the manual work is more or less eliminated in the part of a process. For example, the batching plant for mixing concrete, hoists to lift materials to a great height and bagger and bulldozer to do earthwork come under this category.

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11.2.3 In the case of complex mechanization leading to automation, a number of processes leading to the end-product are all mechanized to a large extent (without or with a little manual or human element involved). This type of mechanization reduces manual work to the absolute minimum and guarantee the mass production at a very fast rate and minimum cost.

11.2.4 The equipment shall conform to accepted standards as listed in Part 7 'Construction Management, Practices and Safety' of the Code.

12 PREFABRICATED STRUCTURAL UNITS

For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to the good practice [6-7A(4)].

For design and construction of precast reinforced and prestressed concrete triangulated trusses reference may be made to the good practice [6-7A(5)].

For design and construction of floors and roofs using various precast units, reference may be made to the good practice [6-7A(6)].

For construction with large panel prefabricates, reference may be made to good practice [6-7A(3)].

For construction of floors and roofs with joists and filler blocks, reference may be made to good practice [6-7A(7)].

ANNEX A

(*Foreword*)

COMMON DEFECTS AND REMEDIES

A-1 As defects in precast concrete elements result in direct and indirect cost in terms of rectification and construction time, it is worthwhile to ensure that they are produced and handled in a way to avoid/reduce such incidences. Table 4 illustrates some of these common defects, their causes and preventive measures.

Table 4 List of Common Defects and Recommended Measures
(*Clause* A-1)

Sl No.	Common Defects	Possible Causes	Recommendations	Remedial Measures
(1)	(2)	(3)	(4)	(5)
i)	Dimensional deviation: a) Variation in the dimension of precast elements would affect the joint alignment between these elements when erected b) Precast slab element may warp due to insufficient concrete strength at lifting or improper storage condition	a) Mould forms may not be sufficiently rigid to maintain specified tolerances during concrete placement b) Precast elements may not have gained sufficient concrete strength when demoulded c) Top surface finish of precast elements may not be properly levelled and troweled during production which result in differential thickness d) Precast elements (especially slender wall or slab panels) may be subjected to undue stress and deformation when they are not properly	a) Regular check on the dimensions and rigidity of mould forms before casting operations. As a general guide the recommended thickness for steel mould are: 1) 4.5 mm – up to 50 castings 2) 6 mm – up to 100 castings 3) 9 mm – up to 200 castings Mould forms conditions will deteriorate with time and usage. They should be repaired, stiffened or replaced when needed b) Cube tests should be conducted to ascertain the concrete strength of	a) For minor deviation, corrective measures such as surface grinding, trimming/hacking and skim coat application can be appropriately used to remedy the situation b) Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
		supported during storage	elements before demoulding. c) Spreading and levelling of concrete placement using appropriate tools such as screeder d) Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system	
ii)	Cracks	a) Precast elements may not have gained sufficient concrete strength before demoulding b) Cracks may have occurred during initial lifting due to friction between the elements and the casting mould forms c) Thickness of the precast elements may be too thin (70 mm or less) and flimsy for safe demoulding and handling d) Cracks may have occurred during erection due to lack of planning and provisions given to the precast panel geometry, crane rigging configuration and location of openings	a) Proper curing method, curing time and temperature should be maintained b) Cube tests should be conducted to ascertain the concrete strength of elements before demoulding c) Appropriate form release agents should be used and uniformly applied onto the mould surface to minimize friction d) Sectional thickness of precast elements should be increased to accommodate demoulding and handling stresses e) Proper handling techniques should be adopted f) Sufficient lifting points should be used to minimize over-stressing on certain areas g) Additional reinforcing bars should be placed around the opening and odd corners h) Temporary stiffeners for openings should be provided during erection	a) All cracks should be examined by a qualified engineer to determine if they present a structural problem b) Depending on the locations and seriousness of the cracks, different repair methods can be used to make good the affected precast elements c) Hairline cracks (not more than 0.3 mm) can be repaired by cutting V-groove of specified minimum depth along the crack-lines, followed by patching d) For surface cracks (more than 0.3 mm) or through cracks, epoxy injection method should be used to ensure that the cracks are completely bound and filled with epoxy
iii)	Chip-off and damages	a) Chip-off at panel edges are usually caused by the hard bearing at supports or excessive force exerted on the elements when handling b) Improper storage method	a) Precautions should be taken to avoid damaging the elements in the course of placement on vehicle, travel to site and during the unloading operation. Bearing pads should be used to cushion the contact areas from damage b) The storage area should be relatively flat and dry c) Precast elements should be properly stored and stacked at designated points using suitable support spacers and frame rack system d) The casting slab or mould form should be thoroughly cleansed, levelled to achieve a smooth surface e) The coverage of form release agents should be	a) Remove all loose concrete and wash off any dust or dirt in the affected area b) Apply bonding agent to affected concrete surface c) Welded wire mesh can be included to provide support for the patch mix concrete or grout d) Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete e) Formwork is to be put up where necessary to contain the patch mix or grout f) Protect the affected

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
			adequate and uniformly applied onto the mould surface f) Spacers of the correct sizes should be used and well secured to maintain the concrete cover required during casting g) Lifting inserts and concrete strength of elements should be of adequate capacity for the intended lift. Use lifting proprietary products for safe and efficient handling h) Lifting inserts or hooks should be inspected for proper location. They should be fastened to specified depth prior to concrete placement	area from any disturbance during curing period
iv)	Honeycomb and excessive pinholes	a) Poor concrete compaction due to ineffective vibration or rebars congestion b) Grout leakage along the perimeter side forms due to, 1) loose or missing bolts, fixing pins 2) damaged rubber gasket seal 3) mould part, if defective	a) Proper compaction method should be adopted and carried out b) Concrete mix design and workability should be reviewed and adjusted when needed c) Appropriate concrete vibrator such as clamp-on form vibrator can be used to attain better compaction d) Rebar congestion can be alleviated by having larger (that is, lesser) rebars or by increasing the sectional dimensions of the elements, where possible e) Mechanical couplers or sleeves can be used to simplify the reinforcement layout and to minimize rebar congestion f) Defective mould forms and accessories should be repaired or replaced to prevent grout leakage during concreting	a) Remove all loose concrete and wash off any dust or dirt in the affected area b) Apply bonding agent to affected concrete surface c) Welded wire mesh can be included to provide support for the patch mix concrete or grout d) Patch mix composition or grout should be consistent with the strength requirements of the adjacent concrete e) Formwork is to be put up where necessary to contain the patch mix or grout f) Protect the affected area from any disturbance during curing period
v)	Missing or wrong details such as cast-in items, architectural nib and groove details, lifting hooks, reinforcement/starter bars/blockout/corrugated pipes	a) Items may not have been included in the shop drawing b) Quality checks may not be properly in place	a) All items should be reflected in the shop drawings for production. Any changes should be made known to the production team b) The use of checklists during inspection can help to ensure that all items specified in the drawing are included before casting	a) Certain details such as missing starter bars/ reinforcement and lifting hooks can be replaced by welding additional reinforcement bars after hacking off the concrete at the affected area b) Other items such as cast-in items, groove and blockout can be provided by chasing or chiseling out the face of the precast panels
vi)	Strand slippage which exceed allowable design values (item	a) Insufficient bond strength between concrete and the	a) Required concrete strength of the precast elements	a) It is not possible to rectify the elements

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Table 4 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)
	applicable to pre-stressed elements only) Slippages of pre-stressing strands can be detected by visual inspection	pre-stressing strands b) Poor compaction of concrete around pre-stressed strands	should be attained and verified by cube test results before de-tensioning of strands b) Proper compaction method should be adopted and carried out during casting c) Concrete mix design and workability should be reviewed and adjusted when needed d) Provision of appropriate concrete vibrator to attain better compaction	from strand slippage b) Design verification should be carried out to ascertain the reduced capacity of the elements due to slippage, if adopted
vii)	Alignment	a) Inaccurate setting out and positioning of precast elements during erection b) Deviation in the dimensions of the precast element	a) Appropriate surveying and leveling equipment should be used to achieve better alignment b) Required alignment and level should be confirmed before permanent jointing c) Critical dimensions of precast concrete elements should be verified before installation	a) Minor adjustments of the element/panel alignment can be done during installation However the effects on the final alignment and deviation of the building should be evaluated b) For minor deviations, corrective measures such as surface grinding, trimming/hacking and skim coat application can be appropriately used to rectify the precast elements before installation c) Precast elements that are not within acceptable tolerance limits and have significant effects on the structural integrity or architectural performance should not be used

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of reference in this Subsection.

	IS No.	*Title*
(1)	2185	Specification for concrete masonry units
	(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
	(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
	(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
	(Part 4) : 2008	Cellular concrete blocks using preformed foam
	3201 : 1988	Criteria for design and construction of precast trusses and purlins (*first revision*)
	6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
	6073 : 2006	Specification for autoclaved reinforced cellular concrete floor and roof slabs (*first revision*)
	9893 : 1981	Specification for precast concrete blocks for lintels and sills
	10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored slab unit
	10505 : 1983	Code of practice for construction of floors and roofs using precast concrete waffle units
	11447 : 1985	Code of practice for construction with large panel prefabricates
	12440 : 1988	Specification for precast concrete stone masonry blocks
	13990 : 1994	Specification for precast reinforced concrete planks and joists for flooring and roofing
	14143 : 1994	Specification for prefabricated brick panel and partially precast concrete joist for flooring and roofing
	14201 : 1994	Specification for precast

	IS No.	*Title*
		reinforced concrete channel unit for construction of floors and roofs
	14241 : 1995	Specification for precast L-Panel units for roofing
(2)	4905 : 1968	Methods for random sampling
(3)	11447 : 1985	Code of practice for construction with large panel prefabricates
(4)	3935 : 1966	Code of practice for composite construction
(5)	3201 : 1988	Criteria for design and construction of precast trusses and purlins (*first revision*)
(6)	6332 : 1984	Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*)
	10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored slab units
	10505 : 1983	Code of practice for construction of floors and roofs using precast reinforced concrete waffle units
	13994 : 1994	Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists
	14142 : 1994	Code of practice for design and construction of floors and roofs with prefabricated brick panel
	14215 : 1994	Code of practice for construction of floor and roof with RC channel units
	14242 : 1995	Code of practice for design and construction of roof with L-Panel units
(7)	6061	Code of practice for construction of floor and roof with joists and filler blocks
	(Part 1) : 1971	With hollow concrete filler blocks
	(Part 2) : 1981	With hollow clay filler blocks (*first revision*)
	(Part 3) : 1981	With precast hollow clay block joists and hollow clay filler blocks
	(Part 4) : 1981	With precast hollow clay block slab panels

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction:
7B Systems Building and Mixed/Composite Construction

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 6/Subsection 7B) covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for systems building and mixed/composite construction.

Systems building and mixed/composite building construction, popularly referred to as pre-engineered building (PEB) construction, is an upcoming field as far as its development and use in the country is concerned. Two aspects specifically to be borne in mind are the system to be adopted for the different categories of buildings and the sizes of their components. Here the principle of modular coordination is of value and its use is recommended.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005.

In the second revision in 2005, this Section, earlier named as prefabrication and systems building was renamed and restructured as follows:

Section 7 Prefabrication, Systems Buildings and Mixed/Composite Construction
- 7A Prefabricated Concrete
- 7B Systems Buildings and Mixed/Composite Construction

This Subsection 7B covering systems building and mixed/composite construction, introduced in 2005, prescribed general requirements applicable to all valid existing systems and mixed/composite constructions as also to accommodate any new system introduced in the country. The Subsection 7A covered those systems approach which predominantly uses concrete as the material for components.

In this revision of this Subsection, following modifications have been incorporated:

a) Definitions of some existing terminologies have been modified, wherever required.
b) Aspects enlisted relevant to devising systems and structural schemes, have been updated.
c) Design considerations have been reviewed and modified based on latest thinking and practices.

The information contained in this Subsection is largely based on IS 15917 : 2010 ‘Building design and erection using mixed/composite construction — Code of practice’.

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 7 Prefabrication, Systems Building and Mixed/Composite Construction: 7B Systems Building and Mixed/Composite Construction

1 SCOPE

This Code (Part 6/Subsection 7B) covers recommendations regarding modular planning, component sizes, joints, manufacture, storage, transport and erection of prefabricated elements for use in buildings and such related requirements for systems building and mixed/composite construction.

2 TERMINOLOGY

For the purpose of this Subsection, the following definitions shall apply.

2.1 Authority Having Jurisdiction — The authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official or an agency to act on its behalf; hereinafter called the 'Authority'.

2.2 Basic Module — The fundamental module used in modular coordination, the size of which is selected for general application to building and its components.

NOTE — The value of the basic module has been chosen as 100 mm for the maximum flexibility and convenience. The symbol for the basic module is *M*.

2.3 Cellular Concrete — The material consisting of an inorganic binder (such as lime or cement or both) in combination with a finely ground material containing siliceous acid (such as sand), gas generating material (for example, aluminium powder), water and harmless additives (optional); and steam cured under pressure in autoclaves.

2.4 Component — A building product formed as a distinct unit having specified sizes in three dimensions.

2.5 Composite/Mixed Construction — Construction involving two or more different kinds of components such as prefabricated structural units of steel, prestressed concrete or reinforced concrete and cast *in-situ* concrete, ferrocement, timber, masonry in brickwork and blockwork, glass and glazing connected together in such a manner that they act integrally.

2.6 Increments — Difference between two homologous dimensions of components of successive sizes.

2.7 Module — A unit of size used in dimensional coordination.

2.8 Modular Coordination — Dimensional coordination employing the basic module or a multimodule.

NOTE — The purposes of modular coordination are:

a) To reduce the variety of component sizes produced, and

b) To allow the building designer greater flexibility in the arrangement of components.

2.9 Modular Grid — A rectangular coordinate reference system in which the distance between consecutive lines is the basic module or a multimodule. This multimodule may differ for each of the three orthogonal dimensions of the grid, two in plan and one in vertical direction.

2.10 Multimodule — A module whose size is a selected multiple of the basic module.

2.11 Prefabricate — Fabrication of components or assembled units prior to erection or installation in a building.

2.12 Prefabricated Building — The partly/fully assembled and erected building, of which the structural parts consist of prefabricated individual units or assemblies using ordinary or controlled materials, including service facilities; and in which the service equipment may be either prefabricated or constructed *in-situ*.

2.13 Sandwich Panels — Panels made by sandwiching a layer of insulation material between two outer layers of hard durable materials like steel, dense concrete, plastic, cement based sheet, ceramic, etc. The hard coverings on two outer faces may be of same or different materials; the three layers may or may not be bonded with each other to behave as a composite panel.

2.14 Self-Compacting Concrete — Concrete that is able to flow under its own weight and completely fill the voids with in the formwork, even in the presence of dense reinforcement without any vibration, whilst maintaining homogeneity without segregation.

2.15 Shear Connectors — Structural elements, such as anchors, studs, channels, loops and spirals, intended to transmit the shear between the prefabricated member

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and the cast *in-situ* concrete and also to prevent separation at the interface.

2.16 System — The method of construction of buildings with certain order and discipline and repetitive operations using the prefabricated components, tunnel form or engineered shuttering, where the work is organized and follows a defined procedure.

2.17 Unit — Building material formed as a simple article with all three dimensions specified, complete in itself but intended to be part of a compound unit or complete building. Examples are brick, block, tile, etc.

3 MATERIALS, PLANS AND SPECIFICATIONS

3.1 Materials

3.1.1 Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/ Composite Construction, Subsection 7A Prefabricated Concrete' of the Code shall be referred for requirements of materials and also for the characteristics to be considered in their selection.

3.1.2 The materials used in prefabricated components may be many and the modern trend is to use concrete, ferrocement, steel, treated timber, aluminium, cellular concrete, light weight concrete, ceramic products, etc. However, this Subsection pertains to mixed/composite construction.

3.2 Plans and Specifications

This shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

4 MODULAR COORDINATION, ARCHITECTURAL TREATMENT AND FINISHES

4.1 Modular Coordination

This shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

4.2 Architectural Treatment and Finishes

This shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

5 COMPONENTS

5.1 The preferred dimensions of precast elements used and their casting tolerances shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

5.2 The permissible tolerances of timber used shall be in accordance Part 6 'Structural Design, Section 3 Timber and Bamboo, Subsection 3A Timber' of the Code.

5.3 For permissible tolerances of steel and masonry, reference may be made to relevant Indian Standards.

6 FORMWORK SYSTEMS

The formwork systems which are utilized in buildings shall be as given in **6.1** to **6.5**.

6.1 Tunnel Form

This is a system which casts walls and slab monolithically in a single pour of concrete. Façade walls are precast or of block masonry to enable removal of tunnel form. All components of the formwork are made up of steel. This produces very rapid construction in a building where the plans are of modular nature suitable for this technology. Accelerated curing, if required, is possible enabling early stripping of formwork.

6.2 Slipform

Slipform is a continuously moving form at such a speed that the concrete when exposed has already achieved enough strength to support the vertical pressure from concrete still in the form as well as to withstand nominal lateral forces. Slipform may be classified as straight slipform, tapering slipform and slipform for special applications. Construction of lift cores and stairwell using slipform technique comes under special applications because of their complex sizes, shapes and loads to be lifted along with the slipform like walkway truss, etc, which is essential for construction. This system uses hydraulic jacks avoiding crane for lifting of assembly during construction operation. This system facilitates rapid construction and continual casting, creating a monolithic structure thereby avoiding construction joints.

6.3 Aluminium Formwork

This system of formwork uses modular aluminium panels, which are light and rust free, in both sheathing and framework. It may be used for a broad range of applications from wall to slab construction panels to more complicated structures involving bay windows, stairs and hoods. Every component is light enough to be handled easily thereby minimizing the need for heavy lifting equipment.

6.4 Large Panel Shuttering System

This is a system, which gives an advantage of combining speed and quality of construction. The vertical load

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carrying members are made of steel whereas the horizontal members are of plywood inserted into two wooden beams thereby forming a web flange. All the formwork and support systems shall be designed for the loads coming during the actual execution stage.

6.5 Other/New Systems

Any other/new system may be used for systems building after due examination and approval by the Authority.

7 SYSTEM AND STRUCTURAL SCHEMES

7.1 Several schemes are possible, with certain constraints, using the same set of components. The degree of flexibility varies from system to system. However, in all the systems there is a certain order and discipline.

7.2 The following aspects, among others, are to be considered in devising a system:

a) Effective utilization of spaces;
b) Straight and simple walling scheme;
c) Limited sizes and numbers of components;
d) Limited opening in bearing walls;
e) Regulated locations of partitions;
f) Standardized service and stair units;
g) Limited sizes of doors and windows with regulated positions;
h) Structural clarity and efficiency;
j) Suitability for adoption in low and high rise building;
k) Ease of manufacturing, storing and transporting;
m) Speed and ease of erection;
n) Optimization of available handling equipment; and
p) Simple jointing system.

7.3 Systems for Mixed/Composite Construction

The system of mixed/composite construction depends on the extent of the use of prefabricated components, their materials, sizes and the technique adopted for their manufacture and use in building.

7.3.1 *Combinations of System Components for Mixed/ Composite Construction*

The following combinations may be used in mixed/ composite construction:

a) Structural steel work and timber roofs on precast frames.
b) Precast floors onto steel and concrete beams, and masonry walls.
c) Profiled metal decking on precast beams.
d) Precast frames onto cast *in-situ* foundations, retaining walls, etc.
e) Precast frames stabilized by masonry walls, steel bracing, etc.
f) Precast cladding in steel or cast *in-situ* frames and *vice-versa*.
g) Glass curtain walling (*see* Part 6 'Structural Design, Section 8 Glass and Glazing' of the Code), stone cladding or metal sheeting onto precast concrete frames, etc.
h) Reinforced concrete and structural steel as composite columns and beams.

7.3.1.1 Precast concrete may be combined with cast *in-situ* concrete, often termed hybrid construction. Cast *in-situ* is mostly used to form homogenous connections between precast elements and provide a structural topping for horizontal diaphragm action. In other cases it is used to form the foundations and sub-structure to the building.

7.3.1.2 Structural steel work is largely used in long span prestressed concrete floors supported on rolled and prefabricated steel beams and also as steel roof trusses supported on concrete columns.

7.3.1.3 Timber may be used as long span glue-laminated beams and rafters, with precast concrete. Precast floors may be used in timber frame construction. Similarly, timber frames with precast elements shall be used as a building system.

7.3.1.4 Brick and block masonry may be combined with precast concrete structures and floors. The most common combinations is to use prestressed floors on load bearing walls.

8 DESIGN CONSIDERATIONS

8.1 The mixed/composite structures shall be analyzed appropriately and the joints in them designed to take the forces of an equivalent discrete system. Resistance to horizontal loading shall be provided by placing beams, walls and/or bracings in two directions at right angles or otherwise. The individual components shall be designed, taking into consideration appropriate end conditions and loads at various stages of construction. The components of the structure shall be designed for loads in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code. In addition, members shall be designed for handling, erection and impact loads that may be expected during handling and erection.

8.2 For mixed and composite construction the following shall be considered:

a) *Positions of stability cores, walls, bracing, etc* — In high rise buildings, the most

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popular method is a central core constructed several storeys ahead of the framework. The core could be built using precast concrete panels, CIP walls, steel cross bracing or precast concrete diagonal bracing.

b) *Maturity of connections* — Cast *in-situ* grouted joints need temporary propping until desired design strength is achieved unless combined mechanical connections are also used. The overall construction sequence should be planned ahead of time carefully as per the design requirements. The design of temporary bracing system using key components should be looked at critically.

c) *The availability and/or positioning of equipments to transport and erect components* — The size and weight of the various components shall be organized to make optimum use of crane capacity, for example, the lightest units farthest from the operating zone.

d) *Erection safety and speed of construction, with attention to cast in-situ concreting sequences* — This is particularly important where fixing gangs are unaccustomed to working with different materials.

e) *Tolerances for economical construction* — This is particularly important where different manufacturers are producing components in different materials.

8.3 Other design considerations and safety requirements against progressive collapse shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

9 JOINTS

Design of joints shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

10 TESTS FOR COMPONENTS/ STRUCTURES

Sampling procedure, testing on individual components and load testing of structure shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

11 ERECTION

11.1 Manufacture, Storage, Transport and Erection

The requirements relating to manufacture, storage, transport and erection of precast concrete elements shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/ Composite Construction, Subsection 7A Prefabricated Concrete' of the Code, including the requirements applicable to mixed/composite constructions given therein.

11.2 Decking

Constructional practices relating to decking shall be as given in Annex A.

11.3 Concreting on Decking

Concreting on decking shall be carried out in accordance with Annex B.

12 EQUIPMENT

The requirements relating to equipment used in the precast concrete construction shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication, Systems Building and Mixed/ Composite Construction, Subsection 7A Prefabricated Concrete' of the Code.

13 PREFABRICATED STRUCTURAL UNITS

For the design and construction of composite structures made up of prefabricated structural units and cast *in-situ* concrete, reference may be made to good practice [6-7B(1)].

For design and construction of precast reinforced and prestressed concrete triangulated trusses reference may be made to the good practice [6-7B(2)].

For design and construction of floors and roofs using various precast units, reference may be made to the good practice [6-7B(3)].

For construction with large panel prefabricates, reference may be made to good practice [6-7B(4)].

For construction of floors and roofs with joists and filler blocks, reference may be made to good practice [6-7B(5)].

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ANNEX A

(*Clause* 11.2)

CONSTRUCTION PRACTICE FOR DECKING

A-1 RECEIVING, STORING AND LIFTING THE DECKING

A-1.1 Receiving Decking

Decking is packed by the manufacturer into bundles of up to 24 sheets, and the sheets are normally secured with metal banding. Each bundle may be up to 1 m wide (the width of a single sheet) by 750 mm deep, and may weigh up to 2.5 t, depending on sheet length. Loads are normally delivered by articulated vehicles approximately 16 m long with a maximum gross mass of up to 40 t, and a turning circle of approximately 19 m. It shall be ensured that there is suitable access and appropriate standing and off-loading areas.

Each bundle will be given an identification tag by the manufacturer. The information on each tag shall be checked immediately upon arrival, to prevent incorrect sheets being used, or unnecessary delays if changes are necessary. In particular, the stated sheet thickness shall be checked against the requirement specified on the drawings, and a visual inspection shall be made to ensure that there is no damage.

The bundles shall be lifted from the vehicle. Bundles shall never be off-loaded by tipping, dragging, dropping or other improvised means.

A-1.2 Storing of Decking

The decking shall not be delivered more than one month before its anticipated use, as it may be vulnerable to abuse and damage if stored for longer periods on site. If it is not for immediate use, the decking shall be stored on the steel frame. If this is not possible, it shall be located in an area where it will not be contaminated by site traffic, and placed on bearers, which provide a gentle slope to the bundle. This will allow any condensation or rain to drain and a free flow of air around the bundle. Bundles shall not be stacked more than 4 m high, and no other materials shall be stored on top of them. Bearers shall be placed between bundles, and positioned to prevent bending of the sheets.

A-1.3 Lifting and Positioning the Decking

The support steelwork shall be prepared to receive the decking before lifting the bundles onto it. The top surface of the underlying beams shall be reasonably clean. When through-deck welding of shear studs is specified, the tops of the flanges shall be free of primer, paint and galvanizing.

The identification tags shall be used to ensure that bundles are positioned on the frame at the correct floor level, and in the nominated bay shown on the deck layout drawing. The bundles shall be positioned such that the interlocking side laps are on the same side. This will enable the decking to be laid progressively without the need to turn the sheets. The bundles shall also be positioned in the correct span orientation, and not at 90° to it. Care shall be taken to ensure that the bundles are not upside down, particularly with trapezoidal profiles. For most trapezoidal decking profiles, the embossments shall be oriented so that they project upwards.

Care is needed when lifting the decking bundles; protected chain slings are recommended for the same. Unprotected chain slings can damage the bundle during lifting. When synthetic slings are used there is a risk of the severing them on the edges of the decking sheets.

If timber packers are used, they shall be secured to the bundle before lifting so that when the slings are released they do not fall to the ground (with potentially disastrous results). Bundles shall never be lifted using metal banding.

A-2 DECK INSTALLATION

A-2.1 Placement of Decking

Breaking open the bundles and installing the decking shall be done only when all the sheets can be positioned and secured. The decking layout drawing shall also be checked to ensure that any temporary support that need to be in position prior to deck laying, is in place.

Access for installation may normally be achieved using ladders connected to the steel frame. Once the laying out the sheets is started by erectors, they shall create working platform by securely fixing the decking as they progress.

The laying of sheets shall begin at the locations indicated on the decking layout drawings. These would normally be at the corner of the building at each level, to reduce the number of ‘leading edges’, that is unprotected edges where the decking is being laid. When the bundles have been properly positioned, as provided above, there shall be no need to turn the sheets manually, and there shall be no doubt which way up the sheet shall be fixed.

Individual sheets shall be slid into place and, where possible, fixed to the steelwork before moving onto the next sheet. This will minimize the risk of an accident

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occurring as a result of movement of a sheet when it is being used as a platform. However, for setting-out purposes, it may be necessary to lay out an entire bay using a minimum number of temporary fixings before fully securing the sheets later.

Sheets shall be positioned to provide a minimum bearing of 50 mm on the steel support beams. The ends of adjacent sheets shall be butted together. A gap of up to 5 mm is generally considered not to allow excessive seepage, but, if necessary, the ends of the sheets may be taped together. When end gaps are greater than 5 mm, it is normally sufficient to seal them with an expanding foam filler. The longitudinal edges shall be overlapped, to minimize concrete seepage along the seams. Although not normally required, seam fixings may be necessary in some circumstances. Sheets projecting freely more than 600 mm shall be avoided.

If necessary, sheets shall be cut using a grinder or a nibbler. However, field cutting shall be kept to a minimum and shall only be necessary where a column or other obstruction interrupts the decking. Gaps adjacent to the webs of columns shall be filled in with off-cuts or thin strips of steel. Decking sheets shown as continuous on the decking layout drawing shall never be cut into more than one length. Also, sheets shall never be severed at the location of a temporary support, and the decking shall never be fastened to a temporary support.

As the work progresses, scraps and off-cuts shall be disposed of in a skip placed alongside the appropriate level of working. The skip shall be positioned carefully over a support beam to avoid overloading the decking. If a skip is not available, scraps shall be gathered for collection as soon as possible. Partially used bundles shall be secured, to avoid individual sheets moving in strong winds.

A-2.2 Fixing of Decking

Decking sheets shall be fixed to the top of the supporting structure. All fixings shall be made through the troughs in the decking. Fixings shall be at approximately 300 mm centres (or in every trough) along the end supports, and at 600 mm centres (or in alternate troughs) along the internal supports. As an absolute minimum, each sheet shall be connected at least twice to each permanent support. The number and placement of fasteners will normally be given on the decking layout drawing. Fixings shall not be made to temporary supports.

The fixings, together with 'through-deck' welded studs (if present) normally provide lateral restraint to the beams during the construction stages.

ANNEX B

(*Clause* 11.3)

CONSTRUCTION PRACTICE FOR CONCRETING ON DECKING

B-1 PLACING CONCRETE

B-1.1 Preparation

Prior to beginning work on the decking, guardrails shall be in position at all perimeters, internal edges and voids. The positions of any props (and back props) shall be checked against the details shown on the decking layout drawings to ensure that adequate support has been provided.

B-1.2 Cleaning the Decking

The surface of the decking shall be reasonably free of dirt, oil, etc, prior to concreting.

B-1.3 Construction Joints

Although there is no technical limitation to the area that may be concreted, the usual pour area is up to 1 000 m^2/day. Where the limits of the pour do not coincide with permanent slab edges, construction joints are used to define the extent of the pour.

The locations and details of the construction joints may have an effect on the cracking. The layout and details of the joints shall be determined by the structural designer. For example, when brittle bonded finishes are used, the relationship between the joints in the concrete and the joints in the finishes shall be considered at the outset, to reduce the risk of cracking in undesirable locations.

Where possible, the construction joints shall be located close to butt joints in the decking. Where shear connectors are used, it is preferable to create the joint to one side of the line of the shear connectors, to ensure

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sound concrete around the studs. If the construction joint cannot be made near a butt joint, it is suggested that no more than one-third of the decking span from a butt joint shall be left unpoured. Concreting shall not be stopped within a sheet length, because excessive deflections may occur when the loads on a continuous decking sheet are not balanced on either side of the intermediate support beam.

Stop ends, usually in the form of timber or plastic inserts, are used to create the construction joints. As with all the joints and ends of the decking, they shall be checked for potential grout loss.

B-1.4 Reinforcement

All reinforcement shall be properly supported so that it does not get displaced during concreting. Plastic stools, loops or preformed mesh may be used as 'chairs', but not plastic channels, which can induce cracking. Chairs shall be robust. In particular, the handling and movement of concrete carrying pipes during pumping can cause significant local impacts on the reinforcement.

The reinforcement that has been fixed shall be checked. Particular attention shall be given to checking any additional bar reinforcement, such as may be needed around openings.

B-1.5 Grout Loss

The decking joints shall be closely butted and exposed ends shall be 'stopped' with proprietary filler pieces to avoid grout loss. Gaps greater than 5 mm shall be sealed.

B-2 PLACEMENT

B-2.1 Concrete shall be placed in a way that minimizes the permanent deformation of the decking. This is particularly important for spans greater than 3 m. When concreting is progressed in the same direction as the span of the decking (that is parallel to the decking ribs), it shall be placed first over supports where the decking is continuous, followed by the mid-span region and finally the areas above the end supports. When concreting is progressed in a direction perpendicular to the decking span (that is transverse to the decking ribs), it shall be placed first at the edge where a decking sheet is supported by the underlap of an adjacent sheet. This helps to ensure that longitudinal seams between panels remain closed.

The concrete shall be well compacted, particularly near and around any shear connectors. This may be done using a vibrating beam, which may require adequate supports at either ends, or an immersion needle vibrator. Hand tamping is not recommended as a way of compacting the concrete. For slim floors with deep decking, or for other partially encased beams, a needle vibrator is needed to ensure proper concrete flow around the beams, beyond the ends of the decking.

B-2.2 Concrete Pumping

Pumping may be adopted for both normal and lightweight concrete mixes. Flow rates in the order of 0.5 m^3 to 1 m^3 of concrete per minute may be achieved, although, clearly, the longer the pump lines and the higher the concrete is to be pumped, the slower the operation. A pump may normally lift the concrete up to 30 m. Secondary pumps, placed at intermediate levels, may be necessary for higher lifts.

Pumplines are normally 150 mm in diameter and are assembled in segments. As the force exerted at bends may be significant, straight line pumping is preferred. The lines shall be supported on timber blocks at intervals of 2 m to 3 m. Resetting of pumplines is required at frequent intervals as the pour progresses. This means that the outlet pipe shall be moved frequently and carefully so that concrete heaping is minimized. A minimum of two operatives are necessary for this operation, one to hold and manoeuvre the outlet pipe, the other to shovel away excess concrete. No more than 4 workmen shall be present around the pipe outlet during pumping, because of the potential for overloading the decking. The concrete shall not be dropped from the outlet pipe onto the decking from a height of more than about 1 m.

B-2.3 Skip and Barrow

Placing concrete from a skip hung from a crane may be difficult because of obstructions from beams and decking at higher floor levels. However, despite being time consuming, it is sometimes efficient to use the skip and barrow technique for small infill bays.

Skips shall have a means of controlling the rate of discharge, and shall not be discharged from more than 0.5 m above the decking or barrow. When discharging into a barrow, the barrow shall be supported by thick (about 30 mm) boards covering a 2 m x 2 m area, or by a finished part of the slab. Either provision limits impact loads. Barrows shall be run over thick boards placed on the mesh, which shall be supported locally.

B-3 FINISHING, CURING AND DRYING

If power floating is to be carried out, this shall be done within 2 h to 3 h of casting. This allows time for the concrete to harden sufficiently.

As the concrete is only exposed on one surface of a composite floor, it can take longer than a traditional reinforced concrete slab to dry out.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Subsection.

	IS No.	*Title*
(1)	3935 : 1966	Code of practice for composite construction
(2)	3201 : 1988	Criteria for the design and construction of precast — Trusses and purlins (*first revision*)
(3)	6332 : 1984	Code of practice for construction of floor and roofs using precast doubly-curved shell units (*first revision*)
	10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/ prestressed concrete ribbed or cored units
	10505 : 1983	Code of practice for construction of floors and roofs using precast reinforced concrete waffle units
	13994 : 1994	Code of practice for design and construction of floor and roof with precast reinforced concrete planks and RC joists
	14142 : 1994	Code of practice for design and construction of floors and roofs with prefabricated brick panel
	14215 : 1994	Code of practice for construction of floor and roof with RC channel units
	14242 : 1994	Code of practice for design and construction of roof with L-Panel units
(4)	11447 : 1985	Code of practice for construction with large panel prefabricates
(5)	6061	Code of practice for construction of floor and roof with joists and filler blocks:
	(Part 1) : 1971	With hollow concrete filler blocks
	(Part 2) : 1981	With hollow clay filler blocks (*first revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 8 Glass and Glazing

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 6/Section 8) deals with the use of glass in buildings. Glazing has become an important item in building construction. Glass, the primary glazing element has to be selected to cater to several requirements and the glazing has to be designed to meet various engineering requirements. Fixing of glass a specialized operation, when properly done, will avoid the hazards of broken glass. Growing trend in resorting to glazed windows/doors in buildings and structures has considerably increased the importance of glazing and the need for proper workmanship. Considering all these, this Section is being introduced in this third revision of the Code.

This Section provides guidance in the selection of appropriate glazing for various types for building construction; guidance on the energy and light aspects while choosing glazing; guidance on determining the appropriate thickness of glass used in building glazing and guidance with respect to human impact safety while using glazing in buildings.

Use of organic coated films including safety films on glass shall not classify the glass as safety glass as per this Code, and hence users should exercise caution in choosing their options.

Information on installation of glass mirrors and glass railings are given in the informative Annexes G and H, respectively.

The information contained in this Section is largely based on the following Indian Standards:

IS No.	*Title*
IS 16231	Code of practice for use of glass in buildings:
(Part 1) : 2016	General methodology and selection
(Part 2) : 2016	Energy and light
(Part 3) : 2016	Fire and loading
(Part 4) : 2014	Safety related to human impact

Assistance has also been derived from the following publications in the formulation of this Section:

ISO 9845-1 : 1992	Solar energy — Reference solar spectral irradiance at the ground at different receiving conditions — Part 1: Direct normal and hemispherical solar irradiance for air mass 1,5
ISO 10291 : 1994	Glass in building — Determination of steady-state U-values (thermal transmittance) of multiple glazing — Guarded hot plate method
ISO 10292 : 1994	Glass in building — Calculation of steady-state U-values (thermal transmittance) of multiple glazing
ISO 10293 : 1997	Glass in building — Determination of steady-state U-values (thermal transmittance) of multiple glazing — Heat flow metre method

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 6 STRUCTURAL DESIGN

Section 8 Glass and Glazing

1 SCOPE

1.1 This Code (Part 6/Section 8) covers,

a) selection and application of glass in buildings, different types of glass, their requirements and associated glazing materials;

b) guiding provision for glazing in buildings with respect to their effect on energy, visual (light) and solar environments in the building;

c) selection of glass in buildings, subject to wind loading, seismic loading and special considerations for fire rated glass and related materials;

d) provisions for the selection, manifestation of glass in buildings, subject to safety with respect to human impact of the occupants; and

e) provisions relating to glazing systems such as selection, design, fabrication, installation, testing and maintenance.

1.2 This Section does not cover patent glazing.

NOTE — The provision of this Section pertains to glass and installation thereof. However, parties, as per their mutual agreement, may appropriately utilize the relevant provisions for installation of alternative sheeting materials used for similar purposes such as plastic glazing sheets/polycarbonate sheets taking also into account requirements of safety issues as applicable with the specific material.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply, and for other terms those given in accepted standards [6-8(1)] shall apply.

2.1 Annealed Glass (*see* **Glass**) — Also known as 'normal' glass, which has not been subjected to toughening, lamination and heat strengthening. It is the product obtained from the process of slow and steady cooling of hot glass in order to relieve internal stresses or thermal induced stresses.

NOTE — This term is most commonly used for flat glass.

2.2 Annealed Fire Resistant Glass — Type of glass which is made out of annealed glass combination and is tested for the required duration and satisfies the intended criteria of fire resistance. These types of glasses may not possess the best of the impact resistance characteristics and may be used as vision panels.

2.3 As-Cut Finished Sizes — Finished panes of flat glass cut from stock/standard sizes. They may be subject to further processing, such as edge working drilling, face decoration, etc.

2.4 Aspect Ratio — The ratio of a longer side of glass pane to its shorter side.

2.5 Balustrade — A low barrier forming a parapet to a stair, ramp, balcony, raised level or a change in level.

2.6 Beads or Glazing Beads — A strip of wood, metal or other suitable material attached to the rebate to retain the glass in position in the frame.

2.7 Bite — The minimum distance by which the inner edge of a frame (or a stop) overlaps the edge of the glass panel.

2.7.1 *Glazing Bite* — The dimension by which the framing system overlaps the edge of the glazing infill.

2.8 Block (Setting Block) — A small piece of wood, plastic, rubber or other suitable material used between the edges of the glass (generally the bottom edge only) to centralize the glass in the frame (frequently called a setting block).

2.9 Chair Rail — A fixed rigid bar that provides protection from human impact.

2.10 Clear Glass — A transparent glass with neutral/near colourless appearance.

2.11 Coefficient of Linear Expansion — It is expressed as the strain (change in length per unit length) per unit variation of temperature of a material.

2.12 Combustible Material — The material which when burnt adds heat to a fire when tested for combustibility in accordance with accepted standard [6-8(2)].

2.13 Corridor — A common passage or circulation space including a common hall.

2.14 Coupled Glazing (also known as Secondary Glazing) — Two panes of glazing spaced apart in an opening, either in the frame or glazed separately, to form an unsealed cavity.

2.15 Curtain Wall — Non-load bearing structure/partition of glass attached to the building frame, usually on the exterior face. Curtain wall vertical framing members run past the face of floor slabs, and provision for anchorage is typically made at vertical framing members only.

NOTE — In contrast to combination assemblies and composite units, curtain wall systems often need to meet additional performance requirements for inter-story differential movement, seismic drift, dynamic water infiltration, etc. Operating vents and entrance doors are provided as separate inserts.

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2.16 Distance Piece — A small piece of wood or other suitable material used to locate the glass between the bead and the back of the rebate to prevent lateral movement.

2.17 Door or Shutter Assembly Door-Set — A pedestrian door-set or industrial type door-set including any frame or guide, door leaf or leaves, rolling or folding curtain, etc, which is provided to give a fire resisting capability when used for the closing of permanent openings in fire resisting separating elements, which includes any side panel(s), vision panel(s), flush over panel(s) and/or transom panel(s) together with the building hardware and any seals (whether provided for the purpose of fire resistance or smoke control or for other purposes such as draught or acoustics) which form the assembly.

2.18 Double Glazed Fire Resistant Glass — A fire resistant glass that is used in a double glazed unit.

NOTE — These shall be tested as a complete Double Glazed Unit (DGU) or other multiple glazed units as the case may be. Double glazed fire resistant glass can be a combination of intumescent laminated fire rated or tempered fire resistant glass. Fire resistant glass cannot be combined with another glass and used as a DGU unless the combined double glazed or multiple glazed units are also tested.

2.19 Double Glazing — Glazing formed by an assembly of two glass panes separated by a spacer and the gap may be filled by vacuum, air or inert gases and hermetically sealed along the periphery to improve the thermal insulation.

2.20 Edge Deterioration — The discolouration of the reflective coating at the edge of the silvered glass.

2.21 Edge Faults — The faults that affect the as-cut edge of the glass. They may include entrant/emergent faults, shelling, corners on/off and vents.

2.22 Edge Polished — It is usually applied to flat glass, the edges of which have been polished after cutting.

2.23 Edging — Grinding the edge of flat glass, to a desired shape or size.

2.24 Exposed Edge — A glass panes' edge that is not covered.

2.25 Facade — It is the front or face of the building which is part of framed or frameless system.

2.26 Faceted Glazing — It is a type of glazing in which flat panes of glass are installed vertically at an angle to each other to form a faceted surface.

2.27 Fenestration — All area (including frame) in the building envelope that let in light, including window, plastic panels, clerestories, skylight, fanlight and glass doors that are generally more than one-half the floor height, and glass block walls.

2.28 Fin — A piece of glass positioned and fastened to provide lateral support.

2.29 Fire Separation — The distance, in metre, measured from the external wall of the building concerned to the external wall of any other building on the site, or from other site, or from the opposite side of street or other public space for the purpose of preventing the spread of fire.

2.30 Float Glass — Flat, transparent, clear or tinted soda-lime silicate glass having parallel and polished surfaces obtained by continuous casting and floatation on a metal bath.

NOTE — Flat glass is a general term covering sheet glass, float glass and various forms of rolled and plate glass in which shape of the glass is flat and commonly used for windows, glass doors, transparent walls and other architectural applications.

2.31 Flush Over Panel — A panel which is incorporated within a door-set or openable window and fitted above the leaf or leaves within the frame head and the jambs and with no transom.

2.32 Frame — An element made of timber/metal/aluminium or other durable material/combinations of materials, such as glass fins and structural sealant, supporting the full length of a glazed panel edge.

2.33 Frameless Glazing — An unframed glazing which maintains the integrity through pointed support structures.

2.34 Front Putty — The compound forming a triangular fillet between the surface of the glass and the front edge of the rebate.

2.35 Fully Framed Glazing — The glazing whose panels have all its four edges framed.

2.36 Gap — A clearance between two adjacent surfaces and/or edges, for example between the edge of the leaf and the reveal of the frame or between the face of the leaf and the frame stop.

2.37 Glass — An inorganic product of fusion which has cooled to a rigid condition without crystallizing. It is typically hard and brittle, and has a conchoidal fracture. It may be colourless or tinted and transparent to opaque. The term glass refers to monolithic glass unless specified otherwise.

2.38 Glass Appearance Faults — Faults such as spot and/or linear and/or enlarged area faults which alter the visual quality of glass.

2.39 Glazing — Act of securing of glass or other glazing material into a building in prepared openings in windows, door panels, partitions, etc.

2.40 Guard Rail — A permanent physical barricade used to prevent human impact on glass/glazing.

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2.41 Hairline Scratch — Very fine scratch that can hardly be seen with naked eye and is associated with glass cleaning techniques.

2.42 Halo — It is the distortion zone around a spot fault.

2.43 Heat Soaking — It is done on toughened/ tempered glass by reheating to a temperature of 290°C and keeping it at this temperature for 8 h and cooling it gradually. The glass can break spontaneously and without provocation due to possible impurity of nickel sulphide in basic glass used for toughening/tempering. This risk of spontaneous breakage can be minimised by heat soaking process by forcing such glasses to break during the test itself.

2.44 Heat Strengthened Glass — Glass within which a permanent surface compressive stress has been induced by a controlled heating and cooling process in order to give it increased resistance to mechanical and thermal stress and prescribed fracture characteristics.

2.45 Hermetic Seal — A complete seal (especially against the escape or entry of air which is impervious to outside interference or influence) done on insulating glass units.

2.46 High Activity Area — An area where multiple and major human activity takes place.

2.47 High Risk Area — An area prone to human injury and causality.

2.48 Infill Balustrades — The balustrades in which the supported glass resists an infill pressure and/or point load applied to the glass panel.

2.49 Insulating Glass Unit (IGU) — An assembly consisting of at least two panes of glass, separated by one or more spaces, hermetically sealed along the periphery, mechanically stable and durable.

2.50 Interlayer — Layer or material acting as an adhesive and separator between plies of glass and/or plastic glazing sheets.

NOTE — It can be designed to give additional performance to the finished product, for example impact resistance, fire resistance, solar control and acoustic insulation

2.51 Internal Partition — An interior dividing wall or such portion of an interior dividing wall that is not a door, side panel, shop front or atrium wall.

2.52 Laminated Safety Glass — It is a glass made of two or more pieces of glass which are held together by an interleaving layer or layers of plastic materials.

2.53 Light Transmission — It is the measure of light passing through a transparent or a translucent material.

2.54 Light Transmittance — It is the measure of percent of visible light transmitted through glass pane which depends on type of body substrate and coating done on glass.

2.55 Linear Defects — They are the scratches and extended spot faults on the glass.

2.56 Manifestation — Any technique for enhancing a person's awareness of the presence of transparent glass.

2.57 Maximum Thickness — The thickness of a pane of glass at the maximum thickness tolerance.

2.58 Minimum Thickness — The thickness of a pane of glass at the minimum thickness tolerance.

2.59 Modulus of Elasticity (Young's Modulus) — This modulus expresses the tensile force that theoretically has to be applied to a glass specimen to stretch it by an amount equal to its original length. It is expressed as a force per unit area (for glass, $E = 0.7 \times 10^5$ N/mm^2 = 70 GPa).

2.60 Monolithic Glass — A single sheet of flat glass which could be either annealed, toughened or heat strengthened.

2.61 Mullion — Vertical framing member separating and supporting two adjacent panes of glass or panels.

2.62 Nominal Thickness — A numeric designation that indicates the approximate thickness of glass.

2.63 Non-Combustible Material — A material not liable to burn itself or to add heat to a fire when tested for combustibility in accordance with good practice [6-8(2)].

2.64 Organic Coated Glass — A sheet of glass coated on one or both sides with an applied organic coating or sheeting.

2.65 Pane — A single piece of glass or plastic glazing sheet material in a finished size ready for glazing.

2.66 Panel — An assembly containing one or more panes of glass.

2.67 Partition — It means an interior non-load bearing divider, one storey in height or part.

2.68 Partly Framed or Unframed Glazing — The panels that have one or more edges unframed.

2.69 Passive Solar Gain — The solar radiation in the form of energy and light which is transmitted through the glazing into the building and which can be utilized as a source of energy to reduce the need for artificial lighting.

2.70 Patterned Glass — A rolled glass having a distinct pattern on one or both surfaces.

2.71 Protective Coating(s) Faults —The faults where the metallic layer is exposed. They can be scratches or loss of adhesion of the protective coating(s).

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2.72 Rebate — The part of a surround; the cross-section of which forms an angle into which the edge of the glass is received.

2.73 Reflective Coated Glass — It is a glass with reflective coating which uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass, its absorption of solar energy is also increased.

NOTE — In comparison with float glass surface, these reflecting coatings (due to their composition) exhibit lower level of emissivity which improves their *U*-value.

2.74 Reflective Silver Coating Faults — It is the fault on reflective silver layer which shall alter the appearance of the silvered glass. They consist of scratches, stains, colour spots and edge deteriorations.

2.75 Residual Protection — It is the protection provided to avoid the human impact on glass. It is provided on the side of glass where there are chances of human impact. It can be achieved by providing a sill structure or a grill inside.

2.76 Shading Coefficient — The ratio of the rate of solar heat gain through a specific unit assembly of glass to the solar heat gain through a single light of 3 mm clear glass in the same environment.

2.77 Sheet Glass — Glass made in large sheet directly from furnace or by making a cylinder and then flattening it.

NOTE — These transparent glass have a glossy, fire-finished, apparently plane and smooth surfaces, but having a characteristic waviness of surface.

2.78 Skylight — A fenestration surface having a slope of less than 60° from the horizontal plane. Other fenestration, even if mounted on roof of a building is considered as either a vertical glazing or sloped glazing depending upon the angle of the glazing.

2.79 Sloped Overhead Glazing — A glazing that is inclined at less than 75° to the horizontal and located, wholly or partially, directly above an area that may be used by people.

2.80 Solar Energy Absorption — The percentage of the solar spectrum energy (ultraviolet, visible, and near-infrared) from 300 nm to 2 500 nm that is absorbed by a glass product.

2.81 Solar Energy Transmittance (Direct) — The percentage of energy in the solar spectrum, ultraviolet, visible, and near-infrared energy, 300 nm to 2 500 nm, that is directly transmitted through the glass.

2.82 Solar Heat Gain Coefficient (SHGC) — The SHGC is the fraction of incident solar radiation admitted through a fenestration, both directly transmitted, and absorbed and subsequently released inward through conduction, convection and radiation.

2.83 Spandrel — A non-vision portion of the exterior wall of a building.

2.84 Spot Faults — The nuclei (solid or gaseous inclusions), deposits, crush marks, etc, in the glass. In certain instances spot faults are accompanied by a distortion zone called 'halo'. The nucleus of the spot fault is measurable.

2.85 Stain — An alteration of the reflective coating characterized by a more or less brownish, yellowish or greyish colouration of zones which can sometimes cover the whole reflective surface.

2.86 Stock/Standard Sizes — The panes of flat glass such as coated, mirror, enamelled glass, etc, supplied with as-cut edges which are intended for further processing. These are generally corresponded with manufacturer's production size.

2.87 Tempered or Toughened Glass — Flat glass within which a permanent surface compressive stress has be induced by a controlled heating and cooling (quenching) process in order to give it greatly increased resistance to mechanical and thermal stress and prescribed fragmentation characteristics.

2.88 Tempered Fire Resistant Glass — A single piece of specially thermally-treated or chemically treated glass, tested for fire resistance for the required duration and having such a stress pattern that the piece when fractured, it reduces to numerous granular fragments, with no large jagged edges.

2.89 Thermal Transmittance (*U*) — Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in steady state conditions. It is also called as *U*-value. Its unit is W/m^2K.

NOTES

1 Thermal transmittance differs from thermal conductance insofar as temperatures are measured on the two surfaces of a building unit in the latter case and in the surrounding air (or other fluid) of the material on the two sides, in the former case. Thermal conductance is a characteristic of the building unit whereas thermal transmittance depends on conductance and surface coefficients of the building unit under the conditions of use.

2 In the case of glazing, thermal transmission is taken through the central part of the glazing, that is, without edge effects.

2.90 Through Component/Connection — The internal spacer or fixing that either penetrates through the door-set or openable window from one face to another or directly connects the faces of one to the other.

2.91 Tinted Glass — A normal flat glass to which colourants (normally metal oxides) are added during

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manufacturing process to achieve tinting and solar radiation absorption properties. It is also referred to as body tinted glass.

2.92 Toughened Safety (Tempered) Glass — A single piece of specially heat-treated glass, with a stress pattern such that the piece when fractured reduces to numerous granular fragments, with no large jagged edges.

2.93 Transom — A horizontal cross bar connecting two vertical members in a glazing frame.

2.94 Unframed Glazing — A glazing with one or more edges unframed.

2.95 UV Transmittance — The percentage of energy in the ultraviolet (UV) spectrum from 300 nm to 380 nm that is directly transmitted through the glass.

2.96 Vertical Fenestration — All fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 300 mm of a mass wall are considered walls and not fenestration.

2.97 Wired Glass — It is a type of glass into which a wire mesh is embedded during production. Wired glass has an impact resistance similar to that of normal glass, but in case of breakage, the mesh retains the pieces of glass.

3 APPLICATION

The type of glass chosen shall satisfy the following criteria:

a) For a given application, the type and thickness of glass selected shall be in accordance with the requirements provided herein and the thickness calculation as subjected to wind load shall also satisfy requirements for human impact safety.

b) Installation of glass to the building is done in accordance with the various provisions available in this Section and in the absence of any specific provisions the same shall be as per manufacturer's instructions.

c) Optical, solar, thermal performance of glazing (clear/tinted/coated reflective glass) shall have the characteristic performances, such as:

   1) Spectral transmittance, external and internal spectral reflectance;
   2) Light transmittance, external and internal light reflectance;
   3) Solar direct transmittance and reflectance;
   4) UV transmittance; and
   5) Better thermal transmittance (*U*-value).

4 GENERAL METHODOLOGY FOR SELECTION

4.1 Selection

4.1.1 Right from the initial project evaluation stage, a suitable methodology that incorporates the implications of use of glass materials and their influence on performance of the building shall have to be looked into. A typical flowchart outlining such a methodology is provided for the users of this Section (*see* Fig. 1).

It is assumed that,

a) the location of area to be glazed and its preliminary size/shape have been decided as part of normal building design process.

b) the designer has gained information on glass/ and plastic glazing sheet materials used in similar circumstances.

c) the designer is cognizant of implications of any innovation in design.

4.1.2 Design requirement including aesthetic considerations and client specified requirements such as security and maintenance to be considered.

4.1.3 Effect of design on cost such as initial cost of glazing (specification of glass/plastic sheeting material; glazing method; access for initial glazing; work schedule; protection during construction); effect of glass/plastic sheeting material on capital/running cost related to building heating/cooling, lighting and ventilation; and maintenance cost of glazed areas (access for cleaning and reglazing) should be considered.

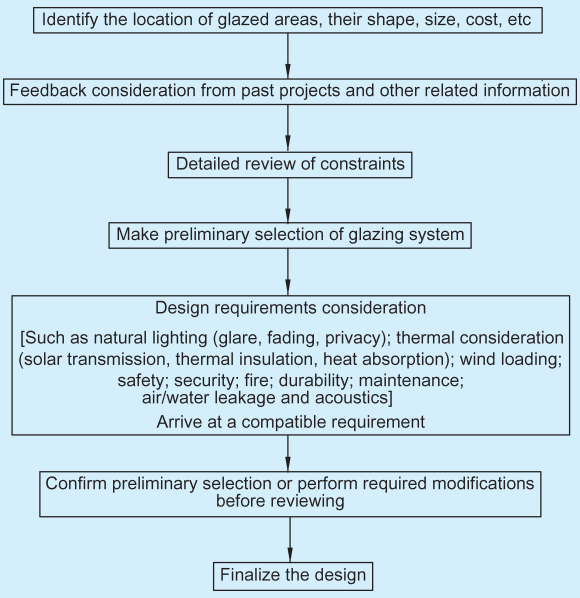


FIG. 1 TYPICAL SEQUENCE OF DESIGN EVALUATION FOR GLAZED AREAS

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4.1.4 Selection of appropriate glass may be done considering the cost benefit analysis in respect of the benefit accrued against the alternatives available. Also, the comparative cost of glazing materials should be considered together with their life expectancy and probability of need for maintenance. In the context of selection of glass, the provisions given in the Part 11 'Approach to Sustainability' of the Code may also be considered in addition to the cost benefit analysis on the use of glass *vis-a-vis* use of other alternatives. To suitably modify to indicate that the selection of appropriate glass may be made considering the cost benefit analysis in respect of the benefit accrued against the alternatives available.

4.2 Types of Glass

4.2.1 The soda lime silicate glass is classified based on the type of internal stress which determines the strength of the glazing towards breakage, design and installation procedure and based on application. Table 1 gives the typical properties of various types of glass.

4.2.2 *Normal (Annealed) Glass*

For requirements including tests on nominal thickness of annealed (flat) glass {*see* Table 1 of accepted standard [6-8(3)]}. Flat transparent sheet glass shall conform to the following classes as specified in accepted standard [6-8(3)] namely; A quality or Selected Quality (SQ), B quality or Ordinary Quality (OQ) and C quality or Greenhouse Quality (GQ). Transparent float glass shall be as per accepted standard [6-8(4)].

A transparent flat glass is designated as clear glass when it is not tinted and when its light transmittance after any necessary pre-treatment is greater than the value prescribed in Table 2 for the nominal thickness.

4.2.3 *Laminated Glass*

4.2.3.1 Laminated glass is a glass configuration made of two or more pieces of glass bonded together by interlayer/interlayers. It is commonly used as a form of safety glass which cracks and breaks under sufficient impact, the broken glass fragments being still held together. When laminated glass is broken, fragments tend to adhere to the interlayer. For requirements of laminated safety glass, accepted standard [6-8(5)] may be referred.

4.2.3.2 Laminated glass does not shatter like ordinary glass. It absorbs impact, resists penetration, and remains intact even if broken, holding glass fragments in place and lowering the risk of injury. Laminated glass is capable to stop flying debris and limit or avoid splintering on opposite side of the impact. When exposed to heat from solar radiation resulting in unequal temperature in the pane, laminated glass breaks but stays in place longer. The risk of thermal breakage is reduced only when heat strengthened/tempered laminated glass is used.

Table 1 Typical Properties of Various Types of Glass

(*Clause* 4.2.1)

Sl No.	Properties	Annealed Glass	Float Glass	Annealed Laminated Glass	Tempered or Toughened Glass
(1)	(2)	(3)	(4)	(5)	(6)
i)	Modulus of rupture	40 N/mm^2	40 N/mm^2	40 N/mm^2	120 to 200 N/mm^2
ii)	Thickness	As per accepted standard [6-8(3)]	As per accepted standard [6-8(4)]	6.38 - 19 mm	3 - 19 mm
iii)	Density (approximate)	← 2 400 – 2 550 kg/m^3 →			
iv)	Modulus of elasticity	← 70 GPa →			
v)	Coefficient of linear expansion	← 9×10^{-6} m/m K →			
vi)	Compressive strength	← 1 000 N/mm^2 →			

NOTE — Conventionally, the following types of glass exist:

a) Annealed (clear) glass.
b) Extra clear glass.
c) Body tinted glass.
d) Coated glass (including Lacquered glass).
   1) Online coated glass.
   2) Offline coated glass.
e) *Processed glass* — Each of the glasses (a) to (e) above can be subjected to further processing to produce the following types:
   1) Heat strengthened,
   2) Toughened or tempered,
   3) Double glazed unit,
   4) Laminated glass (Single laminated),
   5) Laminated double glass unit,
   6) Ceramic/screen printed fritted glass (patterned glass), and
   7) Fire safety glass.

4.2.3.3 Laminated glass can be made from the following typical combinations:

a) Glass which is float/sheet/patterned/polished wired/wired patterned glass, and may be having the following properties:
   1) clear, tinted or coated;
   2) transparent, translucent or opaque;
   3) annealed, heat strengthened or toughened; and
   4) surface treated (such as acid etched or by sandblast).
b) Plastic glazing sheet material which can be polycarbonate or acrylic and may be having the following properties:
   1) clear, tinted or coated; and
   2) transparent or translucent.

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Table 2 Minimum Light Transmittance Value (Designating a Transparent Glass as Clear Glass)

(*Clause* 4.2.2)

Nominal Thickness, mm	2	3	4	5	6	8	10	12	15	19	25
Minimum Value of Light Transmittance, Percent	89	88	87	86	85	83	81	79	76	72	67

c) Interlayers which differ based on material type and composition; mechanical characteristics; and optical characteristics, and may be having the following properties:

1) Clear or coloured;

2) Transparent, translucent or opaque; and

3) Coated.

NOTE — Until standards on plastic glazing sheet materials and interlayers are formulated, they will be subject to the specifications of manufacturers of laminated glazing materials.

4.2.4 *Toughened or Tempered Glass*

4.2.4.1 Toughened glass is a type of safety glass which is heat treated to a uniform temperature of approximately 650ºC and rapidly cooled to induce compressive stresses of 75.5 MPa (770 kg/cm^2) to 143.4 MPa (1 462 kg/cm^2) on the surfaces and edge compression of the order of 66.7 MPa (680 kg/cm^2). For requirements of toughened safety glass, accepted standard [6-8(5)] may be referred.

4.2.4.2 Toughened glass gains its added strength from the compressed surfaces. However, if a deep scratch or an impact penetrates the surface, the glass shall break into a number of small particles. Any attempt to cut, drill, grind or sand blast the glass after toughening may result in glass breakage. The heat treatment process does not change the light transmission and solar radiant heat properties of the glass.

4.2.4.3 Toughened glass provides greater thermal strength. It increases resistance to both sudden temperature changes and temperature differentials up to 250°C compared with normal glass, which can withstand temperature differentials up to 40°C only. Thermally toughened glass is approximately four times stronger than annealed glass of the same thickness and configuration, and shall comply with the requirements of accepted standard [6-8(5)]. Toughened glass is difficult to break and when broken, it breaks into many relatively small fragments, which are less likely to cause serious injury to people, as there are no jagged edges or sharp corners like in normal glass. On the contrary, the toughened glass is also susceptible to breakage when hit with a small tap at its edge using a hammer or a hard object. Toughened glass is often referred to as safety glass because it meets the requirements of the standards which apply to safety glass. Toughened glass cannot be subjected to further processing, such as cutting, drilling, edge grinding after toughening and any alterations such as sandblasting or acid etching will weaken glass and can cause premature failure (*see* Notes).

Float glass contains some level of imperfection. One type of imperfection is nickel sulphide (NiS) inclusions. Most NiS inclusions are stable and cause no problems. There is, however, the potential for NiS inclusions that may cause spontaneous breakage in fully tempered glass without any load or thermal stress being applied. Heat soak testing is a process that exposes critical NiS inclusions in fully tempered glass. The process involves placing the tempered glass inside a chamber and raising the temperature to approximately 290ºC to accelerate nickel sulphide expansion. This causes glass containing nickel sulphide inclusions to break in the heat soak chamber, thus reducing the risk of potential field breakage. However, the heat soak process is not 100 percent effective.

NOTES

1 The process of toughening is used to increase the strength of glass and to produce fracture characteristics that are desirable in many situations. However, the process of toughening can also lead to an increased risk of spontaneous glass fracture (associated with material impurities). Accordingly, the possibility of spontaneous fracture should be taken into account when toughened glass is used.

2 Heat soaking may minimise the risk of nickel sulphide induced spontaneous fracture in toughened glass. Glass manufacturers maybe consulted for advice relating to anticipated nickel sulphide minimization.

4.2.5 *Heat Strengthened Glass*

Heat strengthened glass is a type of tempered glass which has been strengthened thermally by inducing a surface compression of about 44.3 MPa (422 kg/cm^2) to 64.5 MPa (658 kg/cm^2) as compared to a range of 75.5 MPa (770 kg/cm^2) to 143.4 MPa (1 462 kg/cm^2) in case of fully tempered glass. Heat strengthened glass is valued for its mechanical strength, which is twice that of normal annealed glass though half of toughened glass. With the exception of strength and thermal resistance characteristics, heat strengthened glass retains the normal properties of annealed glass. Heat

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strengthened glass provides necessary resistance to thermal stress associated with high performance glazing materials such as tinted glass and reflective glass. It also provides necessary resistance to heat building up when used as spandrel glass. Heat strengthened glass with its flatter surface also results in the facade having less optical distortions. Heat strengthened glass shall have a surface compression of 24 - 52 MPa.

NOTES

1 Heat strengthening associated with relatively less residual stresses ≤ 52.0 MPa has lower risk of spontaneous glass fracture (associated with material impurities).

2 Surface compression (including fragmentation), four point bending, warp and waviness tests are typically carried out to determine the characteristics of heat strengthened glass.

4.2.6 *Reflective Glass*

A metallic coating is applied to one side of the glass in order to significantly increase the amount of reflection by the glass of both the visible and infrared (light and heat) ranges of the electromagnetic spectrum. This metallic coating can be applied to clear or body tinted glass, without adversely affecting the transparency of the glass. The reflective glass imparts an enhanced appearance to the exterior of buildings due to the coating of metal oxides on the glass. It is widely applied as an aesthetic and energy efficient product in buildings for its highly reflective surface and wide palette of colours. It reduces heat gain and glare from the exterior and allows optimum visible light transmission to the interior. If designed/used properly, reflective glass can aid at reducing the air conditioning load of buildings

NOTE — Highly reflective glass should be avoided, especially in internal environments. The reflections from these surfaces can be particularly confusing for persons with vision impairment.

4.2.7 *Insulating Glass Unit*

Insulating glass unit, a prefabricated unit of glass having an edge seal that not only binds the individual sheets of glass together to maintain the mechanical strength of the joint but also protects the cavity between the glasses from outside influences. The moisture in the cavity between the two glasses is controlled by desiccants filled in the perforated spacer. The spacer may be aluminum, composites, plastics, etc. The spacer ensures the precise distance between the glass panes. The cavity is normally filled with dry air but can be also filled with gases such as argon or krypton for better thermal performance. The low heat conductivity of the enclosed dry gas between the glass panes drastically reduces the thermal heat transmission through the glass to 2.8 W/m^2K (12 mm spacer between two 6 mm glass) as compared to 5.73 W/m^2K for normal 6 mm glass. It also helps in reducing the direct solar energy specifically when the outer pane is a solar control glass. For sizes greater than 3 m^2, the thickness of the spacer shall be chosen such that physical contact of glass panes (white spots) does not occur.

NOTE — Moisture penetration test and argon/krypton gas level test are typically carried out to determine the characteristic of IGUs.

4.2.8 *Wired Glass*

The general requirements including thickness, dimensional tolerance and tests for wired glass as specified in accepted standard [6-8(6)] are valid.

4.2.9 *Glass Fins*

When glass fins are used as a decorative member, it can be either toughened (tempered) or laminated glass.

When glass fins are used as a structural member, it shall be toughened and laminated. The depth and thickness may vary as per elevation and wind load requirements. Design should also accommodate movements. It is recommended to use finite element analysis to determine the appropriate glass fin sizes.

4.3 Application

Glass can be designed/suited to use in building occupancies such as in residential, assembly and mercantile in elements such as façades, windows, doors, partitions, display units, shop fronts, greenhouses (where plants are grown), atrium. Different types of glass are selected based on requirements. For safety against accidental breakage and strength requirement (mechanical and thermal), toughened glass or laminated glass may be considered over annealed glass. For increased high security requirements, acoustic insulation, sloped glazing and skylights, laminated glass may be considered.

4.4 Associated Glazing Materials

4.4.1 *Structural Sealant*

The structural sealant could be of silicone type with requirements meeting the design criteria. Structural sealant shall be shelf-stable, natural-cured, elastomeric adhesive exhibiting the desired adhesion to building substrates. The structural sealant may require cleaning and or priming to get good adhesion for structural glazing application. For laminated glass applications where glass edges are sealed with a sealant, compatibility shall be ensured with the interlayer to avoid delamination.

4.4.2 *Gaskets*

Gasket is a mechanical seal that fills the space between two mating surfaces, to prevent leakage from or into the joined objects and will be able to deform while under compression and tightly fills the space it is designed for, including any slight irregularities.

4.4.3 *Preformed Tape*

Typical requirements of preformed butyl and foam tapes shall be as given in Table 3.

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4.4.4 *Setting Blocks, Location Blocks and Distance Pieces*

Setting blocks, location blocks, and distance pieces shall be designed in accordance with **6** which are,

a) resilient, load-bearing, non-absorbent and rot-proof materials; and
b) compatible with all other materials that may come in contact with them.

4.5 General Requirements

4.5.1 Glazing and associated materials used for the proper installation shall satisfy the minimum dimensional and framing requirements in accordance with the procedures given in this Section. The dimensional and thickness tolerance of the glass used in exterior and interior is determined from the provisions given hereunder.

4.5.2 *Dimensional Requirement*

4.5.2.1 The dimensions for edge clearance, edge cover, and front and back clearance, as defined in Fig. 2, shall be not less than the values given in Table 4.

NOTE — For glazing systems where the framing member is aluminium or steel and gaskets are used to capture the glazing, minimum glazing bite of 12.7 mm is recommended for architectural glazing.

4.5.2.2 *Front putty width*

The front putty width shall be not less than 10 mm for panels up to 1 m^2, and not less than 12 mm for panels between 1 m^2 and 2 m^2.

Table 3 Typical Properties of Preformed Tapes

(*Clause* 4.4.3)

Sl No.	Properties	Requirement
(1)	(2)	(3)
i)	Low temperature flex	No cracks at –23°C
ii)	Weight loss	2 percent, *Max*
iii)	Vehicle migration	1 paper stained maximum and this stain shall be no more than 3.2 mm from edge of sample maximum
iv)	Backing removal	No transfer of tape compound to the paper
v)	Yield strength	41.4 kPa, *Min*
vi)	Compression/Recovery	Compression index, 1.22 N/mm^2, *Max*
vii)	Water absorption	Weight gain *Max* after boiling, 40 kg/m^3, *Max*
viii)	Flow test	Loss of height, 60 percent, *Max*

4.5.2.3 *Dimensions of rebates and grooves (width and depth)*

Dimensions of rebates and grooves shall accommodate the requirements of Table 4 and allow for the appropriate setting and location blocks (*see also* **6**).

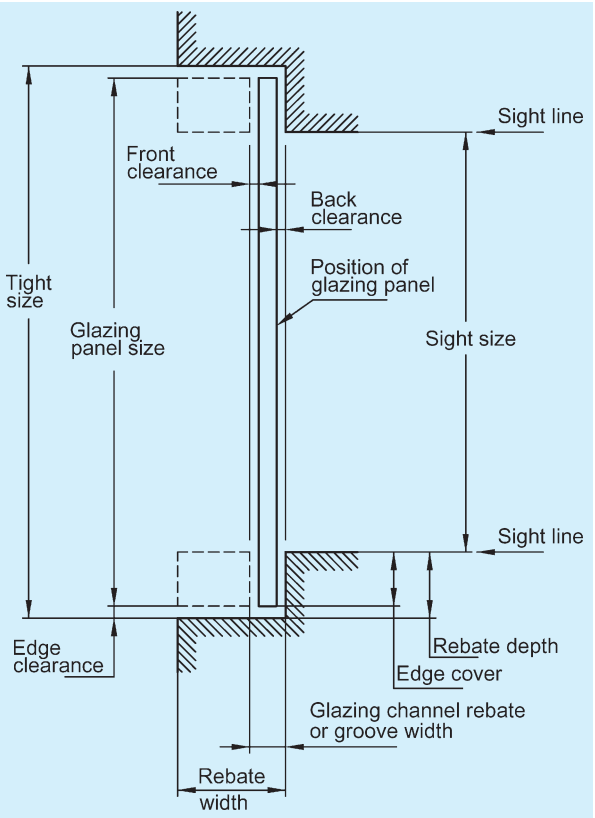


FIG. 2 SIZES AND REBATES

4.5.2.4 *Glass dimensional tolerance*

The tolerance for dimensions shall be as per those in the respective list of Indian Standards.

4.6 Frame Requirements

4.6.1 When completely assembled and glazed, the secondary design action effects due to deflection of the frame member supporting the edge of the glass shall be allowed for.

4.6.2 *Deflection Limits*

The frame deflection limits under serviceability loading shall satisfy the conditions for four sided frames as given in **6.3.6.2**(c).

NOTE — In framing members, where reinforcement/fixing brackets are required to meet the deflection/stress criteria, it may be of aluminium or steel. When steel is used, proper dielectric galvanic separation shall be used. The material chosen for reinforcement shall be in close proximity in the galvanic series, to ensure dielectric separation.

4.6.3 *Panels Glazed into the Building Structure*

A panel glazed directly into a building structure by means of appropriate beads or stops shall be considered to be framed, provided the assembly complies with the deflection requirements of **4.6.2**.

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Table 4 Minimum Dimensions for Glazing Material

(*Clause* 4.5.2.1)

All dimensions in millimetres.

Sl No.	Nominal Thickness	Front and Back Clearance			Edge Clearance	Edge Cover	Rebate Depth
		Type A (*See* Note 1)	Type B (*See* Note 2)	Type C (*See* Note 3)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	3 (for pane area up to 0.1 m^2)	2	—	—	2	4	6
ii)	3 (for pane area > 0.1 m^2)	2	—	—	3	6	9
iii)	3	—	2	1	3	6	9
iv)	4	2	—	—	2	6	8
v)	4	—	2	1	3	6	9
vi)	5	2	2	2	4	6	10
vii)	6	2	2	2	4	6	10
viii)	8	—	3	2	5	8	13
ix)	10	—	3	2	5	8	13
x)	12	—	3	2	6	9	15
xi)	15	—	5	4	8	10	18
xii)	19	—	5	4	10	12	22
xiii)	25	—	5	4	10	15	15

NOTES

1 Type A applies to linseed oil and metal casement putties.

2 Type B applies to non-setting glazing compounds, plastic glazing compounds, two-part rubberizing compounds, sealants and preformed strip materials.

3 Type C applies to gaskets made from extruded materials such as butyl strip, PVC, neoprene and sanoprene held in position by pressure upon the glass.

4 For non-standard glass thicknesses the nearest values of nominal thickness, shall be used.

5 Timber and PVC frames may not require the specified front and back clearances provided the waterproofing performance requirements are met.

6 The dimensions are the minimum necessary for the structural integrity of glass only but do not apply to insulating glass units.

4.6.4 *Mixed Framing*

Glass supported along the top and bottom edges by one means and along the vertical edges by another means shall be considered to be framed provided each frame member of the assembly complies with the deflection requirements of **4.6.2**.

4.7 Glass Dimensions

4.7.1 The actual thickness for exterior and interior glass [other than DGU (Double Glazing Unit)] use shall be measured using screw caliper {for example as per **5.1** of accepted standard [6-8(3)]}.

The actual thickness of glass, rounded to the nearest 0.1 mm shall not vary from the nominal thickness by more than the tolerances specified in respective Indian Standard or the values provided in this Section (unless Indian Standard specification is developed).

The minimum thickness allowed in insulated glass unit (IGU) should be the sum of minimum thickness allowed of two panes as per accepted standard [6-8(4)] plus thickness of air-gap.

The minimum thickness allowed in laminated glass should be the sum of minimum thickness allowed of two panels as per accepted standard [6-8(4)] plus thickness of interlayer (*see* Table 5).

Table 5 Thickness and Tolerances for Laminated Glass

(*Clause* 4.7.1)

All dimensions in millimetres.

Thickness	6	8	10	12	16	20	24
Tolerance	± 0.6	± 0.6	± 0.6	± 0.6	± 1.2	± 1.2	± 1.2

4.7.2 Length and width are defined with reference to the direction of draw of the flat glass ribbon (*see* Fig. 3).

4.7.3 *Jumbo Sizes*

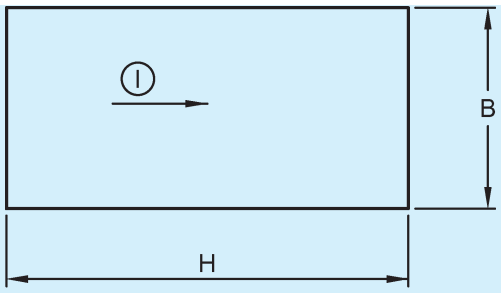
Glass is available commonly in the sizes of nominal length (*H*) 4 500 mm to 6 000 mm and nominal width (*B*) 3 660 mm or 3 210 mm.

NOTE — The usual width is 3 660 mm or 3 210 mm. Other sizes may be mutually agreed to between the manufacturer and the user based on their requirement.

4.7.4 *Stock Size*

Glass is available commonly in the sizes of nominal

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H - Length
B - Width
I - Direction of draw

FIG. 3 REPRESENTATION OF LENGTH, WIDTH AND DIRECTION OF DRAW

length (*H*) 2 250 mm or 2 440 mm and nominal width (*B*) 3 660 mm or 3 210 mm.

NOTE — Maximum glass size available from manufacturer are one consideration, the processing equipment limitation, capabilities of contract fabricator to install unit, availability of specialized transport and handling equipment to deliver unit should be checked in addition.

4.7.5 *Split Sizes*

Glass is delivered in equal or unequal split sizes from the jumbo or stock size.

4.7.6 *Squareness*

The nominal dimensions for length (*H*), and width (*B*), be given, the pane shall not be larger than a prescribed rectangle resulting from the nominal dimensions increased by the permissible plus tolerance or smaller than a prescribed rectangle reduced by the permissible minus tolerance.

The sides of the prescribed rectangles (*see* Fig. 4) shall be parallel to one another and these rectangles shall have a common centre. For stock/standard sizes the tolerances on nominal dimensions length (*H*), and width (*B*), are ± 5 mm.

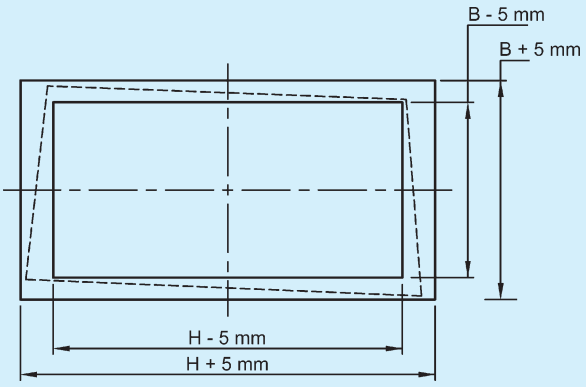


FIG. 4 DETERMINATION OF LENGTH, WIDTH AND SQUARENESS FOR STOCK/STANDARD SIZES

4.7.7 *As-Cut Finished Size*

The nominal dimension for width and length being given, the finished pane or as-cut finished size shall not be greater than the prescribed rectangle from the nominal dimension increased by the tolerance '*t*' or smaller than the prescribed rectangle reduced by the tolerance '*t*'. The sides of the prescribed rectangles are parallel to one another and these shall have a common centre in accordance with Fig. 5. The limits of the squareness are also mentioned. Tolerances are given in Table 6.

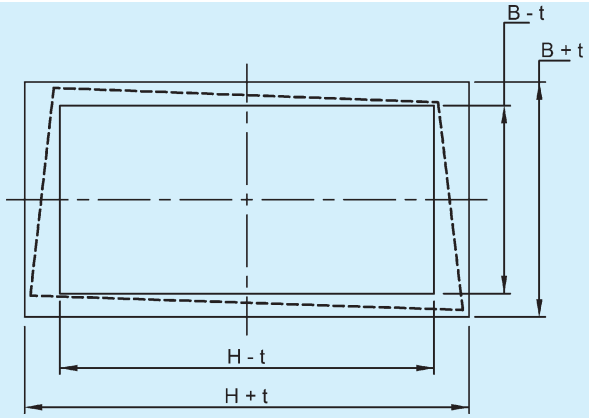


FIG. 5 TOLERANCE (t) FOR WIDTH (B) AND LENGTH (H)

Table 6 Tolerance on Width (*B*) and Length (*H*)

(*Clause* 4.7.7)

Sl No.	Nominal Dimension mm	Tolerance '*t*'	
		Nominal Glass Thickness $d \leq 8$ mm	Nominal Glass Thickness $d > 8$ mm
(1)	(2)	(3)	(4)
i)	≤ 2 000	± 2.5	± 3.0
ii)	2 000 < *B* or *H* ≤ 3 000	± 3.0	± 4.0
iii)	> 3 000	± 4.0	± 4.0

NOTE — While the above tolerances are generally applicable, with the advancements in manufacturing, the following suggested tolerance may be suitably decided between the concerned parties:

a) For glass of thickness up to 8 mm, tolerance shall be 1 mm per linear metre.

b) For glass of thickness above 8 mm and up to 16 mm, tolerance shall be 1.5 mm per linear metre.

c) For glass of thickness above 16 mm, tolerance shall be 2 mm per linear metre.

d) However, upper limit of tolerance shall be:

1) ± 2.0 mm (for glass thickness ≤ 8 mm),

2) ± 3.0 mm (for glass thickness ≤ 16mm), and

3) ± 5.0 mm (for glass thickness > 16 mm).

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5 ENERGY AND LIGHT

5.1 Energy and Thermal Properties of Glass

5.1.1 *General*

The energy and thermal properties of glass is defined by light transmission, internal and external reflection, solar heat gain coefficient and *U*-value. The performance requirement for glazing shall be suitably selected. Minimum performance requirement is mentioned in the Annex A.

Specific methods of calculating light and energy factors for glass in buildings are covered here and their characteristic data can serve as a basis for light, heating and ventilation calculations of rooms and can permit comparison between different types of glazing. It is applicable to all flat glass material.

5.1.2 *Energy*

5.1.2.1 *General*

Glazed areas in buildings should be designed so that account is taken of the overall energy balance in relation to the effects on the thermal comfort of occupants and the total annual energy implications of solar gain and energy loss.

These should be examined separately, since factors affecting one aspect of performance might have no effect on the other. Energy gain is due to transmission of solar radiant energy through the glass into the building. Solar energy is all at relatively short wavelengths and is controlled by using the glass to absorb or reflect the energy. Energy loss is due to the transfer of energy by conduction, convection and long wavelength radiation and can be influenced by a number of factors, for example incorporating air cavities, including gases of low thermal conductivity and/or low emissivity glass.

5.1.2.2 *Thermal comfort*

Energy transmission through glazing can significantly influence occupier comfort by raising or lowering room air temperatures. For example hot sunny weather can give rise to excessive energy gains; and energy losses can occur through the glazing during cold weather or at night. Thermal comfort can also be influenced by direct radiation through the glazing and/or by radiation exchange between the glazing and the occupants.

5.1.2.3 *Solar energy gain*

Factors that can influence the amount of solar gain through the glazing include,

a) orientation;

b) glazed area;

c) shading devices, both internal and external; and

d) properties of the glazing.

5.1.2.4 *Total solar energy transmittance*

5.1.2.4.1 Total solar energy transmittance is the proportion of solar radiation at normal incidence transferred through the glazing. It is composed of the direct transmittance (short wave component) and the part of the solar absorptance dissipated inwards by long wave radiation and convection (long wave component).

The total solar energy transmission properties of solar control glazing can be described by their shading coefficients. The shading coefficient is derived by comparing the properties of the solar control glazing with a clear float glass having a total solar energy transmittance of 0.87 (that is clear glass between 3 mm and 4 mm thick).

NOTE — Total solar energy transmittance is also known as '*g*' value.

5.1.2.4.2 *Solar control glass*

Solar control glass can be manufactured in several forms. The function of solar control glass is to reduce the total solar energy transmittance, which usually leads to a decrease in the transmission of the visible part of the solar spectrum. However, some tints and coatings are able to attenuate preferentially non-visible solar radiation, leaving the transmission of the greater proportion of the visible radiation largely unchanged.

The application of ceramic frit-fired into the surface of the glass can also be used to modify the energy and light transmission of the glass. The effect can be varied across a pane depending on the screen print pattern. Manufacturers should be consulted for specific details.

Solar control glass can be used in single glazed or double glazed unit depending upon the site requirements. The relationship between light transmission and total solar energy transmission is expressed as the light/energy ratio.

There is no optimum light/energy ratio. The selection of an appropriate product depends on the requirements of the building. Solar gain may be relatively high — for making use of passive solar gains, or low — to reduce air conditioning loads. Light transmission will depend on the extent to which daylight is used to obviate artificial lighting.

Some solar control glasses can be toughened or heat strengthened and gives a means of raising the design stress and ensuring safety from thermal fracture.The following are the common varieties.

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NOTE — Some manufacturers use this as a descriptive code, quoting a light transmission figure followed by a total solar energy transmission figure.

a) *Body tinted glass (for increased absorption)* — Solar control properties and colour vary with the thickness of the glass. When used in insulating glass units, body tinted glass should be positioned as the outer pane because the energy due to the absorbed radiation is more easily dissipated to the outside.

b) *Reflective coated glass* — It uses the principle of increasing the direct reflection to maximize solar energy attenuation. In comparison with clear glass, its absorption of solar energy is also increased. An informative annex on test requirements is given at Annex B.

The advantages of such glass types are:

1) Greater performance range than body tinted glass;
2) Higher performances (greater solar energy attenuation);
3) Light/energy ratios nearer to the theoretical limit; and
4) A range of colour appearances in transmission and reflection.

The coatings may be placed on to body-tinted glass to extend the range of performances.

NOTES

1 Compared with a float glass surface, these reflective coatings (owing to their composition) exhibit lower levels of emissivity which improves their *U*-value.

2 Performance data in comparison to clear glass can be had from manufacturers.

c) *Laminated glass* — It is commonly manufactured with clear glass and clear interlayers, but solar control properties can be incorporated into laminated glass by including either solar control glass or tinted interlayers or both.

Laminated glass with clear interlayers and solar control glass exhibits similar properties to the solar control glass from which it is made.

Laminated glass with a tinted interlayer acts in a similar manner to body tinted glass, by absorbing the solar radiation, but with a different range of colours and performances.

NOTE — Performance data in comparison to clear glass can be had from manufacturers. Performances of a typical range of laminated glass products with clear glass and tinted interlayers can be had from manufacturers.

d) *Insulating glass units* — These are used primarily for improved thermal transmittance (*U*-value) (*see* **5.1.3**), and can also improve the total solar energy transmittance. This improvement is a result of the incorporation of a second pane of glass together with the hermetically sealed air space. The second glass pane can be of any glass type. The main glasses used as the inner pane are clear glass, hard coat low emissivity glass or soft coat low emissivity glass.

NOTES

1 Soft coat low emissivity glass can be used as the hermetically sealed airspace protects the coating.

2 Performances of a typical range of insulating glass units with clear float inner pane or with hard/soft coat low emissivity glass inner pane can be had from manufacturers.

5.1.2.4.3 *Solar control plastics glazing sheet materials*

Various coloured plastics glazing sheet materials having ability to reduce the transmission of solar radiation can be used in consultation with the manufacturers.

5.1.2.4.4 *Blinds and louvres*

The use of blinds or louvres in windows affects the window shading coefficient. This depends upon the solar optical properties of the glazing and the material of the blind, on the coefficients of energy transfer at the window surfaces, on the geometry and location of the blind, and the angular position of the sun. Manufacturers' advice may be consulted for use of these materials.

5.1.3 *Energy Loss*

5.1.3.1 *General*

Energy loss is quantified by the thermal transmittance or *U*-value.

Glass and thin plastics glazing sheet materials readily conduct energy and so are poor insulators. To improve resistance to energy loss, insulating glass units or coupled glazing should be used, since the air cavities provide extra thermal resistance.

Increasing the thickness of the glass or plastics glazing sheet material makes little difference to the *U*-value of the glazing.

5.1.3.2 *Methods for improving thermal insulation*

5.1.3.2.1 *Use of low emissivity coatings*

Low emissivity (low-E) coatings have surface emissivities of less than 0.2. The use of such a coating on glass improves the thermal insulation. They are most efficient when used on the cavity surfaces of insulating glass units. Certain types of low-E glasses such as silver based are used in double glazed units only, as the silver oxide coating will get oxidized if used in single glazed.

5.1.3.2.2 *Increasing the width of the air space*

Enhanced thermal insulation can be achieved by increasing the width of the airspace. However, there is a convection of the gas in the cavity.

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5.1.3.2.3 *Using gases of lower thermal conductivity*

Replacing the air in the cavity with, for example, argon/krypton, can improve the thermal insulation.

5.1.3.2.4 *Inhibiting convection within the air space*

Filling the cavity with cellular material reduces convection and makes the cavity a more efficient insulator. However, this usually results in loss of vision, since the materials are, at best, translucent.

5.1.3.2.5 *Evacuation of the air space*

In theory, a vacuum shall eliminate energy transfer by conduction and convection. However, a vacuum puts high demands on the glass from the external air pressure.

NOTE — Evacuation of the air space is currently considered to be technically impractical.

5.1.3.2.6 *Evaluation of type of spacer used in double glazed unit*

Thermal performance of the glazing system for conduction can be improved by changing the material of the spacer especially when other options have been exhausted.

5.1.4 *Typical U-Values of Glass Products*

Tables 7, 8 and 9 give typical *U*-values.

Table 7 Thermal Transmittance (*U*-Value) of Glass Products: Single Glazing

(*Clause* 5.1.4)

Sl No.	Glass Thickness mm	*U*-Value W/m^2K
(1)	(2)	(3)
i)	4	5.8
ii)	6	5.7
iii)	10	5.6
iv)	12	5.5

5.1.5 *Thermal Safety of Glass*

Thermal safety of glass should be assessed considering the amount of radiation incident on the surface and the thermal capabilities of the glass. For example, the solar radiation intensity on the glass surface should be determined along with the air temperature range applicable to the location of the building. These measurements, together with the energy transfer coefficients and the glass absorption allow determination of the appropriate basic temperature difference between the central area of the glass and its edge. The difference is related to the thermal stress and then modified for the type of glazing system, taking account of extraneous effects resulting from curtains, blinds, back-up walls, proximity to heaters, etc, to derive a stress of actual service conditions.

NOTES

1 High air temperatures, low rates of air movement, and the insulation provided by curtains, blinds, back-up walls and multiple glazing tend to reduce the loss of energy and uphold the centre temperature. Low temperatures at the edges are maintained by conduction from the glass through the frame to a cold building structure with a large thermal capacity.

Table 8 Thermal Transmittance (*U*-Value) of Glass Products: Insulating Glass Units

(*Clause* 5.1.4)

Sl No.	Clear glass Thickness and Type mm	Cavity Width mm	*U*-Value W/m^2K	
			Air	Argon
(1)	(2)	(3)	(4)	(5)
i)	4 + 4	6	3.3	3.1
		12	2.9	2.7
		16	2.7	2.6
		20	2.8	2.6
ii)	4 + 4 Low E (ε_d = 0.15)	6	2.7	2.3
		12	1.9	1.6
		16	1.7	1.5
		20	1.7	1.5
iii)	4 + 4 Low E (ε_d = 0.04)	6	2.5	2.0
		12	1.6	1.3
		16	1.4	1.2
		20	1.4	1.2
iv)	4 + 4 + 4	6	2.4	2.1
		12	1.9	1.8
		16	1.8	1.7
		20	1.8	1.7
v)	4 Low E (ε_d = 0.15) + 4 + 4 Low E (ε_d = 0.15)	6	1.7	1.4
		12	1.7	1.0
		16	1.0	0.8
		20	0.9	0.8
vi)	4 Low E (ε_d = 0.04) + 4 + 4 Low E (ε_d = 0.04)	6	1.6	1.2
		12	1.0	0.7
		16	0.8	0.6
		20	0.7	0.6

NOTES

1 *U*-values for argon gas-filled cavity based on 90 percent argon/10 percent air.

2 ε_d is the declared (normal) emissivity.

Table 9 Thermal Transmittance (*U*-Value) of Glass Products: Coupled Glazing

(*Clause* 5.1.4)

Sl No.	Clear Glass Thickness and Type mm	Separation mm	*U*-Value W/m^2K
(1)	(2)	(3)	(4)
i)	4 + 4	25	2.8
		75	2.8
ii)	4 + 4 Low E	25	1.7
		75	1.9

NOTE — ε_d is the declared (normal) emissivity.

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2 Advice may be sought from the manufacturer of glass as to the methods for assessing the thermal safety of the glass.

The resultant service stress should then be compared with the design stress for the glass. If on comparison, the service stress is less than or equal to the design stress, the glass and glazing system may be accepted as thermally safe provided, that the edges of the glass are of adequate quality.

NOTE — Where the application of a solar control film is being considered to existing glazing, advice should be sought from the manufacturer on the effect of any additional thermal stress likely to be induced in the glass.

The normal mode of thermal breakage of glass is by the action of tensile stress located in and parallel to an edge, and so the breaking stress of the glass is mainly dependent on the extent and position of flaws in the edges. The condition of the glass edge is therefore extremely important.

Solar control glasses should not be nipped to size and any panes with shelled or vented edges should not be accepted for glazing in orientations subject to direct sunlight. Although a wheel-cut edge is the most satisfactory, laminated glasses with worked edges may be used.

Where clean-cut edges are not permitted, arrises should be created by a wet process, working parallel to the edge and not across the thickness, and the design implications of such an action should be examined.

Where solar control glasses are to be used in sliding doors and windows there is always the possibility that, when opened during sunny periods, the overlapping will function as double glazing with little ventilation in the air space, and it is this condition that should be assumed in assessing the thermal safety of glass.

Thermal safety assessment is based on the behaviour of glass in good condition and properly glazed. Even if the glass is shown to be thermally safe, this depends on close adherence to the recommend glazing procedures. All necessary precautions should be taken to see that only glass with edges of an acceptable condition is used. The glass should be stored and handled so that no contact with hard bodies can damage the edges and each pane or insulating glass unit should be carefully examined immediately before glazing.

5.1.6 *Energy Conservation*

Good window design can, by reducing reliance on artificial lighting, can be one of the largest single means of saving energy and should be carefully considered.

Account should be taken of shape of the room, window orientation, occupancy patterns and task, together with the relationship of windows to surrounding buildings and other obstruction. As with task lighting, possible solar overheating might result and similar precautions should be taken.

5.1.7 *Light Transmission Properties of Window*

Light transmission is defined as the fraction of visible light at normal incidence transmitted through the glazing. For properties of plastic glazing sheet materials, manufacturers may be consulted.

Dirt on glazing reduces the light transmission, often by an appreciable extent before becoming noticeable. To ensure day lighting levels are adequate, an allowance for the reduced light transmission should be made in day lighting calculation by introducing a ‘dirt factor’ between 0.7 and 1.0. Regular cleaning of glass and plastic glazing sheet materials therefore call their importance.

5.1.8 *Glare*

5.1.8.1 *General*

Glare results from excessive contrast of illumination, or from an excess of illumination in the field of view. Reaction to it is subjective. When correctly designed, natural lighting should not be a glare problem.

NOTE — Contrasts in excess of 10 : 1 in illumination in different parts of the field of view might give rise to glare in some form.

5.1.8.2 *Disability glare*

Reducing the light transmission of glazing from 87 percent to 60 percent produces a just perceptible reduction in disability glare caused by direct sunlight. Even when the light transmission of the glazing is as low as 10 percent some 10 000 lux can still be experienced and glare shall almost certainly occur.

Glare can be reduced by some form of mechanical shading, for example a canopy, an overhanging floor, a balcony or a louvre system. Alternatively, internal screening can be provided by louvres or blinds.

NOTE — Any fixed shading system reduces the amount of natural light entering the building throughout the year, irrespective of whether there is a glare problem at any particular time.

It may also be possible to re-orientate the glazing to avoid entry of direct solar radiation. Alternatively, the interior layout can be suitably designed to eliminate glare.

5.1.8.3 *Discomfort glare*

Glazing products with light transmission lower than 50 percent can ameliorate discomfort glare. These products decrease the sky luminance components but permanently reduce the admission of daylight. Alternatively, shading devices, internal or external, movable or fixed, may be used.

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Other methods of reducing the problems of glare should be considered, including,

a) installation of windows in more than one wall to raise the general background illumination and, in so doing, to reduce the contrast between a window and its surrounding surfaces;
b) use of light coloured matt finishes for the window frames and the surrounding surfaces;
c) splayed reveals, to assist in reducing the contrast between the window and its surroundings;
d) use of slender glazing bars and transoms of high reflectance; and
e) lowering window sills to allow increased illumination to enter, which increases the adaptation level and reduces the likelihood of discomfort glare.

5.1.9 *Diffusion and Obscuration*

The nature of some glazing products (for example, patterned or acid etched glass) can cause the direct incident solar beam to be scattered diffusely. Hence the window might assume an uncomfortable high brightness and become a discomfort glare source in its own right. Diffusing glazing used within the normal field of view should be used with caution.

5.1.10 *Fading*

Most materials can fade when subjected to either daylight (particularly direct sunlight) or artificial light. Fading is a complex phenomenon involving many chemical reactions, initiated or accelerated by light of different wavelengths. Generally, the better quality dyes and pigments fade relatively slowly and react only to the shorter wavelengths (ultraviolet and the blue end of the visible spectrum). Other materials can fade quickly and might do so under light of much longer wavelengths. It is the combination of wavelength, available light and transmission which determines glass selection to minimise fading, not simply the UV transmission.

5.1.11 *Determination of Characteristic Parameters*

5.1.11.1 *General*

The characteristic parameters are determined for quasi-parallel, almost normal radiation incidence.

5.1.11.2 *Test setup*

The samples shall be irradiated by a beam whose axis is at an angle not exceeding 10° from the normal to the surface. The angle between the axis and any ray of the illuminating beam shall not exceed 5°.

The characteristic parameters are as follows:

a) Spectral transmittance $\tau(\lambda)$, the spectral external reflectance $\rho_o(\lambda)$ and the spectral internal reflectance $\rho_i(\lambda)$ in the wavelength range of 300 nm to 2 500 nm;
b) Light transmittance τ_V, the external light reflectance $\rho_{v,0}$ and the internal light reflectance $\rho_{v,i}$ for illuminant D65;
c) Solar direct transmittance τ_e and the solar direct reflectance ρ_e;
d) Total solar energy transmittance (solar heat gain co-efficient SHGC) *g*; and
e) UV-transmittance τ_{UV};

When calculating the characteristic parameters of multiple glazing, the spectral data of each glass component is to be used instead of integrating data of the complete unit.

5.1.11.3 *Performance requirements of optical measurements*

Optical measurements in transmission and reflection require special care to achieve accuracy in transmittance and reflectance of about ±0.01.

The wavelength calibration and the photometric linearity of commercial spectrophotometers shall be checked periodically using reference materials obtained from metrological laboratories.

The wavelength calibration shall be performed by measuring glass plates which feature relatively sharp absorption bands at specified wavelengths; the photometric linearity shall be checked using grey filters with a certified transmittance.

For reflectance measurements, reference materials having reflection behaviour (that is, reflectance level and ratio of diffuse and direct reflectance).

Thick samples (that is, laminated glass or insulating units) can modify the optical path of the instrument's beam as compared to the path in air and therefore the sample beam hits an area of the detector having a different responsivity.

A similar source of inaccuracy occurs in case of samples with significant wedge angles which deflect the transmitted (and reflected) beams. It is recommended to check the reproducibility by repeating the measurement after rotating the sample.

Additionally, in the case of reflectance measurements, glass sheets cause a lateral shear of the beam reflected by the second surface, causing reflectance losses (whose extent is particularly evident in the case of thick and/or wedged samples). This source of inaccuracy shall be taken into account particularly in the case of reflectance measurements through the uncoated side. In order to quantify and correct systematic errors, it is

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recommended to use calibrated reflectance standards with a thickness similar to the unknown sample.

In the case of diffusing samples (or samples with a non-negligible diffusing component or wedged samples), transmittance and reflectance measurements shall be performed using integrating spheres whose openings are sufficiently large to collect the entire diffusely transmitted or reflected beam. The sphere diameter shall be adequate and the internal surface adequately coated with a highly diffusing reflectance material, so that the internal area can provide the necessary multiple reflections. Reference materials with characteristics similar to the unknown sample as specified above shall be used. If the transmittance or reflectance curve recorded by the spectrometer exhibits a high level of noise for some wavelengths, the values to be considered for those wavelengths should be obtained after a smoothing of the noise.

5.1.11.4 *Light transmittance*

Light transmittance is the measure of the amount of light passing through the glazing. The visible light lies between the wavelength 380 nm and 780 nm. The light transmission of the glazing depends on the substrate type and coating layer done on the base glass.

The light transmittance τ_v of glazing shall be calculated using the following formula:

$$\tau_v = \frac{\sum_{\lambda=380\,nm}^{780\,nm} \tau(\lambda) D_\lambda V(\lambda) \Delta\lambda}{\sum_{\lambda=380\,nm}^{780\,nm} D_\lambda V(\lambda) \Delta\lambda}$$

where

D_λ = relative spectral distribution of illuminant D65;

$\tau(\lambda)$ = spectral transmittance of glazing;

$V(\lambda)$ = spectral luminous efficiency for photopic vision defining the standard observer for photometry; and

$\Delta\lambda$ = wavelength interval.

Table 10 indicates the values for $D_\lambda V(\lambda)\Delta\lambda$ for wavelength intervals of 10 nm. The table has been drawn up in such a way that $\sum D_\lambda V(\lambda)\Delta\lambda = 1$.

In the case of multiple glazing, the spectral transmittance $\tau(\lambda)$ shall be obtained by calculation from the spectral characteristics of the individual components. Alternatively, measurements on non-diffusing multiple units may be performed using an integrating sphere. This may be achieved after reducing the interspaces under conditions that allow the collection of the whole transmitted beam.

The calculation of the spectral transmittance $\tau(\lambda)$ shall be performed using methods such as algebraic manipulation. Any algorithm that can be shown to yield consistently the correct solution is acceptable.

For the calculation of $\tau(\lambda)$ as well as for the calculation of spectral reflectance the following symbols for the spectral transmittance and spectral reflectance of the individual components are used:

$\tau_1(\lambda)$ = spectral transmittance of the outer (first) pane;

$\tau_2(\lambda)$ = spectral transmittance of the second pane;

$\tau_n(\lambda)$ = the spectral transmittance of the n^{th} (inner) pane (for example, for triple glazing $n = 3$);

$\rho_1(\lambda)$ = spectral reflectance of the outer (first) pane measured in the direction of incident radiation;

$\rho'_1(\lambda)$ = spectral reflectance of the outer (first) pane measured in the opposite direction of incident radiation;

$\rho_2(\lambda)$ = spectral reflectance of the second pane measured in the direction of incident radiation;

$\rho'_2(\lambda)$ = spectral reflectance of the second pane measured in the opposite direction of incident radiation;

$\rho_n(\lambda)$ = spectral reflectance of the n^{th} (inner) pane measured in the direction of incident radiation;

$\rho'_n(\lambda)$ = spectral reflectance of the n^{th} (inner) pane measured in the opposite direction of incident radiation.

For the spectral transmittance $\tau(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are obtained:

a) For double glazing, and

b) For triple glazing.

For multiple glazing with more than three components, relationships similar to above expressions are found to calculate $\tau(\lambda)$ of such glazing from the spectral characteristics of the individual components.

As an example for calculating $\tau(\lambda)$ according to the procedures of this Section, a glazing composed of five components may be treated as follows:

1) First consider the first three components as triple glazing and calculate the spectral characteristics of this combination;

2) Next, run the same procedure for the next two components as double glazing; and

3) Then calculate $\tau(\lambda)$ for the five component glazing, considering it as double glazing

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consisting of the preceding triple and double glazing.

The light transmission requirement for the glazing should be selected in accordance with relevant Indian Standards.

Table 10 Normalized Relative Spectral Distribution $D_\lambda V(\lambda)\Delta\lambda$

(*Clause* 5.1.11.4)

Sl No.	λ nm	$D_\lambda V(\lambda)\Delta\lambda \times 10^2$
(1)	(2)	(3)
i)	380	0
ii)	390	0.000 5
iii)	400	0.003 0
iv)	410	0.010 3
v)	420	0.035 2
vi)	430	0.094 8
vii)	440	0.227 4
viii)	450	0.419 2
ix)	460	0.666 3
x)	470	0.985 0
xi)	480	1.518 9
xii)	490	2.133 6
xiii)	500	3.349 1
xiv)	510	5.139 3
xv)	520	7.052 3
xvi)	530	8.799 0
xvii)	540	9.442 7
xviii)	550	9.807 7
xix)	560	9.430 6
xx)	570	8.689 1
xxi)	580	7.899 4
xxii)	590	6.330 6
xxiii)	600	5.354 2
xxiv)	610	4.249 1
xxv)	620	3.150 2
xxvi)	630	2.081 2
xxvii)	640	1.381 0
xxviii)	650	0.807 0
xxix)	660	0.461 2
xxx)	670	0.248 5
xxxi)	680	0.125 5
xxxii)	690	0.053 6
xxxiii)	700	0.027 6
xxxiv)	710	0.014 6
xxxv)	720	0.005 7
xxxvi)	730	0.003 5
xxxvii)	740	0.002 1
xxxviii)	750	0.000 8
xxxix)	760	0.000 1
xxxx)	770	0.000 0
xxxxi)	780	0.000 0

NOTE — Normalized relative spectral distribution D_λ of illuminant D65 multiplied by the spectral luminous efficiency $V(\lambda)$ and by the wavelength interval $\Delta\lambda$. The values in this table are calculated according to the trapezoidal rule.

5.2 Light Reflectance

5.2.1 *External Light Reflectance of Glazing*

External light reflectance corresponds to the amount of sunlight reflected by the external glass surface. The amount of light reflection depends on the type of base glass (substrate tint) and the position of coating on the glass surface.

The external light reflectance of glazing $\rho_{v,o}$ shall be calculated using the following formula:

$$\rho_{v,o} = \frac{\sum_{\lambda=380\,nm}^{780\,nm} \rho_o(\lambda) D_\lambda V(\lambda) \Delta\lambda}{\sum_{\lambda=380\,nm}^{780\,nm} D_\lambda V(\lambda) \Delta\lambda}$$

where

$\rho_o(\lambda)$ = spectral external reflectance of glazing, and D_λ, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are defined in **5.1.11.4**.

For multiple glazing, the calculation of the spectral external reflectance $\rho_o(\lambda)$ shall be performed using the same methods as given in **5.1.11.4** for the calculation of the spectral transmittance $\tau(\lambda)$.

For the spectral external reflectance $\rho_o(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied:

a) *For double glazing*:

$$\rho_o(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda)\rho_2(\lambda)}{1-\rho_1'(\lambda)\rho_2(\lambda)}$$

b) *For triple glazing:*

$$\rho_o(\lambda) = \rho_1(\lambda) + \frac{\tau_1^2(\lambda)\rho_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] + \tau_1^2(\lambda)\tau_2^2(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)}$$

For multiple glazing with more than three components, relationships similar to above equations are found to calculate $\rho_o(\lambda)$ of such glazing from the spectral characteristics of the individual components.

As an example for calculating $\rho_o(\lambda)$, a glazing composed of five components may be treated in the same way as described in **5.1.11.4**.

5.2.2 *Internal Light Reflectance of Glazing*

Internal light reflectance corresponds to the amount of light reflected by the inner glass surface. The amount of light reflection depends on the type of base glass (substrate tint) and the position of coating on the glass surface.

The internal light reflectance of glazing $\rho_{v,i}$ shall be calculated using the following formula:

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$$\rho_{v,i} = \frac{\sum_{\lambda=380\,nm}^{780\,nm} \rho_i(\lambda) D_\lambda V(\lambda) \Delta\lambda}{\sum_{\lambda=380\,nm}^{780\,nm} D_\lambda V(\lambda) \Delta\lambda}$$

where

$\rho_i(\lambda)$ = spectral internal reflectance of glazing, and

$D\lambda$, $V(\lambda)$, $\Delta\lambda$ and the integration procedure are as defined in light transmittance.

For multiple glazing, the calculation of the spectral internal reflectance $\rho_i(\lambda)$ shall be performed using the same methods as given in **5.1.11.4** for the calculation of the spectral transmittance $\tau(\lambda)$.

For the spectral internal reflectance $\rho_i(\lambda)$ as a function of the spectral characteristics of the individual components of the unit, the following formulae are applied.

a) *For double glazing*:

$$\rho_i(\lambda) = \rho'_2(\lambda) + \frac{\tau_2^2(\lambda)\rho'_1(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)}$$

b) *For triple glazing:*

$$\rho_i(\lambda) = \rho'_3(\lambda) + \frac{\tau_3^2(\lambda)\rho'_2(\lambda)\left[1-\rho_2(\lambda)\rho'_1(\lambda)\right] + \tau_3^2(\lambda)\tau_2^2(\lambda)\rho'_1(\lambda)}{\left[1-\rho_3(\lambda)\rho'_2(\lambda)\right]\cdot\left[1-\rho_2(\lambda)\rho'_1(\lambda)\right] - \tau_2^2(\lambda)\rho_3(\lambda)\rho'_1(\lambda)}$$

For multiple glazing with more than three components, relationships similar to above expressions are found to calculate $\rho_i(\lambda)$ of such glazing from the spectral characteristics of the individual components.

5.3 Total Solar Energy Transmittance (Solar Heat Gain Coefficient)

5.3.1 Solar heat gain coefficient (SHGC)/solar factor (SF) is the measure of amount of heat transfer from outside to inside by direct transmission (Short Wave Radiation) and internal remitted radiation (Long Wave Radiation). The SHGC (*see* Fig. 6) or SF depends on the tint of the substrate and also the type of coating that is done on the base glass. The amount of solar energy gained through glass is between 0 and 1. Multiplying the SHGC or SF by 100 gives the percentage of solar energy allowed into the building.

The total solar energy transmittance g is the sum of the solar direct transmittance τ_e and the secondary heat transfer factor q_i towards the inside, the latter resulting from heat transfer by convection and long-wave IR-radiation of that part of the incident solar radiation which has been absorbed by the glazing and is expressed as:

$$g = \tau_e + q_i$$

5.3.2 *Division of Incident Solar Radiation Flux*

The incident solar radiant flux per unit area φ_e is divided into the following three parts (*see* Fig. 7):

a) Transmitted part, $\tau_e\varphi_e$;
b) Reflected part, $\rho_e\varphi_e$; and
c) Absorbed part, $\alpha_e\varphi_e$;

where

τ_e = solar direct transmittance,
ρ_e = solar direct reflectance, and
α_e = solar direct absorptances.

The relationship between the three characteristics is:

$$\tau_e + \rho_e + \alpha_e = 1$$

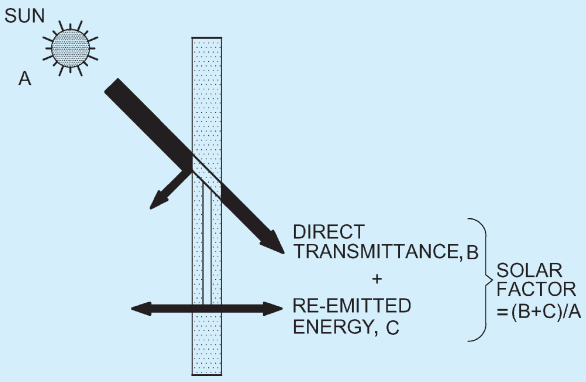
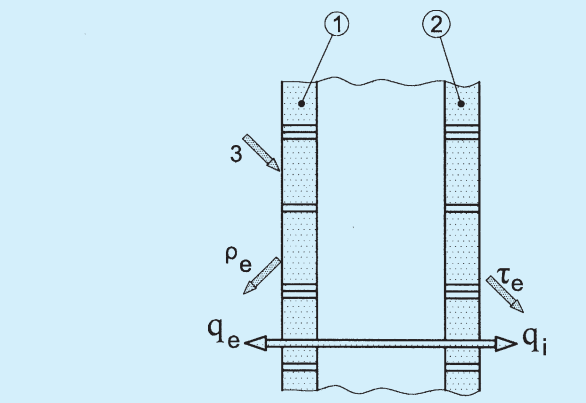


FIG. 6 SOLAR HEAT GAIN COEFFICIENT



KEY
1 OUTER PANE
2 SECOND INNER PANE
3 UNIT INCIDENT RADIANT FLUX
ρ_e = 0.38; q_e = 0.17;
τ_e = 0.41; q_i = 0.04; therefore g = 0.45

FIG. 7 COMPONENTS OF INCIDENT SOLAR RADIANT FLUX

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The absorbed part $\alpha_e\varphi_e$ is subsequently divided into two parts $q_i\varphi_e$ and $q_e\varphi_e$, which are energy transferred to the inside and outside, respectively:

$$\alpha_e = q_i + q_e$$

where

q_i = secondary heat transfer factor of the glazing towards the inside; and

q_e = secondary heat transfer factor of the glazing towards the outside.

5.3.3 *Solar Direct Transmittance*

The solar direct transmittance τ_e of glazing shall be calculated using the following formula:

$$\tau_e = \frac{\sum_{\lambda=300\text{ nm}}^{2\,500\text{ nm}} \tau(\lambda) S_\lambda \Delta\lambda}{\sum_{\lambda=300\text{ nm}}^{2\,500\text{ nm}} S_\lambda \Delta\lambda}$$

where

S_λ = relative spectral distribution of the solar radiation;

$\tau(\lambda)$ = spectral transmittance of the glazing; and

$\Delta\lambda$ = integration procedure are the same as in **5.1.11.4** except that the data points shall be chosen at the wavelengths given in Table 11.

5.3.4 *Solar Direct Reflectance*

The solar direct reflectance ρ_e of the glazing shall be calculated using the following formula:

$$\rho_e = \frac{\sum_{\lambda=300\text{ nm}}^{2\,500\text{ nm}} \rho_o(\lambda) S_\lambda \Delta\lambda}{\sum_{\lambda=300\text{ nm}}^{2\,500\text{ nm}} S_\lambda \Delta\lambda}$$

where

S_λ = relative spectral distribution of the solar radiation (*see* **5.3.3**);

$\rho_o(\lambda)$ = spectral external reflectance of the glazing; and

$\Delta\lambda$ = integration procedure are the same as in light transmittance except that the data points shall be chosen at the wavelengths given in Table 11.

In the case of multiple glazing, the spectral external reflectance $\rho_o(\lambda)$ is calculated in accordance with **5.2.1**.

Table 11 Normalized Relative Spectral Distribution of Global Solar Radiation

(*Clauses* 5.3.3, 5.3.4, 5.3.6.3 *and* 5.3.6.4)

λ nm (1)	$S_\lambda\Delta\lambda$ (2)
300	0
305	0.000 057
310	0.000 236
315	0.000 554
320	0.000 916
325	0.001 309
330	0.001 914
335	0.002 018
340	0.002 189
345	0.000 260
350	0.002 445
355	0.002 555
360	0.002 683
365	0.003 020
370	0.003 359
375	0.003 509
380	0.003 600
385	0.003 529
390	0.003 551
395	0.004 294
400	0.007 812
410	0.011 638
420	0.011 877
430	0.011 347
440	0.013 245
450	0.015 343
460	0.016 166
470	0.016 178
480	0.016 402
490	0.015 794
500	0.015 801
510	0.015 973
520	0.015 357
530	0.015 857
540	0.015 827
550	0.015 844
560	0.015 590
570	0.015 255
580	0.014 745
590	0.014 330
600	0.014 663
610	0.015 030
620	0.014 859
630	0.014 622
640	0.014 526
650	0.014 445
660	0.014 313
670	0.014 023
680	0.012 838
690	0.011 788
700	0.012 453
710	0.012 798
720	0.010 589
730	0.011 233
740	0.012 175
750	0.012 181
760	0.009 515
770	0.010 479
780	0.011 381
790	0.011 262
800	0.026 718

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Table 11 — (*Concluded*)

(1)	(2)
850	0.048 240
900	0.040 297
950	0.021 384
1 000	0.036 097
1 050	0.034 110
1 100	0.018 861
1 150	0.013 228
1 200	0.022 551
1 250	0.023 376
1 300	0.017 756
1 350	0.003 743
1 400	0.000 741
1 450	0.003 792
1 500	0.009 693
1 550	0.013 693
1 600	0.012 203
1 650	0.010 615
1 700	0.007 255
1 750	0.007 183
1 800	0.002 157
1 850	0.000 395
1 900	0.000 082
1 950	0.001 087
2 000	0.003 024
2 050	0.003 988
2 100	0.004 229
2 150	0.004 142
2 200	0.003 690
2 250	0.003 592
2 300	0.003 436
2 350	0.003 163
2 400	0.002 233
2 450	0.001 202
2 500	0.000 475

NOTE — The values in this table are calculated according to the trapezoidal rule.

5.3.5 *Solar Direct Absorptance*

The solar direct absorptance α_e shall be calculated from the following formula:

$$\tau_e + \rho_e + \alpha_e = 1$$

5.3.6 *Secondary Heat Transfer Factor Towards the Inside*

5.3.6.1 *Boundary conditions*

For the calculation of the secondary heat transfer factor towards the inside, q_i, the heat transfer coefficients of the glazing towards the outside, h_e, and towards the inside, h_i, are needed. These values mainly depend on the position of the glazing, wind velocity, inside and outside temperatures and, furthermore, on the temperature of the two external glazing surfaces.

As the purpose of this Section is to provide basic information on the performance of glazing, the following conventional conditions have been stated for simplicity:

a) Position of the glazing: vertical;

b) Outside surface: wind velocity approximately 4 m/s; corrected emissivity 0.837;

c) Inside surface: natural convection; emissivity optional; and

d) Air spaces are unventilated.

Under these conventional, average conditions, standard values for h_e and h_i are obtained:

$$h_e = 23 \text{ W/m}^2\text{K}$$

$$h_i = \left(3.6 + \frac{4.4\varepsilon_i}{0.837}\right) \text{W/m}^2K$$

where

ε_i = corrected emissivity of the inside surface [for soda lime glass, $\varepsilon_i = 0.837$ and $h_i = 8$ W/m^{2}K].

If other boundary conditions are used to meet special requirements they shall be stated in the test report.

Values for ε_i lower than 0.837 (due to surface coatings with higher reflectance in the far infrared) should only to be taken into account if condensation on the coated surface can be excluded.

5.3.6.2 *Single glazing*

The secondary heat transfer factor towards the inside, q_i, of single glazing shall be calculated using the following formula:

$$q_i = \alpha_e \frac{h_i}{h_e + h_i}$$

where

α_e = solar direct absorptance obtained from the in accordance with **5.3.2**, and

h_e, h_i = heat transfer coefficients towards the outside and inside, respectively, in accordance with **7.6.1.**

5.3.6.3 *Double glazing*

The secondary heat transfer factor towards the inside, q_i, of double glazing shall be calculated using the following formula:

$$q_i = \frac{\left(\frac{\alpha_{e1} + \alpha_{e2}}{h_e} + \frac{\alpha_{e2}}{\Lambda}\right)}{\left(\frac{1}{h_i} + \frac{1}{h_e} + \frac{1}{\Lambda}\right)}$$

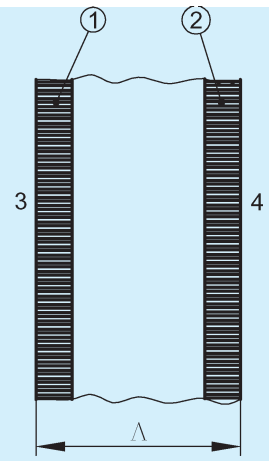
where

α_{e1} = solar direct absorptance of the outer (first) pane within the double glazing;

α_{e2} = solar direct absorptance of the second pane within the double glazing;

Λ = thermal conductance between the outer surface and the innermost surface of the double glazing (*see* Fig. 8), in Watt Per square metre per Kelvin (W/m^{2}K); and

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KEY
1 PANE 1
2 PANE 2
3 OUTSIDE
4 INSIDE

FIG. 8 ILLUSTRATION OF THE MEANING OF THERMAL CONDUCTANCE, Λ

h_e, h_i = heat transfer coefficients towards the outside and the inside, respectively in accordance with **5.3.6.1**.

Characteristics α_{e1} and α_{e2} are calculated as follows:

$$\alpha_{e1} = \frac{\sum_{\lambda=300\,nm}^{2\,500\,nm} \left\{ \alpha_1(\lambda) + \frac{\alpha'_1(\lambda)\tau_1(\lambda)\rho_2(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum_{\lambda=300\,nm}^{2\,500\,nm} S_\lambda \Delta\lambda}$$

$$\alpha_{e2} = \frac{\sum_{\lambda=300\,nm}^{2\,500\,nm} \left\{ \frac{\alpha_2(\lambda)\tau_1(\lambda)}{1-\rho'_1(\lambda)\rho_2(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum_{\lambda=300\,nm}^{2\,500\,nm} S_\lambda \Delta\lambda}$$

where

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\rho_1(\lambda)$, $\rho'_1(\lambda)$ and $\rho_2(\lambda)$ are as defined in light transmittance.

$\alpha_1(\lambda)$ = spectral direct absorptance of the outer pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_1(\lambda) = 1 - \tau_1(\lambda) - \rho_1(\lambda)$$

$\alpha'_1(\lambda)$ = spectral direct absorptance of the outer pane, measured in the opposite direction to the incident radiation, given by the relationship:

$$\alpha_1'(\lambda) = 1 - \tau_1(\lambda) - \rho'_1(\lambda)$$

$\alpha_2(\lambda)$ = spectral direct absorptance of the second pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_2(\lambda) = 1 - \tau_2(\lambda) - \rho_2(\lambda)$$

$\Delta\lambda$ and the integration procedure are the same as in **5.1.11.4** except that the data points shall be chosen at the wavelengths given in Table 11.

The thermal conductance Λ shall be determined for a temperature difference of $\Delta T = 15°C$ across the sample and a mean temperature of the sample of 10°C, or by measuring methods using the standard guarded hot plate method, or the standard heat flow metre method.

If another temperature difference ΔT across the sample and/or another mean temperature of the sample is used for the determination of the thermal conductance Λ to meet special requirements, this shall be stated in the test report.

5.3.6.4 *Multiple glazing with n > 2 components*

The secondary heat transfer factor towards the inside, q_i, of a multiple glazing with more than two components shall be calculated using the following formula:

$$q_i = \frac{\frac{\alpha_{e1}+\alpha_{e2}+\alpha_{e3}+\ldots+\alpha_{en}}{h_e} + \frac{\alpha_{e2}+\alpha_{e3}+\ldots+\alpha_{en}}{\Lambda_{12}} + \frac{\frac{\alpha_{e3}+\ldots+\alpha_{en}}{\Lambda_{23}} + \ldots + \frac{\alpha_{en}}{\Lambda_{(n-1)n}}}{\frac{1}{h_i}+\frac{1}{h_e}+\frac{1}{\Lambda_{12}}+\frac{1}{\Lambda_{23}}+\ldots+\frac{1}{\Lambda_{(n-1)n}}}$$

where

α_{e1} = solar direct absorptance of the outer (first) pane within the *n*-fold glazing;

α_{e2} = solar direct absorptance of the second pane within the *n*-fold glazing;

α_{en} = solar direct absorptance of the n^{th} (inner) pane of the *n*-fold glazing;

h_e, h_i = heat transfer coefficients towards the outside and towards the inside, respectively in accordance with **5.3.6.1**;

Λ_{12} = thermal conductance between the outer surface of the outer (first) pane and the centre of the second pane (*see* Fig. 9);

$\Lambda_{(n-1)n}$ = thermal conductance between the centre of the $(n-1)^{th}$ pane and the outer surface of the n^{th}(inner) pane (*see* Fig. 9); and

Λ_{23} = thermal conductance between the centre of the second pane and the centre of the third pane (*see* Fig. 9);

The thermal conductances Λ_{12}, Λ_{23}……$\Lambda_{(n-1)n}$ shall be determined by iteration technique. The calculation of the direct solar absorptances α_{e1}, $\alpha_{e2,\ldots}\alpha_{en}$ shall be performed using the methods given in **5.3.6.3**.

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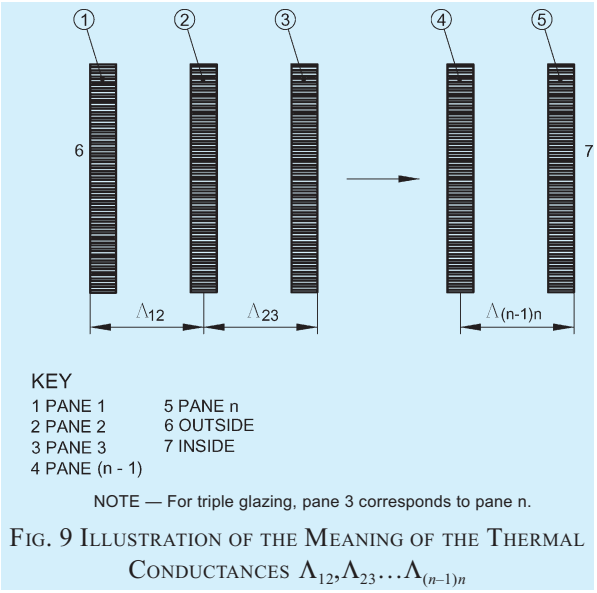


FIG. 9 ILLUSTRATION OF THE MEANING OF THE THERMAL CONDUCTANCES $\Lambda_{12}, \Lambda_{23} \ldots \Lambda_{(n-1)n}$

As an example for the calculation of the direct solar absorptances the following procedure is given which consist of the following (n–1) steps for a glazing consisting of n components:

a) *First step* — Calculate the spectral characteristics of a unit consisting of (n–1) components 2, 3,.....n according to what has been prescribed in **5.1.11.4** and **6.1**. Then combine this unit with the first (outer) pane as a double glazing.

b) *Second step* — Calculate the spectral characteristics of a unit consisting of the (n–2) components 3, ..., n and furthermore, those of a double glazing consisting of pane 1 and pane 2. These units are then combined as a double glazing. The sum $\alpha_{e1} + \alpha_{e2}$ is then obtained. This procedure is continued up to the last $(n-1)^{th}$ step.

c) *$(n-1)^{th}$ step* — Combine the (n–1) panes 1,2,... (n–1) and determine the spectral characteristics of this unit. This unit is then combined with the n^{th} (inner) pane as a double glazing. From the second equation in **5.3.6.3**, the sum $\alpha_{e1,} \alpha_{e2} \ldots \alpha_{e(n-1)}$ is obtained, that is with the known values $\alpha_{e1}, \alpha_{e2,} \ldots \alpha_{e(n-2)}$ from the previous steps $\alpha_{e(n-1)}$ is determined. α_{en} is obtained according to the expression of α_{e2} in **5.3.6.3**.

In the case of triple glazing for the solar absorptances α_{e1}, α_{e2} and α_{e3} as a function of the spectral characteristics of the individual components of the unit, the following formulae are obtained:

$$\alpha_{e1} = \frac{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \alpha_1(\lambda) + \frac{\tau_1(\lambda)\alpha_1'(\lambda)\rho_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] + \tau_1(\lambda)\tau_2^2(\lambda)\alpha_1'(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

$$\alpha_{e2} = \frac{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \frac{\tau_1(\lambda)\alpha_2(\lambda)\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] + \tau_1(\lambda)\tau_2(\lambda)\alpha_2'(\lambda)\rho_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

$$\alpha_{e3} = \frac{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} \left\{ \frac{\tau_1(\lambda)\tau_2(\lambda)\alpha_3(\lambda)}{\left[1-\rho_1'(\lambda)\rho_2(\lambda)\right]\cdot\left[1-\rho_2'(\lambda)\rho_3(\lambda)\right] - \tau_2^2(\lambda)\rho_1'(\lambda)\rho_3(\lambda)} \right\} S_\lambda \Delta\lambda}{\sum_{\lambda=300\,\text{nm}}^{2\,500\,\text{nm}} S_\lambda \Delta\lambda}$$

where

$\tau_1(\lambda)$, $\tau_2(\lambda)$, $\tau_3(\lambda)$, $\rho_1(\lambda)$, $\rho'_1(\lambda)$, $\rho_2(\lambda)$, $\rho'_2(\lambda)$, $\rho_3(\lambda)$ are as defined in light transmittance;

$\alpha_1(\lambda)$, $\alpha'_1(\lambda)$ and $\alpha_2(\lambda)$ are as defined in **5.3.6.3** double glazing;

$\alpha'_2(\lambda)$ = spectral direct absorptance of the second pane, measured in the opposite direction to the incident radiation, given by the relationship:

$$\alpha'_2(\lambda) = 1 - \tau_2(\lambda) - \rho'_2(\lambda)$$

$\alpha_3(\lambda)$ = spectral direct absorptance of the third pane, measured in the direction of the incident radiation, given by the relationship:

$$\alpha_3(\lambda) = 1 - \tau_3(\lambda) - \rho_3(\lambda)$$

$\Delta\lambda$ and the integration procedure are the same as in **5.1.11.4** except that the data points shall be chosen at the wavelengths given in Table 5.

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For a glazing with more than three components, the formulae for the solar absorptances α_{e1}, α_{e2}, ..., α_{en} as a function of the individual components.

5.3.6.5 *Mean radiant temperature (MRT)*

MRT can be calculated by various methods, among which measuring with globe thermometer is the most common and is given by:

$$MRT = \sqrt[4]{T_g^{\,4} + \frac{h_{cg}}{\varepsilon_g \sigma}(T_g - T_a)^4}$$

where

T_a = air temperature, in Kelvin;
T_g = black globe temperature, in Kelvin;
ε_g = emissivity of black globe;
σ = Stefan-Boltzmann constant; and
h_{cg} = convective heat transfer coefficient of the black globe.

5.4 Total Solar Energy Transmission

The total solar energy transmitted into the room per unit area of glazing φ_{ei} is given by the relationship:

$$\varphi_{ei} = \varphi_e g$$

where

φ_e = incident solar radiation flux per unit area;
g = total solar energy transmittance of the glazing; and

The values of φ_e can be obtained from appropriate tables in meteorological literature.

NOTE — The SHGC/SF requirement for the glazing should be selected based on the prescriptive requirements are mentioned in Annex A.

5.4.1 *Additional Heat Transfer*

If the room temperature T_i differs from the outside temperature T_o, an additional heat transfer occurs in addition to φ_{ei}. This additional heat flow q_z can be calculated as follows:

$$q_z = U(T_o - T_i)$$

where U is the U-value (thermal transmittance) of glazing.

5.5 UV-Transmittance

The UV-transmittance of glazing is the fraction of the incident solar radiation transmitted by the glazing in the 300 nm to 380 nm range (UV-B range from 300 nm to 315 nm and UV-A range from 315 nm to 380 nm). The UV-transmittance τ_{UV} is calculated as follows:

$$\tau_{UV} = \frac{\sum_{\lambda=300\text{ nm}}^{380\text{ nm}} \tau(\lambda) S_\lambda \Delta\lambda}{\sum_{\lambda=300\text{ nm}}^{380\text{ nm}} S_\lambda \Delta\lambda}$$

where

S_λ = relative spectral distribution of UV radiation;
$\tau(\lambda)$ = spectral transmittance of the glazing; and
$\Delta\lambda$ and the integration procedure are the same as **5.1.11.4** except that the data points shall be chosen at the wavelength given in Table 12.

This average extends over the defined UV-portion of the solar spectrum. It may not be correlated with solar radiation damage of materials and skin.

5.6 *U*-Value

Heat transmittance through a surface by conduction, convection, and radiation is expressed by its U-value. U-value is the amount of heat transferred that is lost or gained due to a temperature differential of 1 K through 1 m^2. The rate of heat transfer (U-value) is minimised by the use of double glazing, using gas inside cavity or by using low-E glass for inside pane of double glazed unit.

The U-value requirement for the glazing system should be selected in accordance with the Table 13 and Annex A.

Table 12 Normalized Relative Spectral Distribution of Global Solar Radiation

(*Clause* 5.5)

Sl No.	λ nm	$S_\lambda \Delta\lambda$
(1)	(2)	(3)
i)	300	0
ii)	305	0.001 859
iii)	310	0.007 665
iv)	315	0.017 961
v)	320	0.029 732
vi)	325	0.042 466
vii)	330	0.062 108
viii)	335	0.065 462
ix)	340	0.071 020
x)	345	0.073 326
xi)	350	0.079 330
xii)	355	0.082 894
xiii)	360	0.087 039
xiv)	365	0.097 963
xv)	370	0.108 987
xvi)	375	0.113 837
xvii)	380	0.058 351

NOTE — The values in this table are calculated according to the trapezoidal rule.

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Table 13 Thermal Performance of Different Glass Shading Devices

(*Clause* 5.6)

Sl No. (1)	Name of the Shading Device (2)	Transmittance, *U*-Value (3)	Shade Factor (4)
i)	Plain glass sheet (3.0 mm thick)	5.23	1.00
ii)	Plain glass + Wire mesh outside	5.00	0.65
iii)	Painted glass:		
	a) White paint	5.22	0.35
	b) Yellow paint	5.22	0.37
	c) Green paint	5.22	0.40
iv)	Heat absorbing glass	4.65	0.45
v)	Plain glass sheet + Venetian blind inside:	3.14	
	a) Light colour		0.35
	b) Dark colour		0.40
vi)	Plain glass sheet which is,	5.23	
	a) 100 percent shaded		0.14
	b) 75 percent shaded		0.34
	c) 60 percent shaded		0.56

NOTE — Indicative values, actual value of the system to be measured using either approved simulation software or testing laboratory

6 FIRE AND LOADING

6.1 Determination of Appropriate Glass Thickness

6.1.1 *General*

This Section gives provisions to determine the minimum glass thickness to be used to resist the ultimate limit state design wind pressures. However, the location of the glass within the building require additional considerations, such as safety with respect to human which may impose either a minimum glass thickness above the basic calculation of this part or a provision for a specific glass type or both.

In addition to the provisions herein, the design requirements such as wind loads determined in accordance with good practice [6-8(7)] and the serviceability deflection requirement limit given in this Section shall have to be complied.

The provisions under **6** are applicable provided the following parameters are satisfied:

a) Ultimate limit state wind pressure shall not be greater than 10 kPa.

b) For laminated glass, the two sheets are of equal thickness and the interlayer material is either polyvinyl butyral or an equivalent type of interlayer with a modulus of elasticity of about 24 MPa and a Poisson's ratio of 0.50 at 20°C.

c) Design flexural tensile strength of glass depends upon the design strength obtained after applying a factor of safety of 2.5. The minimum design strength of normal glass for thickness up to 6 mm is 16.7 N/mm^2 and for thickness above 6 mm is 15.2 N/mm^2.

6.1.2 *Design Considerations*

The following design considerations shall be considered in determination of appropriate thickness of glass:

a) Maximum area of glass panel is restricted to 15 m^2.

b) Maximum span of window is restricted to 4 m.

c) Aspect ratio of the glass panel should be greater than 1.5. If it is less than 1.5, next higher available thickness should be selected.

d) Factor of safety used is 2.5 considering the variability in strength of glass.

e) Applicable to normal, reflective, laminated, tempered and insulating glass.

f) Applicable to rectangular panels properly secured.

g) Design minimum thickness of laminated glass will be the maximum value of thickness in accordance with the Table 5.

h) Any recognized method of analysis may be used for design, in consultation with the manufacturer.

6.1.3 *Empirical Relationship*

Empirical relation between the wind pressure, area of the glass panel and the required glass thickness can be used:

$P_{net}. A = 200T^k$ (for $T \leq 6$ mm)

$P_{net}. A = 200T^k + 1\,900$ (for $T > 6$ mm)

where

P_{net} = Net design wind pressure as per **6.1.4**, in N/m^2;

A = Area of glass panel, in m^2;

T = Standard nominal thickness (SNT) of glass from Table 14, in mm; and

k = Constant from the Table 14.

Table 14 Value of k for the Corresponding Standard Nominal Thickness of Float Glass

(*Clause* 6.1.3)

T, mm	3	4	5	6	8	10	12	15	19	25
k	1.683	1.732	1.753	1.765	1.57	1.578	1.583	1.579	1.569	1.569

6.1.3.1 *Glass supported on two opposite sides*

a) Normal and laminated glass panels supported on two opposite sides can be designed using following empirical relations:

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1) For $T \leq 6$ mm :

$$b = \frac{4.39\,T}{\sqrt{\left(\frac{P_{net}}{P_f}\right)}}$$

2) For $T > 6$ mm :

$$b = \frac{4.22\,T}{\sqrt{\left(\frac{P_{net}}{P_f}\right)}}$$

b) Tempered/toughened panel supported on two opposite sides can be designed using following empirical relations:

1) For $T \leq 6$ mm :

$$b = \frac{3.268\,8\,T}{\sqrt{\left(\frac{P_{net}}{P_f}\right)}}$$

2) For $T > 6$ mm :

$$b = \frac{2.906\,9\,T}{\sqrt{\left(\frac{P_{net}}{P_f}\right)}}$$

where

b = span, in m; and

P_f = strength factor as in Table 15.

For insulated glass, thickness of only one glass pane shall be considered. If the glass panes are of different thickness, the minimum of the two thicknesses shall be considered.

For laminated glass, the thickness of PVB has not been considered. The value to be used is;

T = Standard nominal thickness – Thickness of PVB.

For non-linear analysis, specialist literature may be consulted.

6.1.4 *Determination of Design Wind Pressure*

Net design wind pressure (P_{net}) is an important parameter governing the thickness of glass to be used in the window panels. It depends on factors as given below:

a) Location of the building (wind zone);
b) Construction patterns around buildings (terrain category);
c) Topography of site;
d) Building plan and height, etc.

Net design wind pressure (P_{net}), may be defined using the following equation:

$$P_{net} = p_z.C_p$$

where

C_p = net pressure coefficient as per good practice [6-8(7)]; and

p_z = design wind pressure as per good practice [6-8(7)], in N/m^2.

= $0.6\,V_z^2$

V_z = $V_b.k_1.k_2.k_3.k_4$

where

V_b = basic wind speed based on Location [as per Fig. 1 of good practice [6-8(7)];

k_1 = risk co-efficient factor;

k_2 = terrain factor;

k_3 = topography factor;

k_4 = importance factor for the cyclonic region and

V_z = design wind speed, in m/s.

6.1.4.1 *Laminated/tempered/insulating glass*

To determine the thickness of laminated/tempered/insulating glass, the design wind pressure P_{net} is modified by dividing it with the strength or pressure factor P_f, dependent on the type of glass. The values of the P_f are given in Table 15.

Using the modified values of P_{net}, the thickness of other glass types can be obtained in accordance with **6.1.3**.

Table 15 Strength Factor, P_f

[*Clause* 6.1.3.1(b)]

Sl No. (1)	Glass Type (2)	P_f (3)
i)	Normal (Annealed)	1.00
ii)	Laminated	0.80
iii)	Tempered	2.50
iv)	Insulated	1.50
v)	Heat strengthened	1.60
vi)	Wired glass	0.50

6.1.5 *Aspect Ratio (AR_{max})*

The design of the thickness using empirical relation in accordance with **6.1.3** shall be valid up to a limiting aspect ratio AR_{max}. The value of AR_{max} for different thickness (T) of glass is given in Table 16.

Table 16 Thickness and Corresponding AR_{max} Values

(*Clause* 6.1.5)

T, mm	3	4	5	6	8	10	12	15	19	25
AR_{max}	7.3	6.8	6.5	6.3	5.9	4.9	4.3	3.8	3.3	2.9

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6.1.6 *Seismic Design*

6.1.6.1 *Seismic load (EQ)*

The design for seismic forces shall be performed in steps to establish upper and lower bound force and movement response parameters. In addition, the response of the structure sensitive to certain parameters such as the damping and the stiffness of the support points may be evaluated.

The principal design criteria for the seismic design are,

a) Structure will remain elastic during the design seismic event.
b) 'Hangers' will stiffen the cantilever 'tree' structure.
c) 'Hangers' will not go slack.

6.1.6.2 *Non-structural elements*

Depending on response sensitivity, non-structural elements can be classified as deformation sensitive, acceleration sensitive, or both deformation and acceleration sensitive. Table 17 classifies non-structural elements according to their response sensitivity

Table 17 Response Sensitivity of Architectural Component

(*Clause* 6.1.6.2)

Sl No.	Component	Sensitivity	
		Acceleration Sensitive	Deformation Sensitive
(1)	(2)	(3)	(4)
i)	Exterior skin:		
	a) Adhered veneer	S	P
	b) Anchored veneer	S	P
	c) Glass blocks	S	P
	d) Prefabricated panel	S	P
	e) Glazing system	S	P
ii)	Partitions:		
	a) Heavy	S	P
	b) Light	S	P
iii)	Interior veneers:		
	a) Stone, including marble	S	P
	b) Ceramic tile	S	P
iv)	Parapets and appendages	P	—
v)	Canopies and marquees	P	—
vi)	Stairs	P	S

NOTES

1 P = Primary response.
2 S = Secondary response.

6.1.6.3 *Design seismic force*

Design seismic force, F_p, on the non-structural element shall be calculated using the following expression:

$$F_p = \frac{Z}{2}\left(1+\frac{x}{h}\right)\frac{a_p}{R_p} I_p W_p \geq 0.10\, W_p$$

where

Z = zone factor {as per Table 2 of good practice [6-8(8)]};
x = height of point of attachment of the non-structural element above the foundation;
h = height of the structure;
a_p = component amplification factor given in Table 18;
R_p = component response factor of the non-structural modification factor given in Table 18;
I_p = importance element (to be taken as 1.5); and
W_p = weight of the non-structural element.

Table 18 Modification Factors

(*Clause* 6.1.6.3)

Sl No.	Architectural Component or Element	a_p (*see* Note)	R_p
(1)	(2)	(3)	(4)
i)	Interior non-structural walls and partitions:		
	a) Plain (unreinforced) masonry walls	1.0	1.5
	b) All other walls and partitions	1.0	2.5
ii)	Cantilever elements (braced to structural frame above its centre of mass):		
	a) Parapets	1.0	1.5
	b) Chimneys and stacks	1.0	2.5
	c) Exterior non-structural walls	1.0	2.5
iii)	Exterior non-structural wall elements and connections:		
	a) Wall element	1.0	2.5
	b) Body of wall panel connection	1.0	2.5
	c) Fasteners of the connecting system	1.25	1.0
iv)	Veneer:		
	a) High deformability elements and attachments	1.0	2.5
	b) Low deformability elements and attachments	1.0	1.5

NOTE — A lower value of a_p is permitted provided a detailed dynamic analysis is performed which justifies a lower value. The value of a_p shall not be less than 1.0. The value of a_p = 1.0 is for equipment generally regarded as rigid and rigidly attached. The value of a_p = 2.5 is for flexible components or flexibly attached components.

6.1.6.4 *Seismic relative displacement*

a) For two connection points on the same structure '*A*', one at a height h_x, and other at a height h_y, seismic relative displacement shall be determined as:

$D_p = \delta_{xA} - \delta_{yA}$

D_p is not required to be taken as greater than

$$R\left(h_x - h_y\right)\frac{\Delta_{aA}}{h_{sx}}$$

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where

δ_{xA} = deflection at building level x of structure A due to design seismic load determined by elastic analysis, and multiplied by response reduction factor R of the building as per Table 9 of good practice [6-8(8)];

δ_{yA} = deflection at building level y of structure A due to design seismic load determined by elastic analysis, and multiplied by response reduction factor R of the building as per Table 9 of good practice [6-8(8)];

h_x = height of level x to which upper connection point is attached;

h_y = height of level y to which lower connection point is attached;

Δ_{aA} = allowable storey drift for structure A calculated as per **7.11.1.1** of good practice [6-8(8)]; and

h_{sx} = storey height below level x.

b) For two connection points on separate structures A and B, or separate structural systems, one at height, h_x, and the other at a height, h_y , D_p shall be determined as:

$$D_p = |\delta_{xA}| + |\delta_{yB}|$$

D_p is not required to be taken as greater than

$$R\left(h_x \frac{\Delta_{aA}}{h_{sx}} + h_y \frac{\Delta_{aB}}{h_{sx}}\right)$$

where

δ_{yB} = deflection at building level y of structure *B* due to design seismic load determined by elastic analysis, and multiplied by response reduction factor, R, of the building as per Table 9 of good practice [6-8(8)]

Δ_{aB} = allowable storey drift for structure *B* calculated as per **7.11.1.1** of good practice [6-8(8)]

6.1.7 *Imposed Loads*

The uniform distributed load and point load is to be considered based on application and is to be selected in accordance with good practice [6-8(9)]. Appropriate uniform distributed load (UDL) and concentrated load are selected in accordance to good practice [6-8(9)] based on nature of building (for example, residential, institutional, industrial building, etc) and nature of activity under each building type.

6.1.8 *Load Contribution*

6.1.8.1 *Wind load*

The wind load is the effect of wind pressure which is dependent on the location, building height, topography and ground roughness factor. The wind speed is taken from good practice [6-8(7)] for the geographic location.

6.1.8.2 *Dead load*

In case of inclined sloped glazing, the dead weight of the glazing should be considered. In case of component of sloped glazing, the following corresponding component of the total glazing may be used:

a) Point load shall be applied as a uniformly distributed load over a circular area of 0.01 m^2.

b) For a glazed panel supported on all edges, the point loading shall be applied at the centre.

c) For free glazing edges, the point load shall be applied adjacent to the centre of the free edge.

d) Ultimate limit state design wind pressure shall not be greater than 1.2 kPa. For greater design wind pressures, the glass shall be separately designed to withstand wind loading in accordance with **6.1.4**.

6.1.9 *Reference Chart Relating Wind Load, Maximum Allowable Area for a Thickness of Glass with respect to Terrain Category*

Table 19 to Table 27 provides relation between design wind pressure and maximum allowable area for a thickness of glass with respect to specific terrain category. User may select the type of glass depending on the support conditions.

Specialist literature may be consulted for use of non-linear analysis and the like for laminated glass.

The deflection at the centre of glass pane can be calculated using the formula in accordance to Annex C.

Typical model calculation to calculate thickness and determine wind load and deflection at the centre of the glazing is given at Annex D.

6.2 Installation

6.2.1 Basic installation requirements and materials used for glass are given hereunder.

NOTES

1 The provisions under this item do not include the use of other methods or systems for glazing, provided the alternate method or system can be demonstrated to satisfy the requirements for correctly supporting the glass within the frame, or glazing system.

2 Patent and other proprietary systems are not described/ covered here.

3 Installation technique for frameless glazing system is not covered here.

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Table 19 Maximum Areas for Annealed Glass Fixed on All Four Sides, m^2

(*Clause* 6.1.9)

Design Wind Pressure N/m^2	Nominal Thickness of Annealed Glass, *T* mm								
	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	2.13	3.86	6.03	8.63	13.06	15.00	15.00	15.00	15.00
550	1.93	3.51	5.48	7.85	11.88	15.00	15.00	15.00	15.00
600	1.77	3.21	5.02	7.19	10.89	14.61	15.00	15.00	15.00
650	1.64	2.97	4.64	6.64	10.05	13.48	15.00	15.00	15.00
700	1.52	2.75	4.31	6.17	9.33	12.52	15.00	15.00	15.00
750	1.42	2.57	4.02	5.76	8.71	11.69	14.75	15.00	15.00
800	1.33	2.41	3.77	5.40	8.16	10.96	13.83	15.00	15.00
850	1.25	2.27	3.55	5.08	7.68	10.31	13.01	15.00	15.00
900	1.18	2.14	3.35	4.80	7.26	9.74	12.29	15.00	15.00
950	1.12	2.03	3.17	4.54	6.88	9.23	11.64	15.00	15.00
1 000	1.06	1.93	3.01	4.32	6.53	8.76	11.06	15.00	15.00
1 050	1.01	1.84	2.87	4.11	6.22	8.35	10.53	14.38	15.00
1 100	0.97	1.75	2.74	3.92	5.94	7.97	10.06	13.73	15.00
1 150	0.93	1.68	2.62	3.75	5.68	7.62	9.62	13.13	15.00
1 200	0.89	1.61	2.51	3.60	5.44	7.30	9.22	12.58	15.00
1 250	0.85	1.54	2.41	3.45	5.23	7.01	8.85	12.08	15.00
1 300	0.82	1.48	2.32	3.32	5.02	6.74	8.51	11.61	15.00
1 350	0.79	1.43	2.23	3.20	4.84	6.49	8.19	11.18	14.98
1 400	0.76	1.38	2.15	3.08	4.67	6.26	7.90	10.78	14.44
1 450	0.73	1.33	2.08	2.98	4.50	6.04	7.63	10.41	13.95
1 500	0.71	1.29	2.01	2.88	4.35	5.84	7.37	10.07	13.48
1 550	0.69	1.24	1.94	2.78	4.21	5.65	7.14	9.74	13.05
1 600	0.67	1.21	1.88	2.70	4.08	5.48	6.91	9.44	12.64
1 650	0.64	1.17	1.83	2.62	3.96	5.31	6.70	9.15	12.25
1 700	0.63	1.13	1.77	2.54	3.84	5.16	6.51	8.88	11.89
1 750	0.61	1.10	1.72	2.47	3.73	5.01	6.32	8.63	11.55
1 800	0.59	1.07	1.67	2.40	3.63	4.87	6.14	8.39	11.23
1 850	0.58	1.04	1.63	2.33	3.53	4.74	5.98	8.16	10.93
1 900	0.56	1.01	1.59	2.27	3.44	4.61	5.82	7.95	10.64
1 950	0.55	0.99	1.55	2.21	3.35	4.49	5.67	7.74	10.37
2 000	0.53	0.96	1.51	2.16	3.27	4.38	5.53	7.55	10.11
2 050	0.52	0.94	1.47	2.11	3.19	4.28	5.40	7.36	9.86
2 100	0.51	0.92	1.44	2.06	3.11	4.17	5.27	7.19	9.63
2 150	0.49	0.90	1.40	2.01	3.04	4.08	5.14	7.02	9.40
2 200	0.48	0.88	1.37	1.96	2.97	3.98	5.03	6.86	9.19
2 250	0.47	0.86	1.34	1.92	2.90	3.90	4.92	6.71	8.99
2 300	0.46	0.84	1.31	1.88	2.84	3.81	4.81	6.56	8.79
2 350	0.45	0.82	1.28	1.84	2.78	3.73	4.71	6.42	8.60
2 400	0.44	0.80	1.26	1.80	2.72	3.65	4.61	6.29	8.43
2 450	0.43	0.79	1.23	1.76	2.67	3.58	4.51	6.16	8.25
2 500	0.43	0.77	1.21	1.73	2.61	3.51	4.42	6.04	8.09
2 550	0.42	0.76	1.18	1.69	2.56	3.44	4.34	5.92	7.93
2 600	0.41	0.74	1.16	1.66	2.51	3.37	4.25	5.81	7.78
2 650	0.40	0.73	1.14	1.63	2.46	3.31	4.17	5.70	7.63
2 700	0.39	0.71	1.12	1.60	2.42	3.25	4.10	5.59	7.49
2 750	0.39	0.70	1.10	1.57	2.38	3.19	4.02	5.49	7.35
2 800	0.38	0.69	1.08	1.54	2.33	3.13	3.95	5.39	7.22
2 850	0.37	0.68	1.06	1.51	2.29	3.08	3.88	5.30	7.09
2 900	0.37	0.66	1.04	1.49	2.25	3.02	3.81	5.21	6.97
2 950	0.36	0.65	1.02	1.46	2.21	2.97	3.75	5.12	6.85
3 000	0.35	0.64	1.00	1.44	2.18	2.92	3.69	5.03	6.74
3 050	0.35	0.63	0.99	1.42	2.14	2.87	3.63	4.95	6.63
3 100	0.34	0.62	0.97	1.39	2.11	2.83	3.57	4.87	6.52
3 150	0.34	0.61	0.96	1.37	2.07	2.78	3.51	4.79	6.42
3 200	0.33	0.60	0.94	1.35	2.04	2.74	3.46	4.72	6.32
3 250	0.33	0.59	0.93	1.33	2.01	2.70	3.40	4.65	6.22
3 300	0.32	0.58	0.91	1.31	1.98	2.66	3.35	4.58	6.13
3 350	0.32	0.58	0.90	1.29	1.95	2.62	3.30	4.51	6.04
3 400	0.31	0.57	0.89	1.27	1.92	2.58	3.25	4.44	5.95
3 450	0.31	0.56	0.87	1.25	1.89	2.54	3.21	4.38	5.86

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Table 19 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
3 500	0.30	0.55	0.86	1.23	1.87	2.50	3.16	4.31	5.78
3 550	0.30	0.54	0.85	1.22	1.84	2.47	3.12	4.25	5.70
3 600	0.30	0.54	0.84	1.20	1.81	2.43	3.07	4.19	5.62
3 650	0.29	0.53	0.83	1.18	1.79	2.40	3.03	4.14	5.54
3 700	0.29	0.52	0.81	1.17	1.77	2.37	2.99	4.08	5.47
3 750	0.28	0.51	0.80	1.15	1.74	2.34	2.95	4.03	5.39
3 800	0.28	0.51	0.79	1.14	1.72	2.31	2.91	3.97	5.32
3 850	0.28	0.50	0.78	1.12	1.70	2.28	2.87	3.92	5.25
3 900	0.27	0.49	0.77	1.11	1.67	2.25	2.84	3.87	5.18
3 950	0.27	0.49	0.76	1.09	1.65	2.22	2.80	3.82	5.12
4 000	0.27	0.48	0.75	1.08	1.63	2.19	2.77	3.77	5.06
4 050	0.26	0.48	0.74	1.07	1.61	2.16	2.73	3.73	4.99
4 100	0.26	0.47	0.74	1.05	1.59	2.14	2.70	3.68	4.93
4 150	0.26	0.46	0.73	1.04	1.57	2.11	2.67	3.64	4.87
4 200	0.25	0.46	0.72	1.03	1.56	2.09	2.63	3.59	4.81
4 250	0.25	0.45	0.71	1.02	1.54	2.06	2.60	3.55	4.76
4 300	0.25	0.45	0.70	1.00	1.52	2.04	2.57	3.51	4.70
4 350	0.24	0.44	0.69	0.99	1.50	2.01	2.54	3.47	4.65
4 400	0.24	0.44	0.69	0.98	1.48	1.99	2.51	3.43	4.60
4 450	0.24	0.43	0.68	0.97	1.47	1.97	2.49	3.39	4.54
4 500	0.24	0.43	0.67	0.96	1.45	1.95	2.46	3.36	4.49
4 550	0.23	0.42	0.66	0.95	1.44	1.93	2.43	3.32	4.44
4 600	0.23	0.42	0.66	0.94	1.42	1.91	2.40	3.28	4.40
4 650	0.23	0.41	0.65	0.93	1.40	1.88	2.38	3.25	4.35
4 700	0.23	0.41	0.64	0.92	1.39	1.86	2.35	3.21	4.30
4 750	0.22	0.41	0.63	0.91	1.38	1.85	2.33	3.18	4.26
4 800	0.22	0.40	0.63	0.90	1.36	1.83	2.30	3.15	4.21
4 850	0.22	0.40	0.62	0.89	1.35	1.81	2.28	3.11	4.17
4 900	0.22	0.39	0.62	0.88	1.33	1.79	2.26	3.08	4.13
4 950	0.21	0.39	0.61	0.87	1.32	1.77	2.23	3.05	4.08
5 000	0.21	0.39	0.60	0.86	1.31	1.75	2.21	3.02	4.04
Maximum aspect ratio	7.3	6.8	6.5	6.3	5.9	4.9	4.3	3.8	3.3

Table 20 Maximum Areas for Laminated Glass Fixed on All Four Sides, m²

(*Clause* 6.1.9)

Design Wind Pressure	Nominal Thickness of Laminated Glass, *T* mm					
N/m^2	5.38	6.38	8.38	10.38	12.38	16.38
(1)	(2)	(3)	(4)	(5)	(6)	(7)
500	4.47	6.28	10.45	14.02	15.00	15.00
550	4.06	5.71	9.50	12.75	15.00	15.00
600	3.72	5.23	8.71	11.69	15.00	15.00
650	3.44	4.83	8.04	10.79	13.93	15.00
700	3.19	4.48	7.46	10.02	12.94	15.00
750	2.98	4.19	6.97	9.35	12.08	15.00
800	2.79	3.92	6.53	8.76	11.32	15.00
850	2.63	3.69	6.15	8.25	10.66	15.00
900	2.48	3.49	5.81	7.79	10.06	14.21
950	2.35	3.30	5.50	7.38	9.53	13.46
1 000	2.23	3.14	5.23	7.01	9.06	12.79
1 050	2.13	2.99	4.98	6.68	8.63	12.18
1 100	2.03	2.85	4.75	6.37	8.23	11.63
1 150	1.94	2.73	4.54	6.10	7.88	11.12
1 200	1.86	2.62	4.35	5.84	7.55	10.66
1 250	1.79	2.51	4.18	5.61	7.25	10.23
1 300	1.72	2.41	4.02	5.39	6.97	9.84
1 350	1.66	2.33	3.87	5.19	6.71	9.47
1 400	1.60	2.24	3.73	5.01	6.47	9.14
1 450	1.54	2.16	3.60	4.84	6.25	8.82
1 500	1.49	2.09	3.48	4.67	6.04	8.53

Table 20 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1 550	1.44	2.03	3.37	4.52	5.84	8.25
1 600	1.40	1.96	3.27	4.38	5.66	7.99
1 650	1.35	1.90	3.17	4.25	5.49	7.75
1 700	1.31	1.85	3.07	4.12	5.33	7.52
1 750	1.28	1.79	2.99	4.01	5.18	7.31
1 800	1.24	1.74	2.90	3.90	5.03	7.11
1 850	1.21	1.70	2.82	3.79	4.90	6.91
1 900	1.18	1.65	2.75	3.69	4.77	6.73
1 950	1.15	1.61	2.68	3.60	4.64	6.56
2 000	1.12	1.57	2.61	3.51	4.53	6.40
2 050	1.09	1.53	2.55	3.42	4.42	6.24
2 100	1.06	1.49	2.49	3.34	4.31	6.09
2 150	1.04	1.46	2.43	3.26	4.21	5.95
2 200	1.02	1.43	2.38	3.19	4.12	5.81
2 250	0.99	1.40	2.32	3.12	4.03	5.68
2 300	0.97	1.36	2.27	3.05	3.94	5.56
2 350	0.95	1.34	2.22	2.98	3.85	5.44
2 400	0.93	1.31	2.18	2.92	3.77	5.33
2 450	0.91	1.28	2.13	2.86	3.70	5.22
2 500	0.89	1.26	2.09	2.80	3.62	5.12
2550	0.88	1.23	2.05	2.75	3.55	5.02
2 600	0.86	1.21	2.01	2.70	3.48	4.92
2 650	0.84	1.18	1.97	2.65	3.42	4.83
2 700	0.83	1.16	1.94	2.60	3.35	4.74
2 750	0.81	1.14	1.90	2.55	3.29	4.65
2 800	0.80	1.12	1.87	2.50	3.23	4.57
2 850	0.78	1.10	1.83	2.46	3.18	4.49
2 900	0.77	1.08	1.80	2.42	3.12	4.41
2 950	0.76	1.06	1.77	2.38	3.07	4.34

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Table 20 — (*Continued*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
3 000	0.74	1.05	1.74	2.34	3.02	4.26
3 050	0.73	1.03	1.71	2.30	2.97	4.19
3 100	0.72	1.01	1.69	2.26	2.92	4.13
3 150	0.71	1.00	1.66	2.23	2.88	4.06
3 200	0.70	0.98	1.63	2.19	2.83	4.00
3 250	0.69	0.97	1.61	2.16	2.79	3.94
3 300	0.68	0.95	1.58	2.12	2.74	3.88
3 350	0.67	0.94	1.56	2.09	2.70	3.82
3 400	0.66	0.92	1.54	2.06	2.66	3.76
3 450	0.65	0.91	1.51	2.03	2.63	3.71
3 500	0.64	0.90	1.49	2.00	2.59	3.65
3 550	0.63	0.88	1.47	1.98	2.55	3.60
3 600	0.62	0.87	1.45	1.95	2.52	3.55
3 650	0.61	0.86	1.43	1.92	2.48	3.50
3 700	0.60	0.85	1.41	1.90	2.45	3.46
3 750	0.60	0.84	1.39	1.87	2.42	3.41
3 800	0.59	0.83	1.38	1.85	2.38	3.37
3 850	0.58	0.82	1.36	1.82	2.35	3.32
3 900	0.57	0.80	1.34	1.80	2.32	3.28
3 950	0.57	0.79	1.32	1.78	2.29	3.24
4 000	0.56	0.78	1.31	1.75	2.26	3.20
4 050	0.55	0.78	1.29	1.73	2.24	3.16

Table 20 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
4 100	0.55	0.77	1.27	1.71	2.21	3.12
4 150	0.54	0.76	1.26	1.69	2.18	3.08
4 200	0.53	0.75	1.24	1.67	2.16	3.05
4 250	0.53	0.74	1.23	1.65	2.13	3.01
4 300	0.52	0.73	1.22	1.63	2.11	2.97
4 350	0.51	0.72	1.20	1.61	2.08	2.94
4 400	0.51	0.71	1.19	1.59	2.06	2.91
4 450	0.50	0.71	1.17	1.58	2.04	2.87
4 500	0.50	0.70	1.16	1.56	2.01	2.84
4 550	0.49	0.69	1.15	1.54	1.99	2.81
4 600	0.49	0.68	1.14	1.52	1.97	2.78
4 650	0.48	0.68	1.12	1.51	1.95	2.75
4 700	0.48	0.67	1.11	1.49	1.93	2.72
4 750	0.47	0.66	1.10	1.48	1.91	2.69
4 800	0.47	0.65	1.09	1.46	1.89	2.66
4 850	0.46	0.65	1.08	1.45	1.87	2.64
4 900	0.46	0.64	1.07	1.43	1.85	2.61
4 950	0.45	0.63	1.06	1.42	1.83	2.58
5 000	0.45	0.63	1.05	1.40	1.81	2.56
Maximum aspect ratio	6.5	6.2	5.7	4.8	4.3	3.6

Table 21 Maximum Areas for Tempered Glass Fixed on All Four Sides, m²

(*Clause* 6.1.9)

Design Wind Pressure N/m²	**Nominal Thickness of Tempered Glass, *T*** mm								
	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	5.32	9.64	15.00	15.00	15.00	15.00	15.00	15.00	15.00
550	4.84	8.76	13.70	15.00	15.00	15.00	15.00	15.00	15.00
600	4.43	8.03	12.56	15.00	15.00	15.00	15.00	15.00	15.00
650	4.09	7.42	11.59	15.00	15.00	15.00	15.00	15.00	15.00
700	3.80	6.89	10.77	15.00	15.00	15.00	15.00	15.00	15.00
750	3.55	6.43	10.05	14.39	15.00	15.00	15.00	15.00	15.00
800	3.33	6.03	9.42	13.49	15.00	15.00	15.00	15.00	15.00
850	3.13	5.67	8.87	12.70	15.00	15.00	15.00	15.00	15.00
900	2.96	5.36	8.37	11.99	15.00	15.00	15.00	15.00	15.00
950	2.80	5.07	7.93	11.36	15.00	15.00	15.00	15.00	15.00
1 000	2.66	4.82	7.54	10.79	15.00	15.00	15.00	15.00	15.00
1 050	2.53	4.59	7.18	10.28	15.00	15.00	15.00	15.00	15.00
1 100	2.42	4.38	6.85	9.81	14.84	15.00	15.00	15.00	15.00
1 150	2.31	4.19	6.55	9.38	14.20	15.00	15.00	15.00	15.00
1 200	2.22	4.02	6.28	8.99	13.61	15.00	15.00	15.00	15.00
1 250	2.13	3.86	6.03	8.63	13.06	15.00	15.00	15.00	15.00
1 300	2.05	3.71	5.80	8.30	12.56	15.00	15.00	15.00	15.00
1 350	1.97	3.57	5.58	7.99	12.10	15.00	15.00	15.00	15.00
1 400	1.90	3.44	5.38	7.71	11.66	15.00	15.00	15.00	15.00
1 450	1.83	3.32	5.20	7.44	11.26	15.00	15.00	15.00	15.00
1 500	1.77	3.21	5.02	7.19	10.89	14.61	15.00	15.00	15.00
1 550	1.72	3.11	4.86	6.96	10.53	14.14	15.00	15.00	15.00
1 600	1.66	3.01	4.71	6.74	10.21	13.69	15.00	15.00	15.00
1 650	1.61	2.92	4.57	6.54	9.90	13.28	15.00	15.00	15.00
1 700	1.56	2.84	4.43	6.35	9.61	12.89	15.00	15.00	15.00
1 750	1.52	2.75	4.31	6.17	9.33	12.52	15.00	15.00	15.00
1 800	1.48	2.68	4.19	6.00	9.07	12.17	15.00	15.00	15.00
1 850	1.44	2.61	4.07	5.83	8.83	11.84	14.95	15.00	15.00
1 900	1.40	2.54	3.97	5.68	8.59	11.53	14.55	15.00	15.00
1 950	1.36	2.47	3.86	5.53	8.37	11.24	14.18	15.00	15.00
2 000	1.33	2.41	3.77	5.40	8.16	10.96	13.83	15.00	15.00
2 050	1.30	2.35	3.68	5.26	7.97	10.69	13.49	15.00	15.00

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Table 21 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
2 100	1.27	2.30	3.59	5.14	7.78	10.43	13.17	15.00	15.00
2 150	1.24	2.24	3.51	5.02	7.59	10.19	12.86	15.00	15.00
2 200	1.21	2.19	3.43	4.91	7.42	9.96	12.57	15.00	15.00
2 250	1.18	2.14	3.35	4.80	7.26	9.74	12.29	15.00	15.00
2 300	1.16	2.10	3.28	4.69	7.10	9.53	12.02	15.00	15.00
2 350	1.13	2.05	3.21	4.59	6.95	9.32	11.77	15.00	15.00
2 400	1.11	2.01	3.14	4.50	6.80	9.13	11.52	15.00	15.00
2 450	1.09	1.97	3.08	4.40	6.66	8.94	11.29	15.00	15.00
2 500	1.06	1.93	3.01	4.32	6.53	8.76	11.06	15.00	15.00
2 550	1.04	1.89	2.96	4.23	6.40	8.59	10.84	14.80	15.00
2 600	1.02	1.85	2.90	4.15	6.28	8.43	10.64	14.52	15.00
2 650	1.00	1.82	2.84	4.07	6.16	8.27	10.43	14.24	15.00
2 700	0.99	1.79	2.79	4.00	6.05	8.12	10.24	13.98	15.00
2 750	0.97	1.75	2.74	3.92	5.94	7.97	10.06	13.73	15.00
2 800	0.95	1.72	2.69	3.85	5.83	7.83	9.88	13.48	15.00
2 850	0.93	1.69	2.64	3.79	5.73	7.69	9.70	13.24	15.00
2 900	0.92	1.66	2.60	3.72	5.63	7.56	9.54	13.02	15.00
2 950	0.90	1.63	2.55	3.66	5.54	7.43	9.37	12.79	15.00
3 000	0.89	1.61	2.51	3.60	5.44	7.30	9.22	12.58	15.00
3 050	0.87	1.58	2.47	3.54	5.35	7.18	9.07	12.38	15.00
3 100	0.86	1.56	2.43	3.48	5.27	7.07	8.92	12.18	15.00
3 150	0.84	1.53	2.39	3.43	5.18	6.96	8.78	11.98	15.00
3 200	0.83	1.51	2.36	3.37	5.10	6.85	8.64	11.79	15.00
3 250	0.82	1.48	2.32	3.32	5.02	6.74	8.51	11.61	15.00
3 300	0.81	1.46	2.28	3.27	4.95	6.64	8.38	11.44	15.00
3 350	0.79	1.44	2.25	3.22	4.87	6.54	8.25	11.27	15.00
3 400	0.78	1.42	2.22	3.17	4.80	6.44	8.13	11.10	14.87
3 450	0.77	1.40	2.18	3.13	4.73	6.35	8.02	10.94	14.65
3 500	0.76	1.38	2.15	3.08	4.67	6.26	7.90	10.78	14.44
3 550	0.75	1.36	2.12	3.04	4.60	6.17	7.79	10.63	14.24
3 600	0.74	1.34	2.09	3.00	4.54	6.09	7.68	10.48	14.04
3 650	0.73	1.32	2.06	2.96	4.47	6.00	7.58	10.34	13.85
3 700	0.72	1.30	2.04	2.92	4.41	5.92	7.47	10.20	13.66
3 750	0.71	1.29	2.01	2.88	4.35	5.84	7.37	10.07	13.48
3 800	0.70	1.27	1.98	2.84	4.30	5.77	7.28	9.93	13.30
3 850	0.69	1.25	1.96	2.80	4.24	5.69	7.18	9.80	13.13
3 900	0.68	1.24	1.93	2.77	4.19	5.62	7.09	9.68	12.96
3 950	0.67	1.22	1.91	2.73	4.13	5.55	7.00	9.56	12.80
4 000	0.67	1.21	1.88	2.70	4.08	5.48	6.91	9.44	12.64
4 050	0.66	1.19	1.86	2.66	4.03	5.41	6.83	9.32	12.48
4 100	0.65	1.18	1.84	2.63	3.98	5.34	6.74	9.21	12.33
4 150	0.64	1.16	1.82	2.60	3.93	5.28	6.66	9.09	12.18
4 200	0.63	1.15	1.79	2.57	3.89	5.22	6.58	8.99	12.04
4 250	0.63	1.13	1.77	2.54	3.84	5.16	6.51	8.88	11.89
4 300	0.62	1.12	1.75	2.51	3.80	5.10	6.43	8.78	11.76
4 350	0.61	1.11	1.73	2.48	3.75	5.04	6.36	8.68	11.62
4 400	0.60	1.10	1.71	2.45	3.71	4.98	6.28	8.58	11.49
4 450	0.60	1.08	1.69	2.43	3.67	4.92	6.21	8.48	11.36
4 500	0.59	1.07	1.67	2.40	3.63	4.87	6.14	8.39	11.23
4 550	0.58	1.06	1.66	2.37	3.59	4.82	6.08	8.30	11.11
4 600	0.58	1.05	1.64	2.35	3.55	4.76	6.01	8.21	10.99
4 650	0.57	1.04	1.62	2.32	3.51	4.71	5.95	8.12	10.87
4 700	0.57	1.03	1.60	2.30	3.47	4.66	5.88	8.03	10.76
4 750	0.56	1.01	1.59	2.27	3.44	4.61	5.82	7.95	10.64
4 800	0.55	1.00	1.57	2.25	3.40	4.56	5.76	7.86	10.53
4 850	0.55	0.99	1.55	2.23	3.37	4.52	5.70	7.78	10.42
4 900	0.54	0.98	1.54	2.20	3.33	4.47	5.64	7.70	10.32
4 950	0.54	0.97	1.52	2.18	3.30	4.43	5.59	7.63	10.21
5 000	0.53	0.96	1.51	2.16	3.27	4.38	5.53	7.55	10.11
Maximum aspect ratio	7.3	6.8	6.5	6.3	5.9	4.9	4.3	3.8	3.3

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Table 22 Maximum Areas for Insulating Glass Fixed on All Four Sides, m²

(*Clause* 6.1.9)

Design Wind Pressure	Nominal Thickness of Insulating Glass, *T* mm						
N/m²	3+3	4+4	5+5	6+6	8+8	10+10	12+12
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
500	3.19	5.78	9.04	12.95	15.00	15.00	15.00
550	2.90	5.26	8.22	11.77	15.00	15.00	15.00
600	2.66	4.82	7.54	10.79	15.00	15.00	15.00
650	2.46	4.45	6.96	9.96	15.00	15.00	15.00
700	2.28	4.13	6.46	9.25	14.00	15.00	15.00
750	2.13	3.86	6.03	8.63	13.06	15.00	15.00
800	2.00	3.62	5.65	8.09	12.25	15.00	15.00
850	1.88	3.40	5.32	7.62	11.53	15.00	15.00
900	1.77	3.21	5.02	7.19	10.89	14.61	15.00
950	1.68	3.04	4.76	6.82	10.31	13.84	15.00
1 000	1.60	2.89	4.52	6.48	9.80	13.15	15.00
1 050	1.52	2.75	4.31	6.17	9.33	12.52	15.00
1 100	1.45	2.63	4.11	5.89	8.91	11.95	15.00
1 150	1.39	2.52	3.93	5.63	8.52	11.43	14.43
1 200	1.33	2.41	3.77	5.40	8.16	10.96	13.83
1 250	1.28	2.31	3.62	5.18	7.84	10.52	13.27
1 300	1.23	2.22	3.48	4.98	7.54	10.11	12.76
1 350	1.18	2.14	3.35	4.80	7.26	9.74	12.29
1 400	1.14	2.07	3.23	4.63	7.00	9.39	11.85
1 450	1.10	1.99	3.12	4.47	6.76	9.07	11.44
1 500	1.06	1.93	3.01	4.32	6.53	8.76	11.06
1 550	1.03	1.87	2.92	4.18	6.32	8.48	10.70
1 600	1.00	1.81	2.83	4.05	6.12	8.22	10.37
1 650	0.97	1.75	2.74	3.92	5.94	7.97	10.06
1 700	0.94	1.70	2.66	3.81	5.76	7.73	9.76
1 750	0.91	1.65	2.58	3.70	5.60	7.51	9.48
1 800	0.89	1.61	2.51	3.60	5.44	7.30	9.22
1 850	0.86	1.56	2.44	3.50	5.30	7.11	8.97
1 900	0.84	1.52	2.38	3.41	5.16	6.92	8.73
1 950	0.82	1.48	2.32	3.32	5.02	6.74	8.51
2 000	0.80	1.45	2.26	3.24	4.90	6.57	8.30
2 050	0.78	1.41	2.21	3.16	4.78	6.41	8.09
2 100	0.76	1.38	2.15	3.08	4.67	6.26	7.90
2 150	0.74	1.35	2.10	3.01	4.56	6.11	7.72
2 200	0.73	1.31	2.06	2.94	4.45	5.98	7.54
2 250	0.71	1.29	2.01	2.88	4.35	5.84	7.37
2 300	0.69	1.26	1.97	2.82	4.26	5.72	7.21
2 350	0.68	1.23	1.92	2.76	4.17	5.59	7.06
2 400	0.67	1.21	1.88	2.70	4.08	5.48	6.91
2 450	0.65	1.18	1.85	2.64	4.00	5.37	6.77
2 500	0.64	1.16	1.81	2.59	3.92	5.26	6.64
2 550	0.63	1.13	1.77	2.54	3.84	5.16	6.51
2 600	0.61	1.11	1.74	2.49	3.77	5.06	6.38
2 650	0.60	1.09	1.71	2.44	3.70	4.96	6.26
2 700	0.59	1.07	1.67	2.40	3.63	4.87	6.14
2 750	0.58	1.05	1.64	2.35	3.56	4.78	6.03
2 800	0.57	1.03	1.61	2.31	3.50	4.70	5.93
2 850	0.56	1.01	1.59	2.27	3.44	4.61	5.82
2 900	0.55	1.00	1.56	2.23	3.38	4.53	5.72
2 950	0.54	0.98	1.53	2.19	3.32	4.46	5.62
3 000	0.53	0.96	1.51	2.16	3.27	4.38	5.53
3 050	0.52	0.95	1.48	2.12	3.21	4.31	5.44
3 100	0.51	0.93	1.46	2.09	3.16	4.24	5.35
3 150	0.51	0.92	1.44	2.06	3.11	4.17	5.27
3 200	0.50	0.90	1.41	2.02	3.06	4.11	5.18
3 250	0.49	0.89	1.39	1.99	3.01	4.05	5.11
3 300	0.48	0.88	1.37	1.96	2.97	3.98	5.03
3 350	0.48	0.86	1.35	1.93	2.92	3.92	4.95
3 400	0.47	0.85	1.33	1.90	2.88	3.87	4.88
3 450	0.46	0.84	1.31	1.88	2.84	3.81	4.81
3 500	0.46	0.83	1.29	1.85	2.80	3.76	4.74
3 550	0.45	0.81	1.27	1.82	2.76	3.70	4.67
3 600	0.44	0.80	1.26	1.80	2.72	3.65	4.61
3 650	0.44	0.79	1.24	1.77	2.68	3.60	4.55
3 700	0.43	0.78	1.22	1.75	2.65	3.55	4.48
3 750	0.43	0.77	1.21	1.73	2.61	3.51	4.42
3 800	0.42	0.76	1.19	1.70	2.58	3.46	4.37
3 850	0.41	0.75	1.17	1.68	2.54	3.41	4.31
3 900	0.41	0.74	1.16	1.66	2.51	3.37	4.25
3 950	0.40	0.73	1.14	1.64	2.48	3.33	4.20
4 000	0.40	0.72	1.13	1.62	2.45	3.29	4.15
4 050	0.39	0.71	1.12	1.60	2.42	3.25	4.10
4 100	0.39	0.71	1.10	1.58	2.39	3.21	4.05
4 150	0.38	0.70	1.09	1.56	2.36	3.17	4.00
4 200	0.38	0.69	1.08	1.54	2.33	3.13	3.95
4 250	0.38	0.68	1.06	1.52	2.31	3.09	3.90
4 300	0.37	0.67	1.05	1.51	2.28	3.06	3.86
4 350	0.37	0.66	1.04	1.49	2.25	3.02	3.81
4 400	0.36	0.66	1.03	1.47	2.23	2.99	3.77
4 450	0.36	0.65	1.02	1.46	2.20	2.95	3.73
4 500	0.35	0.64	1.00	1.44	2.18	2.92	3.69
4 550	0.35	0.64	0.99	1.42	2.15	2.89	3.65
4 600	0.35	0.63	0.98	1.41	2.13	2.86	3.61
4 650	0.34	0.62	0.97	1.39	2.11	2.83	3.57
4 700	0.34	0.62	0.96	1.38	2.08	2.80	3.53
4 750	0.34	0.61	0.95	1.36	2.06	2.77	3.49
4 800	0.33	0.60	0.94	1.35	2.04	2.74	3.46
4 850	0.33	0.60	0.93	1.34	2.02	2.71	3.42
4 900	0.33	0.59	0.92	1.32	2.00	2.68	3.39
4 950	0.32	0.58	0.91	1.31	1.98	2.66	3.35
5 000	0.32	0.58	0.90	1.30	1.96	2.63	3.32
Maximum aspect ratio	7.3	6.8	6.5	6.3	5.9	4.9	4.3

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Table 23 Maximum Area for Heat Strengthened Glass Fixed on Four Sides, m²

(*Clause* 6.1.9)

Design Wind Pressure	Nominal Thickness of Heat Strengthened Glass, *T* mm								
N/m²	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	3.41	6.17	9.65	13.81	15.00	15.00	15.00	15.00	15.00
550	3.10	5.61	8.77	12.56	15.00	15.00	15.00	15.00	15.00
600	2.84	5.14	8.04	11.51	15.00	15.00	15.00	15.00	15.00
650	2.62	4.75	7.42	10.63	15.00	15.00	15.00	15.00	15.00
700	2.43	4.41	6.89	9.87	14.93	15.00	15.00	15.00	15.00
750	2.27	4.11	6.43	9.21	13.93	15.00	15.00	15.00	15.00
800	2.13	3.86	6.03	8.63	13.06	15.00	15.00	15.00	15.00
850	2.00	3.63	5.67	8.13	12.29	15.00	15.00	15.00	15.00
900	1.89	3.43	5.36	7.67	11.61	15.00	15.00	15.00	15.00
950	1.79	3.25	5.08	7.27	11.00	14.76	15.00	15.00	15.00
1 000	1.70	3.09	4.82	6.91	10.45	14.02	15.00	15.00	15.00
1 050	1.62	2.94	4.59	6.58	9.95	13.36	15.00	15.00	15.00
1 100	1.55	2.80	4.38	6.28	9.50	12.75	15.00	15.00	15.00
1 150	1.48	2.68	4.19	6.01	9.09	12.19	15.00	15.00	15.00
1 200	1.42	2.57	4.02	5.76	8.71	11.69	14.75	15.00	15.00
1 250	1.36	2.47	3.86	5.53	8.36	11.22	14.16	15.00	15.00
1 300	1.31	2.37	3.71	5.31	8.04	10.79	13.61	15.00	15.00
1 350	1.26	2.29	3.57	5.12	7.74	10.39	13.11	15.00	15.00
1 400	1.22	2.20	3.45	4.93	7.46	10.02	12.64	15.00	15.00
1 450	1.17	2.13	3.33	4.76	7.21	9.67	12.21	15.00	15.00
1 500	1.14	2.06	3.22	4.60	6.97	9.35	11.80	15.00	15.00
1 550	1.10	1.99	3.11	4.46	6.74	9.05	11.42	15.00	15.00
1 600	1.06	1.93	3.01	4.32	6.53	8.76	11.06	15.00	15.00
1 650	1.03	1.87	2.92	4.19	6.33	8.50	10.73	14.64	15.00
1 700	1.00	1.81	2.84	4.06	6.15	8.25	10.41	14.21	15.00
1 750	0.97	1.76	2.76	3.95	5.97	8.01	10.11	13.80	15.00
1 800	0.95	1.71	2.68	3.84	5.81	7.79	9.83	13.42	15.00
1 850	0.92	1.67	2.61	3.73	5.65	7.58	9.57	13.06	15.00
1 900	0.90	1.62	2.54	3.64	5.50	7.38	9.31	12.71	15.00
1 950	0.87	1.58	2.47	3.54	5.36	7.19	9.08	12.39	15.00
2 000	0.85	1.54	2.41	3.45	5.23	7.01	8.85	12.08	15.00
2 050	0.83	1.50	2.35	3.37	5.10	6.84	8.63	11.78	15.00
2 100	0.81	1.47	2.30	3.29	4.98	6.68	8.43	11.50	15.00
2 150	0.79	1.43	2.24	3.21	4.86	6.52	8.23	11.24	15.00
2 200	0.77	1.40	2.19	3.14	4.75	6.37	8.04	10.98	14.71
2 250	0.76	1.37	2.14	3.07	4.64	6.23	7.87	10.74	14.38
2 300	0.74	1.34	2.10	3.00	4.54	6.10	7.69	10.50	14.07
2 350	0.72	1.31	2.05	2.94	4.45	5.97	7.53	10.28	13.77
2 400	0.71	1.29	2.01	2.88	4.35	5.84	7.37	10.07	13.48
2 450	0.69	1.26	1.97	2.82	4.27	5.72	7.22	9.86	13.21
2 500	0.68	1.23	1.93	2.76	4.18	5.61	7.08	9.66	12.94
2 550	0.67	1.21	1.89	2.71	4.10	5.50	6.94	9.47	12.69
2 600	0.65	1.19	1.86	2.66	4.02	5.39	6.81	9.29	12.44
2 650	0.64	1.16	1.82	2.61	3.94	5.29	6.68	9.12	12.21
2 700	0.63	1.14	1.79	2.56	3.87	5.19	6.55	8.95	11.98
2 750	0.62	1.12	1.75	2.51	3.80	5.10	6.44	8.78	11.76
2 800	0.61	1.10	1.72	2.47	3.73	5.01	6.32	8.63	11.55
2 850	0.60	1.08	1.69	2.42	3.67	4.92	6.21	8.48	11.35
2 900	0.59	1.06	1.66	2.38	3.60	4.84	6.10	8.33	11.16
2 950	0.58	1.05	1.63	2.34	3.54	4.75	6.00	8.19	10.97
3 000	0.57	1.03	1.61	2.30	3.48	4.67	5.90	8.05	10.78
3 050	0.56	1.01	1.58	2.26	3.43	4.60	5.80	7.92	10.61
3 100	0.55	1.00	1.56	2.23	3.37	4.52	5.71	7.79	10.44
3 150	0.54	0.98	1.53	2.19	3.32	4.45	5.62	7.67	10.27
3 200	0.53	0.96	1.51	2.16	3.27	4.38	5.53	7.55	10.11
3 250	0.52	0.95	1.48	2.13	3.22	4.31	5.45	7.43	9.95
3 300	0.52	0.93	1.46	2.09	3.17	4.25	5.36	7.32	9.80
3 350	0.51	0.92	1.44	2.06	3.12	4.19	5.28	7.21	9.66
3 400	0.50	0.91	1.42	2.03	3.07	4.12	5.21	7.10	9.52
3 450	0.49	0.89	1.40	2.00	3.03	4.06	5.13	7.00	9.38

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Table 23 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
3 500	0.49	0.88	1.38	1.97	2.99	4.01	5.06	6.90	9.24
3 550	0.48	0.87	1.36	1.95	2.94	3.95	4.99	6.80	9.11
3 600	0.47	0.86	1.34	1.92	2.90	3.90	4.92	6.71	8.99
3 650	0.47	0.85	1.32	1.89	2.86	3.84	4.85	6.62	8.86
3 700	0.46	0.83	1.30	1.87	2.82	3.79	4.78	6.53	8.74
3 750	0.45	0.82	1.29	1.84	2.79	3.74	4.72	6.44	8.63
3 800	0.45	0.81	1.27	1.82	2.75	3.69	4.66	6.36	8.51
3 850	0.44	0.80	1.25	1.79	2.71	3.64	4.60	6.27	8.40
3 900	0.44	0.79	1.24	1.77	2.68	3.60	4.54	6.19	8.30
3 950	0.43	0.78	1.22	1.75	2.65	3.55	4.48	6.12	8.19
4 000	0.43	0.77	1.21	1.73	2.61	3.51	4.42	6.04	8.09
4 050	0.42	0.76	1.19	1.71	2.58	3.46	4.37	5.96	7.99
4 100	0.42	0.75	1.18	1.68	2.55	3.42	4.32	5.89	7.89
4 150	0.41	0.74	1.16	1.66	2.52	3.38	4.26	5.82	7.80
4 200	0.41	0.73	1.15	1.64	2.49	3.34	4.21	5.75	7.70
4 250	0.40	0.73	1.13	1.63	2.46	3.30	4.16	5.68	7.61
4 300	0.40	0.72	1.12	1.61	2.43	3.26	4.12	5.62	7.52
4 350	0.39	0.71	1.11	1.59	2.40	3.22	4.07	5.55	7.44
4 400	0.39	0.70	1.10	1.57	2.38	3.19	4.02	5.49	7.35
4 450	0.38	0.69	1.08	1.55	2.35	3.15	3.98	5.43	7.27
4 500	0.38	0.69	1.07	1.53	2.32	3.12	3.93	5.37	7.19
4 550	0.37	0.68	1.06	1.52	2.30	3.08	3.89	5.31	7.11
4 600	0.37	0.67	1.05	1.50	2.27	3.05	3.85	5.25	7.03
4 650	0.37	0.66	1.04	1.49	2.25	3.02	3.81	5.19	6.96
4 700	0.36	0.66	1.03	1.47	2.22	2.98	3.77	5.14	6.88
4 750	0.36	0.65	1.02	1.45	2.20	2.95	3.73	5.09	6.81
4 800	0.35	0.64	1.00	1.44	2.18	2.92	3.69	5.03	6.74
4 850	0.35	0.64	0.99	1.42	2.15	2.89	3.65	4.98	6.67
4 900	0.35	0.63	0.98	1.41	2.13	2.86	3.61	4.93	6.60
4 950	0.34	0.62	0.97	1.40	2.11	2.83	3.58	4.88	6.54
5 000	0.34	0.62	0.96	1.38	2.09	2.80	3.54	4.83	6.47
Maximum aspect ratio	7.3	6.8	6.5	6.3	5.9	4.9	4.3	3.8	3.3

Table 24 Maximum Span for Annealed Glass Fixed on Two Opposite Sides, m

(*Clause* 6.1.9)

Design Wind Pressure	**Nominal Thickness of Annealed Glass, *T*** mm								
N/m^2	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	0.53	0.73	0.92	1.12	1.40	1.77	2.11	2.68	3.36
550	0.51	0.69	0.88	1.07	1.33	1.69	2.02	2.56	3.20
600	0.48	0.66	0.84	1.02	1.27	1.62	1.93	2.45	3.07
650	0.46	0.64	0.81	0.98	1.22	1.56	1.85	2.35	2.95
700	0.45	0.61	0.78	0.95	1.18	1.50	1.79	2.26	2.84
750	0.43	0.59	0.75	0.91	1.14	1.45	1.73	2.19	2.74
800	0.42	0.57	0.73	0.88	1.10	1.40	1.67	2.12	2.66
850	0.41	0.56	0.71	0.86	1.07	1.36	1.62	2.06	2.58
900	0.40	0.54	0.69	0.83	1.04	1.32	1.58	2.00	2.50
950	0.38	0.53	0.67	0.81	1.01	1.29	1.53	1.94	2.44
1 000	0.37	0.51	0.65	0.79	0.99	1.25	1.49	1.89	2.38
1 050	0.37	0.50	0.64	0.77	0.96	1.22	1.46	1.85	2.32
1 100	0.36	0.49	0.62	0.75	0.94	1.20	1.43	1.81	2.26
1 150	0.35	0.48	0.61	0.74	0.92	1.17	1.39	1.77	2.22
1 200	0.34	0.47	0.60	0.72	0.90	1.15	1.36	1.73	2.17
1 250	0.34	0.46	0.58	0.71	0.88	1.12	1.34	1.69	2.12
1 300	0.33	0.45	0.57	0.69	0.87	1.10	1.31	1.66	2.08
1 350	0.32	0.44	0.56	0.68	0.85	1.08	1.29	1.63	2.04
1 400	0.32	0.43	0.55	0.67	0.83	1.06	1.26	1.60	2.01
1 450	0.31	0.43	0.54	0.66	0.82	1.04	1.24	1.57	1.97
1 500	0.31	0.42	0.53	0.65	0.81	1.02	1.22	1.55	1.94
1 550	0.30	0.41	0.52	0.64	0.79	1.01	1.20	1.52	1.91
1 600	0.30	0.41	0.52	0.63	0.78	0.99	1.18	1.50	1.88

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Table 24 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1 650	0.29	0.40	0.51	0.62	0.77	0.98	1.16	1.48	1.85
1 700	0.29	0.39	0.50	0.61	0.76	0.96	1.15	1.45	1.82
1 750	0.28	0.39	0.49	0.60	0.75	0.95	1.13	1.43	1.80
1 800	0.28	0.38	0.49	0.59	0.74	0.93	1.11	1.41	1.77
1 850	0.28	0.38	0.48	0.58	0.73	0.92	1.10	1.39	1.75
1 900	0.27	0.37	0.47	0.57	0.72	0.91	1.08	1.37	1.72
1 950	0.27	0.37	0.47	0.57	0.71	0.90	1.07	1.36	1.70
2 000	0.27	0.36	0.46	0.56	0.70	0.89	1.06	1.34	1.68
2 050	0.26	0.36	0.46	0.55	0.69	0.88	1.04	1.32	1.66
2 100	0.26	0.35	0.45	0.55	0.68	0.87	1.03	1.31	1.64
2 150	0.26	0.35	0.44	0.54	0.67	0.86	1.02	1.29	1.62
2 200	0.25	0.35	0.44	0.53	0.67	0.85	1.01	1.28	1.60
2 250	0.25	0.34	0.43	0.53	0.66	0.84	1.00	1.26	1.58
2 300	0.25	0.34	0.43	0.52	0.65	0.83	0.99	1.25	1.57
2 350	0.24	0.34	0.43	0.52	0.64	0.82	0.97	1.24	1.55
2 400	0.24	0.33	0.42	0.51	0.64	0.81	0.96	1.22	1.53
2 450	0.24	0.33	0.42	0.51	0.63	0.80	0.95	1.21	1.52
2 500	0.24	0.32	0.41	0.50	0.62	0.79	0.95	1.20	1.50
2 550	0.23	0.32	0.41	0.50	0.62	0.79	0.94	1.19	1.49
2 600	0.23	0.32	0.40	0.49	0.61	0.78	0.93	1.18	1.47
2 650	0.23	0.32	0.40	0.49	0.61	0.77	0.92	1.16	1.46
2 700	0.23	0.31	0.40	0.48	0.60	0.76	0.91	1.15	1.45
2 750	0.23	0.31	0.39	0.48	0.60	0.76	0.90	1.14	1.43
2 800	0.22	0.31	0.39	0.47	0.59	0.75	0.89	1.13	1.42
2 850	0.22	0.30	0.39	0.47	0.58	0.74	0.89	1.12	1.41
2 900	0.22	0.30	0.38	0.46	0.58	0.74	0.88	1.11	1.39
2 950	0.22	0.30	0.38	0.46	0.57	0.73	0.87	1.10	1.38
3 000	0.22	0.30	0.38	0.46	0.57	0.72	0.86	1.09	1.37
3 050	0.21	0.29	0.37	0.45	0.57	0.72	0.86	1.09	1.36
3 100	0.21	0.29	0.37	0.45	0.56	0.71	0.85	1.08	1.35
3 150	0.21	0.29	0.37	0.45	0.56	0.71	0.84	1.07	1.34
3 200	0.21	0.29	0.36	0.44	0.55	0.70	0.84	1.06	1.33
3 250	0.21	0.28	0.36	0.44	0.55	0.70	0.83	1.05	1.32
3 300	0.21	0.28	0.36	0.44	0.54	0.69	0.82	1.04	1.31
3 350	0.20	0.28	0.36	0.43	0.54	0.69	0.82	1.04	1.30
3 400	0.20	0.28	0.35	0.43	0.54	0.68	0.81	1.03	1.29
3 450	0.20	0.28	0.35	0.43	0.53	0.68	0.80	1.02	1.28
3 500	0.20	0.27	0.35	0.42	0.53	0.67	0.80	1.01	1.27
3 550	0.20	0.27	0.35	0.42	0.52	0.67	0.79	1.01	1.26
3 600	0.20	0.27	0.34	0.42	0.52	0.66	0.79	1.00	1.25
3 650	0.20	0.27	0.34	0.41	0.52	0.66	0.78	0.99	1.24
3 700	0.19	0.27	0.34	0.41	0.51	0.65	0.78	0.99	1.23
3 750	0.19	0.27	0.34	0.41	0.51	0.65	0.77	0.98	1.23
3 800	0.19	0.26	0.33	0.41	0.51	0.64	0.77	0.97	1.22
3 850	0.19	0.26	0.33	0.40	0.50	0.64	0.76	0.97	1.21
3 900	0.19	0.26	0.33	0.40	0.50	0.64	0.76	0.96	1.20
3 950	0.19	0.26	0.33	0.40	0.50	0.63	0.75	0.95	1.20
4 000	0.19	0.26	0.33	0.40	0.49	0.63	0.75	0.95	1.19
4 050	0.19	0.26	0.32	0.39	0.49	0.62	0.74	0.94	1.18
4 100	0.19	0.25	0.32	0.39	0.49	0.62	0.74	0.94	1.17
4 150	0.18	0.25	0.32	0.39	0.48	0.62	0.73	0.93	1.17
4 200	0.18	0.25	0.32	0.39	0.48	0.61	0.73	0.92	1.16
4 250	0.18	0.25	0.32	0.38	0.48	0.61	0.72	0.92	1.15
4 300	0.18	0.25	0.31	0.38	0.48	0.60	0.72	0.91	1.15
4 350	0.18	0.25	0.31	0.38	0.47	0.60	0.72	0.91	1.14
4 400	0.18	0.24	0.31	0.38	0.47	0.60	0.71	0.90	1.13
4 450	0.18	0.24	0.31	0.38	0.47	0.59	0.71	0.90	1.13
4 500	0.18	0.24	0.31	0.37	0.47	0.59	0.70	0.89	1.12
4 550	0.18	0.24	0.31	0.37	0.46	0.59	0.70	0.89	1.11
4 600	0.17	0.24	0.30	0.37	0.46	0.58	0.70	0.88	1.11
4 650	0.17	0.24	0.30	0.37	0.46	0.58	0.69	0.88	1.10
4 700	0.17	0.24	0.30	0.36	0.46	0.58	0.69	0.87	1.10
4 750	0.17	0.24	0.30	0.36	0.45	0.58	0.69	0.87	1.09
4 800	0.17	0.23	0.30	0.36	0.45	0.57	0.68	0.86	1.08
4 850	0.17	0.23	0.30	0.36	0.45	0.57	0.68	0.86	1.08
4 900	0.17	0.23	0.29	0.36	0.45	0.57	0.68	0.86	1.07
4 950	0.17	0.23	0.29	0.36	0.44	0.56	0.67	0.85	1.07
5 000	0.17	0.23	0.29	0.35	0.44	0.56	0.67	0.85	1.06

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Table 25 Maximum Span for Laminated Glass Fixed on Two Opposite Sides, m

(*Clause* 6.1.9)

Design Wind Pressure	Nominal Thickness of Laminated Glass, *T* mm					
N/m^2	5.38	6.38	8.38	10.38	12.38	16.38
(1)	(2)	(3)	(4)	(5)	(6)	(7)
500	0.79	0.95	1.25	1.59	1.92	2.50
550	0.75	0.90	1.19	1.51	1.83	2.38
600	0.72	0.87	1.14	1.45	1.76	2.28
650	0.69	0.83	1.10	1.39	1.69	2.19
700	0.67	0.80	1.06	1.34	1.63	2.11
750	0.65	0.77	1.02	1.30	1.57	2.04
800	0.62	0.75	0.99	1.25	1.52	1.98
850	0.61	0.73	0.96	1.22	1.48	1.92
900	0.59	0.71	0.93	1.18	1.43	1.86
950	0.57	0.69	0.91	1.15	1.40	1.81
1 000	0.56	0.67	0.88	1.12	1.36	1.77
1 050	0.55	0.65	0.86	1.09	1.33	1.72
1 100	0.53	0.64	0.84	1.07	1.30	1.68
1 150	0.52	0.63	0.82	1.05	1.27	1.65
1 200	0.51	0.61	0.81	1.02	1.24	1.61
1 250	0.50	0.60	0.79	1.00	1.22	1.58
1 300	0.49	0.59	0.77	0.98	1.19	1.55
1 350	0.48	0.58	0.76	0.97	1.17	1.52
1 400	0.47	0.57	0.75	0.95	1.15	1.49
1 450	0.46	0.56	0.73	0.93	1.13	1.47
1 500	0.46	0.55	0.72	0.92	1.11	1.44
1 550	0.45	0.54	0.71	0.90	1.09	1.42
1 600	0.44	0.53	0.70	0.89	1.08	1.40
1 650	0.43	0.52	0.69	0.87	1.06	1.38
1 700	0.43	0.51	0.68	0.86	1.04	1.35
1 750	0.42	0.51	0.67	0.85	1.03	1.34
1 800	0.42	0.50	0.66	0.84	1.01	1.32
1 850	0.41	0.49	0.65	0.82	1.00	1.30
1 900	0.41	0.49	0.64	0.81	0.99	1.28
1 950	0.40	0.48	0.63	0.80	0.97	1.27
2 000	0.40	0.47	0.62	0.79	0.96	1.25
2 050	0.39	0.47	0.62	0.78	0.95	1.23
2 100	0.39	0.46	0.61	0.77	0.94	1.22
2 150	0.38	0.46	0.60	0.77	0.93	1.20
2 200	0.38	0.45	0.60	0.76	0.92	1.19
2 250	0.37	0.45	0.59	0.75	0.91	1.18
2 300	0.37	0.44	0.58	0.74	0.90	1.16
2 350	0.36	0.44	0.58	0.73	0.89	1.15
2 400	0.36	0.43	0.57	0.72	0.88	1.14
2 450	0.36	0.43	0.56	0.72	0.87	1.13
2 500	0.35	0.42	0.56	0.71	0.86	1.12
2 550	0.35	0.42	0.55	0.70	0.85	1.11
2 600	0.35	0.42	0.55	0.70	0.84	1.10

Table 25 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2 650	0.34	0.41	0.54	0.69	0.84	1.09
2 700	0.34	0.41	0.54	0.68	0.83	1.08
2 750	0.34	0.40	0.53	0.68	0.82	1.07
2 800	0.33	0.40	0.53	0.67	0.81	1.06
2 850	0.33	0.40	0.52	0.66	0.81	1.05
2 900	0.33	0.39	0.52	0.66	0.80	1.04
2 950	0.33	0.39	0.51	0.65	0.79	1.03
3 000	0.32	0.39	0.51	0.65	0.79	1.02
3 050	0.32	0.38	0.51	0.64	0.78	1.01
3 100	0.32	0.38	0.50	0.64	0.77	1.00
3 150	0.31	0.38	0.50	0.63	0.77	1.00
3 200	0.31	0.37	0.49	0.63	0.76	0.99
3 250	0.31	0.37	0.49	0.62	0.75	0.98
3 300	0.31	0.37	0.49	0.62	0.75	0.97
3 350	0.31	0.37	0.48	0.61	0.74	0.97
3 400	0.30	0.36	0.48	0.61	0.74	0.96
3 450	0.30	0.36	0.48	0.60	0.73	0.95
3 500	0.30	0.36	0.47	0.60	0.73	0.94
3 550	0.30	0.36	0.47	0.60	0.72	0.94
3 600	0.29	0.35	0.47	0.59	0.72	0.93
3 650	0.29	0.35	0.46	0.59	0.71	0.92
3 700	0.29	0.35	0.46	0.58	0.71	0.92
3 750	0.29	0.35	0.46	0.58	0.70	0.91
3 800	0.29	0.34	0.45	0.58	0.70	0.91
3 850	0.28	0.34	0.45	0.57	0.69	0.90
3 900	0.28	0.34	0.45	0.57	0.69	0.89
3 950	0.28	0.34	0.44	0.56	0.68	0.89
4 000	0.28	0.34	0.44	0.56	0.68	0.88
4 050	0.28	0.33	0.44	0.56	0.68	0.88
4 100	0.28	0.33	0.44	0.55	0.67	0.87
4 150	0.27	0.33	0.43	0.55	0.67	0.87
4 200	0.27	0.33	0.43	0.55	0.66	0.86
4 250	0.27	0.33	0.43	0.54	0.66	0.86
4 300	0.27	0.32	0.43	0.54	0.66	0.85
4 350	0.27	0.32	0.42	0.54	0.65	0.85
4 400	0.27	0.32	0.42	0.53	0.65	0.84
4 450	0.26	0.32	0.42	0.53	0.65	0.84
4 500	0.26	0.32	0.42	0.53	0.64	0.83
4 550	0.26	0.31	0.41	0.53	0.64	0.83
4 600	0.26	0.31	0.41	0.52	0.63	0.82
4 650	0.26	0.31	0.41	0.52	0.63	0.82
4 700	0.26	0.31	0.41	0.52	0.63	0.81
4 750	0.26	0.31	0.41	0.51	0.62	0.81
4 800	0.26	0.31	0.40	0.51	0.62	0.81
4 850	0.25	0.30	0.40	0.51	0.62	0.80
4 900	0.25	0.30	0.40	0.51	0.61	0.80
4 950	0.25	0.30	0.40	0.50	0.61	0.79
5 000	0.25	0.30	0.40	0.50	0.61	0.79

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Table 26 Maximum Span for Tempered Glass Fixed on Two Opposite Sides, m

(*Clause* 6.1.9)

Design Wind Pressure	Nominal Thickness of Tempered Glass, *T* mm								
N/m^2	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	0.62	0.86	1.09	1.32	1.52	1.93	2.30	2.92	3.66
550	0.60	0.82	1.04	1.26	1.45	1.84	2.20	2.78	3.49
600	0.57	0.78	0.99	1.20	1.39	1.76	2.10	2.66	3.34
650	0.55	0.75	0.95	1.16	1.33	1.69	2.02	2.56	3.21
700	0.53	0.72	0.92	1.11	1.29	1.63	1.95	2.47	3.09
750	0.51	0.70	0.89	1.08	1.24	1.58	1.88	2.38	2.99
800	0.49	0.68	0.86	1.04	1.20	1.53	1.82	2.31	2.89
850	0.48	0.66	0.83	1.01	1.17	1.48	1.77	2.24	2.81
900	0.47	0.64	0.81	0.98	1.13	1.44	1.72	2.18	2.73
950	0.45	0.62	0.79	0.96	1.10	1.40	1.67	2.12	2.65
1 000	0.44	0.60	0.77	0.93	1.08	1.37	1.63	2.06	2.59
1 050	0.43	0.59	0.75	0.91	1.05	1.33	1.59	2.01	2.52
1 100	0.42	0.58	0.73	0.89	1.03	1.30	1.55	1.97	2.47
1 150	0.41	0.56	0.72	0.87	1.00	1.27	1.52	1.92	2.41
1 200	0.40	0.55	0.70	0.85	0.98	1.25	1.49	1.88	2.36
1 250	0.39	0.54	0.69	0.83	0.96	1.22	1.46	1.85	2.31
1 300	0.39	0.53	0.67	0.82	0.94	1.20	1.43	1.81	2.27
1 350	0.38	0.52	0.66	0.80	0.93	1.18	1.40	1.78	2.23
1 400	0.37	0.51	0.65	0.79	0.91	1.15	1.38	1.74	2.19
1 450	0.37	0.50	0.64	0.77	0.89	1.13	1.35	1.71	2.15
1 500	0.36	0.49	0.63	0.76	0.88	1.12	1.33	1.69	2.11
1 550	0.35	0.49	0.62	0.75	0.86	1.10	1.31	1.66	2.08
1 600	0.35	0.48	0.61	0.74	0.85	1.08	1.29	1.63	2.05
1 650	0.34	0.47	0.60	0.73	0.84	1.06	1.27	1.61	2.01
1 700	0.34	0.46	0.59	0.71	0.82	1.05	1.25	1.58	1.98
1 750	0.33	0.46	0.58	0.70	0.81	1.03	1.23	1.56	1.96
1 800	0.33	0.45	0.57	0.69	0.80	1.02	1.21	1.54	1.93
1 850	0.32	0.44	0.56	0.68	0.79	1.00	1.20	1.52	1.90
1 900	0.32	0.44	0.56	0.68	0.78	0.99	1.18	1.50	1.88
1 950	0.32	0.43	0.55	0.67	0.77	0.98	1.17	1.48	1.85
2 000	0.31	0.43	0.54	0.66	0.76	0.97	1.15	1.46	1.83
2 050	0.31	0.42	0.54	0.65	0.75	0.95	1.14	1.44	1.81
2 100	0.30	0.42	0.53	0.64	0.74	0.94	1.12	1.42	1.79
2 150	0.30	0.41	0.52	0.64	0.73	0.93	1.11	1.41	1.76
2 200	0.30	0.41	0.52	0.63	0.73	0.92	1.10	1.39	1.74
2 250	0.29	0.40	0.51	0.62	0.72	0.91	1.09	1.38	1.72
2 300	0.29	0.40	0.51	0.61	0.71	0.90	1.07	1.36	1.71
2 350	0.29	0.39	0.50	0.61	0.70	0.89	1.06	1.35	1.69
2 400	0.28	0.39	0.50	0.60	0.69	0.88	1.05	1.33	1.67
2 450	0.28	0.39	0.49	0.60	0.69	0.87	1.04	1.32	1.65
2 500	0.28	0.38	0.49	0.59	0.68	0.86	1.03	1.31	1.64
2 550	0.28	0.38	0.48	0.58	0.67	0.86	1.02	1.29	1.62
2 600	0.27	0.38	0.48	0.58	0.67	0.85	1.01	1.28	1.60
2 650	0.27	0.37	0.47	0.57	0.66	0.84	1.00	1.27	1.59
2 700	0.27	0.37	0.47	0.57	0.65	0.83	0.99	1.26	1.57
2 750	0.27	0.36	0.46	0.56	0.65	0.82	0.98	1.24	1.56
2 800	0.26	0.36	0.46	0.56	0.64	0.82	0.97	1.23	1.55
2 850	0.26	0.36	0.46	0.55	0.64	0.81	0.96	1.22	1.53
2 900	0.26	0.36	0.45	0.55	0.63	0.80	0.96	1.21	1.52
2 950	0.26	0.35	0.45	0.54	0.63	0.80	0.95	1.20	1.51
3 000	0.25	0.35	0.44	0.54	0.62	0.79	0.94	1.19	1.49
3 050	0.25	0.35	0.44	0.53	0.62	0.78	0.93	1.18	1.48
3 100	0.25	0.34	0.44	0.53	0.61	0.78	0.92	1.17	1.47
3 150	0.25	0.34	0.43	0.52	0.61	0.77	0.92	1.16	1.46
3 200	0.25	0.34	0.43	0.52	0.60	0.76	0.91	1.15	1.45
3 250	0.24	0.34	0.43	0.52	0.60	0.76	0.90	1.14	1.44
3 300	0.24	0.33	0.42	0.51	0.59	0.75	0.90	1.14	1.42
3 350	0.24	0.33	0.42	0.51	0.59	0.75	0.89	1.13	1.41
3 400	0.24	0.33	0.42	0.51	0.58	0.74	0.88	1.12	1.40
3 450	0.24	0.33	0.41	0.50	0.58	0.74	0.88	1.11	1.39
3 500	0.24	0.32	0.41	0.50	0.57	0.73	0.87	1.10	1.38

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Table 26 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
3 550	0.23	0.32	0.41	0.49	0.57	0.73	0.86	1.10	1.37
3 600	0.23	0.32	0.40	0.49	0.57	0.72	0.86	1.09	1.36
3 650	0.23	0.32	0.40	0.49	0.56	0.72	0.85	1.08	1.35
3 700	0.23	0.31	0.40	0.48	0.56	0.71	0.85	1.07	1.34
3 750	0.23	0.31	0.40	0.48	0.56	0.71	0.84	1.07	1.34
3 800	0.23	0.31	0.39	0.48	0.55	0.70	0.84	1.06	1.33
3 850	0.22	0.31	0.39	0.47	0.55	0.70	0.83	1.05	1.32
3 900	0.22	0.31	0.39	0.47	0.54	0.69	0.82	1.05	1.31
3 950	0.22	0.30	0.39	0.47	0.54	0.69	0.82	1.04	1.30
4 000	0.22	0.30	0.38	0.47	0.54	0.68	0.81	1.03	1.29
4 050	0.22	0.30	0.38	0.46	0.53	0.68	0.81	1.03	1.29
4 100	0.22	0.30	0.38	0.46	0.53	0.67	0.80	1.02	1.28
4 150	0.22	0.30	0.38	0.46	0.53	0.67	0.80	1.01	1.27
4 200	0.22	0.30	0.37	0.45	0.52	0.67	0.79	1.01	1.26
4 250	0.21	0.29	0.37	0.45	0.52	0.66	0.79	1.00	1.25
4 300	0.21	0.29	0.37	0.45	0.52	0.66	0.79	1.00	1.25
4 350	0.21	0.29	0.37	0.45	0.52	0.66	0.78	0.99	1.24
4 400	0.21	0.29	0.37	0.44	0.51	0.65	0.78	0.98	1.23
4 450	0.21	0.29	0.36	0.44	0.51	0.65	0.77	0.98	1.23
4 500	0.21	0.29	0.36	0.44	0.51	0.64	0.77	0.97	1.22
4 550	0.21	0.28	0.36	0.44	0.50	0.64	0.76	0.97	1.21
4 600	0.21	0.28	0.36	0.43	0.50	0.64	0.76	0.96	1.21
4 650	0.20	0.28	0.36	0.43	0.50	0.63	0.75	0.96	1.20
4 700	0.20	0.28	0.35	0.43	0.50	0.63	0.75	0.95	1.19
4 750	0.20	0.28	0.35	0.43	0.49	0.63	0.75	0.95	1.19
4 800	0.20	0.28	0.35	0.43	0.49	0.62	0.74	0.94	1.18
4 850	0.20	0.27	0.35	0.42	0.49	0.62	0.74	0.94	1.17
4 900	0.20	0.27	0.35	0.42	0.49	0.62	0.74	0.93	1.17
4 950	0.20	0.27	0.35	0.42	0.48	0.61	0.73	0.93	1.16
5 000	0.20	0.27	0.34	0.42	0.48	0.61	0.73	0.92	1.16

Table 27 Maximum Span for Heat Strengthened Glass Fixed on Two Opposite Sides, m

(*Clause* 6.1.9)

Design Wind Pressure	**Nominal Thickness of Heat Strengthened Glass, *T*** mm								
N/m^2	3	4	5	6	8	10	12	15	19
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
500	0.50	0.68	0.87	1.05	1.22	1.55	1.84	2.34	2.93
550	0.48	0.65	0.83	1.00	1.16	1.47	1.76	2.23	2.79
600	0.46	0.62	0.79	0.96	1.11	1.41	1.68	2.13	2.67
650	0.44	0.60	0.76	0.92	1.07	1.36	1.62	2.05	2.57
700	0.42	0.58	0.73	0.89	1.03	1.31	1.56	1.97	2.47
750	0.41	0.56	0.71	0.86	0.99	1.26	1.50	1.91	2.39
800	0.39	0.54	0.69	0.83	0.96	1.22	1.46	1.85	2.31
850	0.38	0.52	0.67	0.81	0.93	1.19	1.41	1.79	2.24
900	0.37	0.51	0.65	0.79	0.91	1.15	1.37	1.74	2.18
950	0.36	0.50	0.63	0.76	0.88	1.12	1.34	1.69	2.12
1 000	0.35	0.48	0.61	0.75	0.86	1.09	1.30	1.65	2.07
1 050	0.34	0.47	0.60	0.73	0.84	1.07	1.27	1.61	2.02
1 100	0.34	0.46	0.59	0.71	0.82	1.04	1.24	1.57	1.97
1 150	0.33	0.45	0.57	0.69	0.80	1.02	1.21	1.54	1.93
1 200	0.32	0.44	0.56	0.68	0.79	1.00	1.19	1.51	1.89
1 250	0.32	0.43	0.55	0.67	0.77	0.98	1.16	1.48	1.85
1 300	0.31	0.42	0.54	0.65	0.75	0.96	1.14	1.45	1.82
1 350	0.30	0.42	0.53	0.64	0.74	0.94	1.12	1.42	1.78
1 400	0.30	0.41	0.52	0.63	0.73	0.92	1.10	1.40	1.75
1 450	0.29	0.40	0.51	0.62	0.71	0.91	1.08	1.37	1.72
1 500	0.29	0.40	0.50	0.61	0.70	0.89	1.06	1.35	1.69
1 550	0.28	0.39	0.49	0.60	0.69	0.88	1.05	1.33	1.66
1 600	0.28	0.38	0.49	0.59	0.68	0.86	1.03	1.31	1.64
1 650	0.27	0.38	0.48	0.58	0.67	0.85	1.01	1.29	1.61
1 700	0.27	0.37	0.47	0.57	0.66	0.84	1.00	1.27	1.59
1 750	0.27	0.37	0.46	0.56	0.65	0.83	0.98	1.25	1.56

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Table 27 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1 800	0.26	0.36	0.46	0.56	0.64	0.81	0.97	1.23	1.54
1 850	0.26	0.36	0.45	0.55	0.63	0.80	0.96	1.21	1.52
1 900	0.26	0.35	0.45	0.54	0.62	0.79	0.94	1.20	1.50
1 950	0.25	0.35	0.44	0.53	0.62	0.78	0.93	1.18	1.48
2 000	0.25	0.34	0.43	0.53	0.61	0.77	0.92	1.17	1.46
2 050	0.25	0.34	0.43	0.52	0.60	0.76	0.91	1.15	1.45
2 100	0.24	0.33	0.42	0.51	0.59	0.75	0.90	1.14	1.43
2 150	0.24	0.33	0.42	0.51	0.59	0.75	0.89	1.13	1.41
2 200	0.24	0.33	0.41	0.50	0.58	0.74	0.88	1.11	1.40
2 250	0.24	0.32	0.41	0.50	0.57	0.73	0.87	1.10	1.38
2 300	0.23	0.32	0.41	0.49	0.57	0.72	0.86	1.09	1.36
2 350	0.23	0.32	0.40	0.49	0.56	0.71	0.85	1.08	1.35
2 400	0.23	0.31	0.40	0.48	0.56	0.71	0.84	1.07	1.34
2 450	0.23	0.31	0.39	0.48	0.55	0.70	0.83	1.05	1.32
2 500	0.22	0.31	0.39	0.47	0.54	0.69	0.82	1.04	1.31
2 550	0.22	0.30	0.38	0.47	0.54	0.68	0.82	1.03	1.30
2 600	0.22	0.30	0.38	0.46	0.53	0.68	0.81	1.02	1.28
2 650	0.22	0.30	0.38	0.46	0.53	0.67	0.80	1.01	1.27
2 700	0.21	0.29	0.37	0.45	0.52	0.67	0.79	1.00	1.26
2 750	0.21	0.29	0.37	0.45	0.52	0.66	0.79	1.00	1.25
2 800	0.21	0.29	0.37	0.45	0.51	0.65	0.78	0.99	1.24
2 850	0.21	0.29	0.36	0.44	0.51	0.65	0.77	0.98	1.23
2 900	0.21	0.28	0.36	0.44	0.51	0.64	0.76	0.97	1.22
2 950	0.21	0.28	0.36	0.43	0.50	0.64	0.76	0.96	1.21
3 000	0.20	0.28	0.35	0.43	0.50	0.63	0.75	0.95	1.19
3 050	0.20	0.28	0.35	0.43	0.49	0.63	0.75	0.95	1.19
3 100	0.20	0.27	0.35	0.42	0.49	0.62	0.74	0.94	1.18
3 150	0.20	0.27	0.35	0.42	0.48	0.62	0.73	0.93	1.17
3 200	0.20	0.27	0.34	0.42	0.48	0.61	0.73	0.92	1.16
3 250	0.20	0.27	0.34	0.41	0.48	0.61	0.72	0.92	1.15
3 300	0.19	0.27	0.34	0.41	0.47	0.60	0.72	0.91	1.14
3 350	0.19	0.26	0.34	0.41	0.47	0.60	0.71	0.90	1.13
3 400	0.19	0.26	0.33	0.40	0.47	0.59	0.71	0.90	1.12
3 450	0.19	0.26	0.33	0.40	0.46	0.59	0.70	0.89	1.11
3 500	0.19	0.26	0.33	0.40	0.46	0.58	0.70	0.88	1.11
3 550	0.19	0.26	0.33	0.40	0.46	0.58	0.69	0.88	1.10
3 600	0.19	0.25	0.32	0.39	0.45	0.58	0.69	0.87	1.09
3 650	0.18	0.25	0.32	0.39	0.45	0.57	0.68	0.86	1.08
3 700	0.18	0.25	0.32	0.39	0.45	0.57	0.68	0.86	1.08
3 750	0.18	0.25	0.32	0.38	0.44	0.56	0.67	0.85	1.07
3 800	0.18	0.25	0.32	0.38	0.44	0.56	0.67	0.85	1.06
3 850	0.18	0.25	0.31	0.38	0.44	0.56	0.66	0.84	1.05
3 900	0.18	0.24	0.31	0.38	0.44	0.55	0.66	0.84	1.05
3 950	0.18	0.24	0.31	0.37	0.43	0.55	0.66	0.83	1.04
4 000	0.18	0.24	0.31	0.37	0.43	0.55	0.65	0.83	1.03
4 050	0.18	0.24	0.31	0.37	0.43	0.54	0.65	0.82	1.03
4 100	0.17	0.24	0.30	0.37	0.42	0.54	0.64	0.82	1.02
4 150	0.17	0.24	0.30	0.37	0.42	0.54	0.64	0.81	1.02
4 200	0.17	0.24	0.30	0.36	0.42	0.53	0.64	0.81	1.01
4 250	0.17	0.23	0.30	0.36	0.42	0.53	0.63	0.80	1.00
4 300	0.17	0.23	0.30	0.36	0.41	0.53	0.63	0.80	1.00
4 350	0.17	0.23	0.29	0.36	0.41	0.52	0.62	0.79	0.99
4 400	0.17	0.23	0.29	0.36	0.41	0.52	0.62	0.79	0.99
4 450	0.17	0.23	0.29	0.35	0.41	0.52	0.62	0.78	0.98
4 500	0.17	0.23	0.29	0.35	0.41	0.52	0.61	0.78	0.98
4 550	0.17	0.23	0.29	0.35	0.40	0.51	0.61	0.77	0.97
4 600	0.16	0.23	0.29	0.35	0.40	0.51	0.61	0.77	0.97
4 650	0.16	0.22	0.28	0.35	0.40	0.51	0.60	0.77	0.96
4 700	0.16	0.22	0.28	0.34	0.40	0.50	0.60	0.76	0.95
4 750	0.16	0.22	0.28	0.34	0.39	0.50	0.60	0.76	0.95
4 800	0.16	0.22	0.28	0.34	0.39	0.50	0.59	0.75	0.94
4 850	0.16	0.22	0.28	0.34	0.39	0.50	0.59	0.75	0.94
4 900	0.16	0.22	0.28	0.34	0.39	0.49	0.59	0.75	0.94
4 950	0.16	0.22	0.28	0.33	0.39	0.49	0.59	0.74	0.93
5 000	0.16	0.22	0.27	0.33	0.38	0.49	0.58	0.74	0.93

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6.2.2 *Site Working and Glass Machining Operation*

6.2.2.1 Heat-strengthened and toughened glass shall not be cut or worked after heat treatment. All necessary cutting, drilling, notching and edge-working shall be carried out to correct dimensions prior to value addition to the glass, such as toughening/tempering/heat strengthening. The edges and surfaces of all glass types shall not be damaged during fixing.

6.2.3 *Dimensional Requirement*

The dimensions for edge clearance, edge cover, front and back clearance, rebate depth is selected in accordance with the requirements in **4.5.2**.

6.2.4 *Glazing Materials*

6.2.4.1 *Compatibility of materials*

A glazing material shall be used only when compatible with contiguous materials, including the rebate surface finish, setting or location blocks, distance pieces and glass type are available.

6.2.4.2 *Application of materials*

The application of glazing materials shall be in accordance with relevant/available Indian Standard or manufacturer's recommendations.

6.2.4.3 *Life expectancy of materials*

A glazing material shall only be used where its life expectancy (durability) has been established. The manufacturers' advice/guarantee should be sought for information regarding life expectancy.

6.2.5 *Setting Blocks*

The number and location of setting blocks shall be as shown in Figs. 10 and 12. Generally, setting blocks shall be,

a) positioned at quarter points or not less than 30 mm from the corner, whichever is lesser;
b) the minimum width of each setting block shall be not less than the glass thickness; and
c) If a glazing bridge is used then the thickness of the glazing bridge can be added to the thickness of the setting block to achieve the minimum gap of 6 mm between the edge of glass and the framing member.

Setting blocks shall be located to equally support all panes of glass, and shall be fixed to prevent displacement during installation and service. The minimum length of each setting block (or two blocks side by side) shall be 25 mm in length for every square metre of glass area, with a minimum length of 50 mm. When wood is used as the material for setting blocks, only the seasoned ones should be used as green wood may shrink laterally (in the process of attaining equilibrium moisture content over a period of time) and result in loosened installations.

For example, a 3.0 m^2 glass area, 3.0 × 25 mm = 75 mm long, that is, 75 mm is the length of each setting block.

Setting blocks shall be of resilient, load-bearing, non-absorbent, rot-proof, and material that is compatible with all other glazing materials conforming to available standards (if any) that may come into contact with the blocks.

NOTES

1 Setting blocks are used between the bottom edge of the unit and the frame to centralize and equally support both panes of glass.

2 Setting block width and location should not restrict water drainage.

3 Extruded rubber material with 80 - 90 shore A hardness is recommended.

4 Shaped setting blocks will be required for a glazing platform.

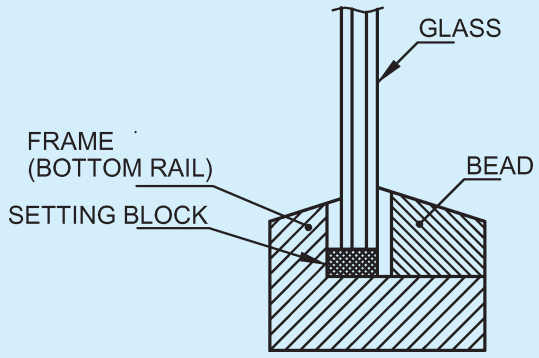


FIG. 10 POSITION OF SETTING BLOCK

6.2.6 *Location Blocks*

The number and position of location blocks shall be as shown in Figs. 11 and 12.

Location blocks shall be,

a) of minimum of 25 mm in length;
b) at least as wide as the glass thickness;
c) positively located to prevent displacement in service; and

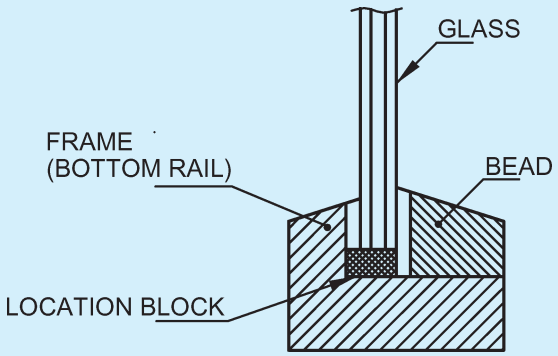


FIG. 11 POSITION OF LOCATION BLOCK

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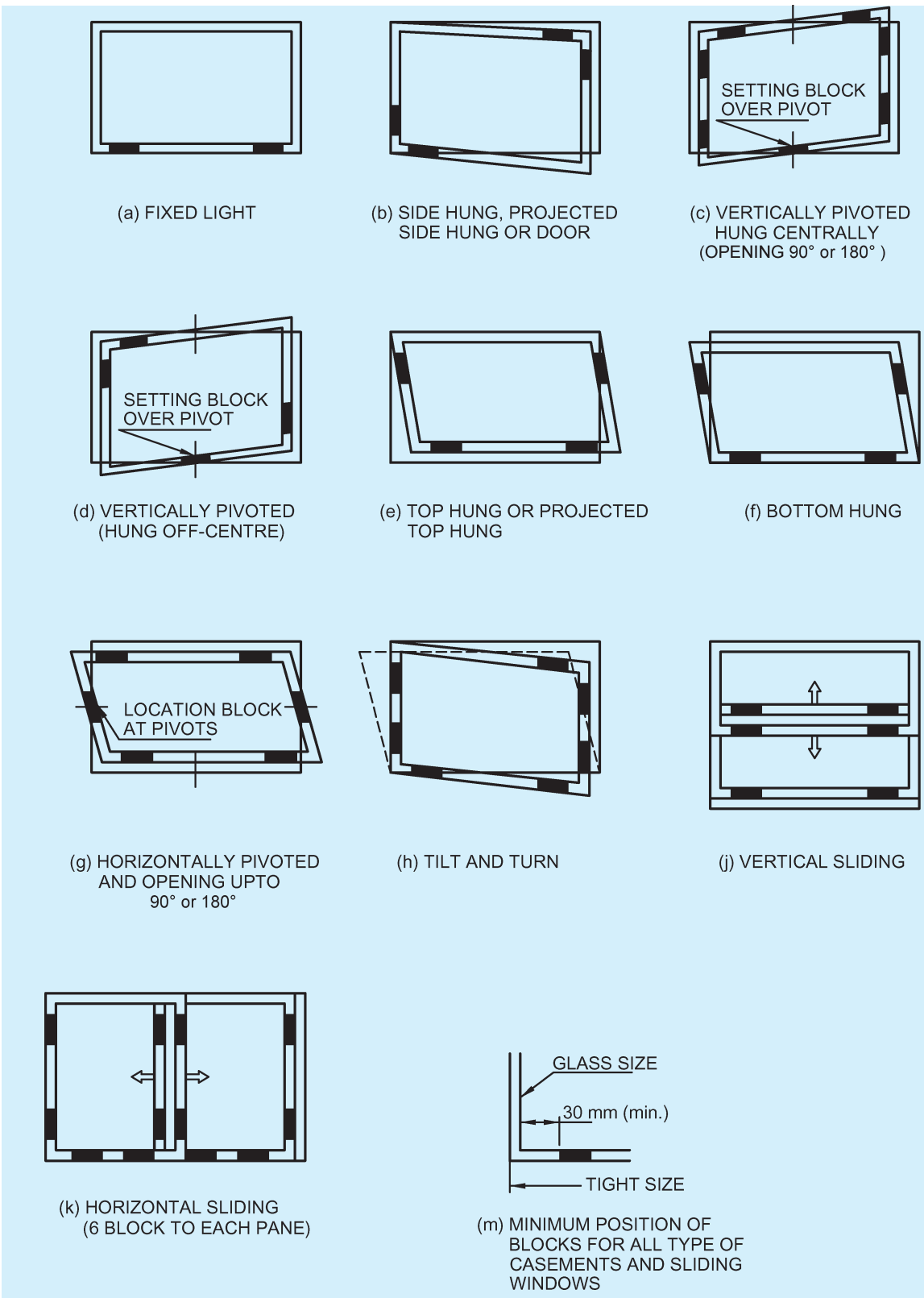


FIG. 12 RECOMMENDED POSITIONS OF SETTING AND LOCATION BLOCKS FOR THE SITE GLAZING OF SOME TYPES OF DOORS AND WINDOWS

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d) sufficiently resilient to accommodate movement within the frame, without imposing stress on the glass, and of resilient, non-absorbent material.

NOTES

1 Location blocks are used between the edges of the glass and the frame to prevent movement of the glass within the frame by thermal expansion or when the window or door is opened or closed. They are required to prevent the weight of the glass from causing the frame to become out of square.

2 Extruded rubber material with 55 - 65 shore A hardness is recommended.

6.2.7 *Distance Pieces*

Distance pieces, as shown in Fig. 13, used where required, shall be,

a) of resilient, non-absorbent material;
b) 25 mm long and of a height to suit the depth of the rebate and the method of glazing; and
c) spaced opposite each other, approximately 50 mm from each corner at intervals of not more than 300 mm.

The thickness shall be equal to the front and back clearance, to retain the glass firmly in the frame.

NOTES

1 Distance pieces are required to prevent displacement of glazing compounds or sealant by external loading, such as wind pressure.

2 Extruded rubber material with 55 - 65 shore A hardness is required.

6.2.8 *Rebates and Grooves for Installation*

Rebates, grooves and beads shall be cleaned and free from grease, moisture and other contaminants. All sealant surfaces shall be primed or sealed in accordance with the recommendations of the manufacturer of the glazing material.

The number and location of setting blocks and location blocks shall be as shown in Fig. 10 to Fig. 12, wherever necessary to maintain the requisite edge clearance. Each block shall support the full thickness of the glass.

6.2.9 *Glazing Beads*

Where used, glazing beads shall be capable of restraining the glass under all design forces.

6.2.10 *Structural Sealants*

Structural silicone shall be installed such that a full adhesive bond to the substrate is achieved. Application of structural silicone may require prior cleaning and or priming of the substrate.

Applied structural silicones shall not be installed adjacent to other materials that may be chemically incompatible with the structural sealant and cause a loss of adhesion or adverse chemical changes within the structural silicone that could lead to a loss of strength in the structural silicone. For guidance on the installation of structural silicone, reference to available standards/literatures may be made.

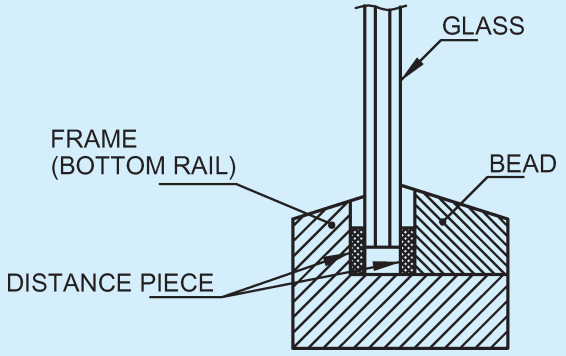


FIG. 13 POSITION OF DISTANCE PIECES

6.3 Design Criteria

6.3.1 *Frame Support Condition*

6.3.1.1 *Maximum area of glass panels subjected to wind loading*

The maximum span for a given standard nominal thickness of ordinary annealed, laminated, heat-strengthened and toughened glass for a given panel size shall be determined in accordance with **6.3.2**, **6.3.3** and **6.3.4** as applicable for the relevant support conditions. For heat strengthened laminated and toughened laminated glass, maximum allowable span shall be determined in accordance with **6.3.5**. For 3 mm monolithic annealed glass, the maximum area shall not exceed 0.85 m^2.

The minimum thickness of the nominal glass size shall be as per the accepted practice in accordance with Indian Standard specifications.

For laminated glass composites, the combined minimum thickness of the glass sheets may be used excluding the interlayer thickness. Alternatively, reference to specialist literature may be drawn for the same purpose.

6.3.2 *Rectangular Glass Supported on All Four Edges*

For rectangular glass supported on all four edges, the maximum area for the design wind pressure shall be determined using the corresponding tables provided for each type of glass. Linear interpolation may be used for any value in between those given therein while maintaining the aspect ratio.

6.3.3 *Rectangles of Glass Supported on Two Opposite Edges*

For rectangles of glass supported on two opposite edges, the maximum glass area for the design wind

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pressure shall be determined from Tables 22 to 25 for ordinary annealed, laminated, heat-strengthened and toughened glass, respectively.

6.3.4 *Rectangles of Glass Supported on Three Edges*

For rectangles of glass supported on three edges, the maximum glass area shall be determined as for two-edge support spanning along the unsupported edge. Alternatively, basic engineering principles shall be adopted in determining the glass thickness for all applications where only three edges of the panel are supported.

NOTE — Butt glazing of adjacent panels in the same plane should not be considered as a support.

6.3.5 *Heat-Strengthened Laminated and Toughened Laminated Glass*

For heat-strengthened laminated and toughened laminated glass, the maximum span for a given standard nominal thickness for a given panel size shall be determined from Tables 23 and 27, and Tables 20 and 25, respectively, with the design wind pressure being divided by the appropriate glass type factor, P_f (*see* Table 15), as applicable for the relevant support conditions.

6.3.6 *Serviceability Checks*

6.3.6.1 Glass complying to Tables 19 to 27 are deemed to meet, the serviceability deflection limits specified (in the absence of any other specified values) or the following values may be had for guidance.

6.3.6.2 *Maximum allowable deflection of framing members*

a) *For mullions*:
   1) *Single height glazing* — Span/175 or 19 mm, whichever is less.
   2) *Double height glazing* — For spans up to 4 110 mm, same as single height glazing; and for spans above 4 110 mm, the same shall be (Span/240) + 6.35 mm.

b) *For transoms*:
   1) Span/500 or 3 mm, whichever is the least for dead load.
   2) Span/175 or 19 mm, whichever is the least for wind load.

c) *Deflection at the centre of the glass*:
   1) *Monolithic glass* — Shortest span/60 or 19 mm, whichever is the least.
   2) *Double glazed unit* — Shortest span/90 or 19 mm, whichever is the least.

d) *Deflection at edge of the glass*:
   Shall be limited to 15 mm.

6.3.6.2.1 *Dielectric separation of dissimilar metals*

When the framing member for the glazing is aluminium and reinforcement is required to meet the deflection criteria, the reinforcement may be of aluminium or galvanized steel (red oxide coating being not recommended) with an insulating material between them at contact points. It is recommended to choose materials as close to each other in the galvanic series as possible.

6.3.7 *Ultimate Stresses*

The ultimate stresses for various types of glass are given in Table 28.

Table 28 Ultimate Limit State Design Stresses for Glass Subjected to Wind Loading

(*Clause* 6.3.7)

Sl No.	Glass Type	Standard Nominal Thickness '*T*' mm	Ultimate Limit State Design Stress at Given Location	
			Away from Edge MPa	At Edge MPa
(1)	(2)	(3)	(4)	(5)
i)	Annealed	3	41.00	32.8
		4	38.99	31.19
		5	37.45	29.96
		6	36.2	28.96
		8	34.33	27.46
		10	32.8	26.24
		12	31.57	25.25
		15	30.15	24.12
		19	28.72	22.98
		25	26.96	21.57
ii)	Toughened	4	97.47	77.97
		5	93.61	74.97
		6	90.49	72.39
		8	85.82	68.65
		10	82.01	65.61
		12	78.91	63.13
		15	75.37	60.3
		19	71.81	57.45
		25	67.41	53.93
iii)	Heat strengthened	3	65.6	52.48
		4	62.38	49.9
		5	59.91	47.93
		6	57.91	46.33
		8	54.92	43.94
		10	52.48	41.99
		12	50.51	40.4
iv)	Annealed laminated	5	37.73	30.18
		6	36.43	29.14
		8	34.41	27.53
		10	32.87	26.3
		12	31.62	25.3
		16	29.75	23.8
		20	28.23	22.58
		24	26.99	21.59

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6.3.8 *Insulating Glass Units*

6.3.8.1 *Determining thickness of structural silicone*

The structural bite requirement is directly proportional to the wind load and the dimension of glass. Higher the wind load and larger the dimensions of the glass are, the greater the amount of structural bite required. The controlling variables which affect the structural bite requirement are the maximum short span dimension of glass and the design wind load which the structural glazing system shall be designed to accommodate.

a) *Structural bite calculation for wind load and glass dimension*

$$\text{Minimum structural bite} = \frac{\text{Glass short span dimension} \times \text{Wind load} \times 0.5}{\text{Maximum allowable design stress}}$$

NOTES

1 Glass' short span dimension (SSD) is the shorter of the two dimensions (in m) of the rectangular glass panel.

2 Wind load is the maximum wind pressure, in Pascal, for a return period of 10 years based on local regulations.

3 The maximum allowable design stress for type of the structural sealant is selected as per manufacturer's recommendations.

b) *Determination of thickness of structural silicone* — With a sealed IGU, there may be load sharing between the two lites (panes) of glass. If so and both panes are of the same thickness, the lateral load (P) is shared almost equally; thus the secondary seal bite is calculated as one half that of the structural sealant bite, but should meet the minimum requirement. If of unequal thickness, the load shared by each pane will vary, depending on the difference in thicknesses. Further details are to be obtained from the manufacturer.

c) *Structural bite calculation for dead load*

$$\text{Minimum bite (m)} = \frac{\text{Weight of glass (kg)}}{\text{Perimeter of the glass (m)} \times \text{Sealant dead load design strength (kg/m}^2\text{)}}$$

$$= \frac{\rho g TA}{Ps}$$

ρ = 2 500 kg/m^3 is the specific mass of flat glass corresponding to approximately of specific weight.

g = 9.81 m/s^2

s = Allowable design stress for dead load (DL) for selected sealant considered for design, Pa.

T = thickness of the bite, m.

P = perimeter (if the horizontal frame members do not support the glass or deflect under the dead load of the glass, consider 2 times of its height only).

A = area of glass panel, m^2.

6.3.8.2 *Maximum allowable span for glass and type*

Maximum allowable span is dependent on the thickness of the glass selected and type of glass used (for example annealed, toughened or heat strengthened glass). The maximum span is calculated in accordance with **6.1.9** (*see* Fig. 14 for details).

6.3.9 *Safety during installation*

Glass and the coating layer (if any) should not be, exposed to/in direct contact, with aggressive materials such as acid, solvent, cement mortar, etc.

The fixing system of the panel should, in no case, cause shear stresses in the panel, and particularly the bonding interface between the glass sheet and the frame, either under the effect of external forces or due to differential expansion of components.

The protection of glass panel by means of a polyethylene sheet is recommended and shall provide ventilation for the glass in order to prevent thermal breakage.

6.3.10 *Handling and Transportation*

6.3.10.1 *Transportation*

During the transportation of the flat glass (clear, tinted), coated glass (solar control and mirror), lacquered or

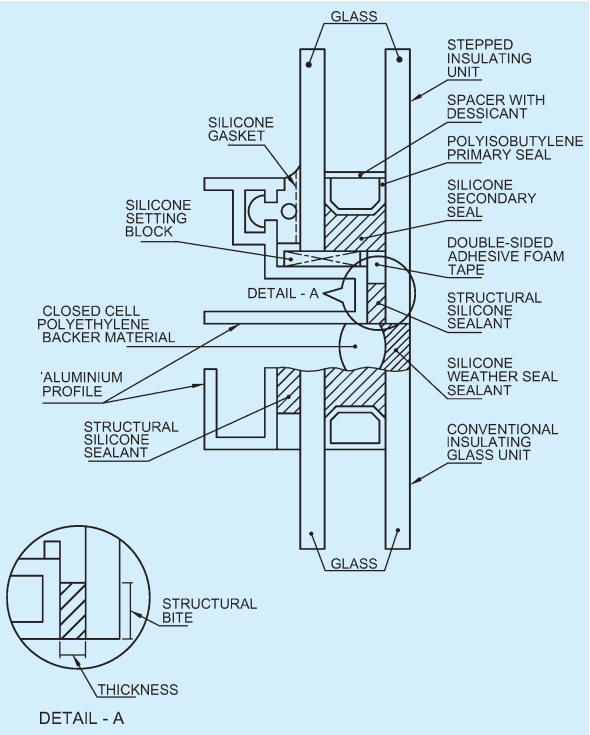


FIG. 14 TYPICAL STRUCTURAL GLAZING DETAIL

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painted glass the following methods (if other standard packaging specifications are not available) of storage, packing and interleaving shall be followed:

a) Flat glass shall be transported vertically;
b) Glass panes should not come into direct contact with each other by using appropriate interleaving such as powder or foam or paper. The lacquer opacified/ enamel coated/ screen printed glasses shall be separated by paper or foam; and
c) The packing and packing material shall be protected from water and if the glass is wrapped and sealed, the seal should remain closed until the product is used and precautions taken to not damage the packing while handling with a hoisting apparatus.

6.3.10.2 *Handling*

During the handling of the flat glass (clear, tinted), coated glass (solar control and mirror), lacquered or painted glass, the following guidelines shall be followed:

a) Glass shall be handled with dry, clean gloves, specifically after washing to prevent stain marks on them.
b) Care shall be taken to avoid contact or friction of the coating or the opacified/ enamel/screen printed side with any rough surface or hard objects.
c) A better practice is to handle glass with vacuum cups, and ensure that the vacuum cups and the glass are clean; and
d) It is recommended to keep it clean, if glass sheets are stored again before their processing or installation in the facade.

6.3.11 *Storage at Site*

To prevent staining, the storage area at site shall be,

a) a dry, well ventilated location at a sufficiently constant temperature;
b) protected from rain and running water;
c) protected from wide changes in temperature or humidity;
d) protected from alkaline material;
e) protected from direct contact of aggressive products such as corrosive vapors, acids, etc; and
f) glass panes are stored vertically on a soft surface such as wooden boards/battens.

6.3.12 *Storage after Cutting*

6.3.12.1 While stacking of coated glass/ mirror in the unpacked condition, the glass surface shall be facing towards the front (paint/coating backing towards the back).

6.3.12.2 Direct stacking of the mirror/coated glass one above the other should be prevented and suitable inter-leaving material as mentioned in **6.3.9** should be used between two glass panes.

6.3.12.3 The support material for glass storage should not have affinity towards moisture absorption.

6.4 Fire Safety

6.4.1 This Section covers the requirement and selection of fire safety glass for buildings. General fire safety provisions for buildings shall be in accordance with Part 4 'Fire and Life Safety' of the Code. It is important for any fire rated glass to provide sufficient amount of human impact safety feature even during fire or in general situations. The level of human impact safety of glass in buildings shall be in accordance with **7**. It is necessary that the fire rated system shall withstand the standard time-temperature curve during a fire test and shall give adequate time to the occupants for safe evacuation. This Section does not deal with the safety and security of people or goods in relation to risks of,

a) vandalism, riots, burglary or break in protection;
b) protection from explosion (terrorist attack);
c) natural disasters like earthquakes, cyclone, etc; and
d) plastic glazing, safety and security glazing, etc.

The requirements given here are minimum fire resistance requirements. In circumstances wherein the requirements of other Indian Standards exceed the requirements of this Section, in such cases the higher requirements shall become applicable.

6.4.2 *Glass for Fire Resistance*

6.4.2.1 Glazing system shall be so constructed, treated, or combined with other materials as to reduce loss of life or property during an event of fire, in comparison with ordinary sheet or flat glass, thereby preventing the passage of flame, hot gases, and smoke.

6.4.2.2 The following are the products in the scope of this Section that may be used for fire resistance in glazing provided they meet the relevant available standards:

a) Wired glass,
b) Annealed fire resistant glass (AFG),
c) Tempered fire resistant glass (TFG),
d) Intumescent laminated fire resistant glass (LFG), and
e) Double glazed fire resistant glass (DFG).

6.4.2.2.1 *Wired glass* (*Not recommended in doors except as vision panel and for window sizes not greater than in Table 29*)

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It is a type of glass into which a wire mesh is embedded during production. Wired glass has an impact resistance similar to that of annealed glass, but in case of breakage, the mesh retains the pieces of glass. Value addition such as tempering and lamination is not possible using wired glass.

6.4.2.2.2 *Annealed fire-resistant glass*

A single piece of fire resistant glass (borosilicate glass) that is tested for fire resistance for the required duration. These types of glasses can be used only in areas where human impact safety is not an issue, typically in areas like vision panels of doors, oven doors, etc. This type of glass has lower coefficient of expansion and cannot be tempered.

6.4.2.2.3 *Tempered fire-resistant glass*

A single piece of specially heat-treated or chemically treated glass that is tested for fire resistance for the required duration and which has a stress pattern such that the piece when fractured reduces to numerous granular fragments, with no large jagged edges. Additionally these glasses should have a impact resistance of highest classification.

6.4.2.2.4 *Intumescent laminated fire resistant glass*

Two or more pieces of glass held together by an interleaving layer or layers of materials and that as a complete system is tested for fire resistance. Fire side of the glass shall crack and break during the fire or under sufficient impact, but the pieces of glass tend to adhere to the inter-layered material and do not allow the fire to penetrate the last layer of glass.

6.4.2.2.5 *Double glazed fire resistant glass*

Fire resistant glass that is used as a double glazed unit has to be tested as a complete Double Glazed Unit (DGU) or other multiple glazed units as the case may be. Double glazed fire resistant glass can be a combination of intumescent laminated fire rated or tempered fire resistant glass. Fire resistant glass cannot be combined with another glass and used as a DGU unless the combined double glazed or multiple glazed units are also tested. Both the panes of the double glazed unit will need to satisfy the required impact safety as mentioned in **7**.

NOTE — It should be noted that use of any fire rated glass has to be installed in a tested system. Fire rated glass alone cannot provide the desired fire resistance since the fire resistance of a partition or a door assembly or any glazed building element is a function of the glass, frames, hardware, gaskets and fixings which forms the glazed system.

6.4.2.3 *Testing procedures*

Any fire rated glazed building element needs to be tested as per accepted standard [6-8(10)]. The fire rating criteria of any building element shall be in accordance with Part 4 'Fire and Life Safety' of the Code.

Table 29 Limiting Size of Wired Glass Panel

(*Clause* 6.4.2.2.1)

Sl No.	Opening Fire Protection Rating	Maximum Area	Maximum Height	Maximum Width
	min	m^2	m	m
(1)	(2)	(3)	(4)	(5)
i)	60 to 90	0.064 5	0.838	0.254
ii)	45	0.836	1.372	1.372
iii)	20	No limit	No limit	No limit

6.4.2.4 *Identification of glass used for fire resistance*

a) All glass used for resisting fire shall conform to and preferably certified against available Indian Standards.

b) Since a fire resistant glass is not easily distinguishable from normal types of glass, it is imperative that every fire rated glass panel/ unit should preferably have an indelible mark on all the panels/units of fire resistant glass showing the name of the manufacturer and the name of the product.

c) Rating of the glass panel may also be provided, although the rating of glazing system is of primary concern.

The glass used for fire resistance shall be in accordance with the requirements of Part 4 'Fire and Life Safety' of the Code.

6.4.3 *Precautions*

6.4.3.1 Fire resistant glass alone shall not be enough to protect occupants from fire. Glass is only one component of the complete system.

6.4.3.2 Fire test certificate report conducted for one application shall not be substituted for any other application. For example, a report for a partition shall not be used for a door application although the glass used and the fire ratings are the same. Approval in vertical orientation cannot be considered for acceptance in horizontal or inclined orientation.

6.4.3.3 The maximum glass size as mentioned in the test report should not be exceeded in practice with respect to the bigger linear dimension or area, unless otherwise validated by an assessment report issued by the testing lab. The aspect ratio may be modified provided that none of the linear sides has a dimension greater than that of the largest dimension of originally tested glass.

6.4.3.4 The dimensions of the profile need to be the same as that tested.

6.4.3.5 In case of any change in hardware they should be replaced following the guidelines laid down in the standard against which the test was conducted.

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6.4.3.6 Factors like edge cover, types of gaskets and type of fixtures also play a very vital role in achieving the fire performance of the building element. These have to be used and installed as per the test report/ available standards.

7 SAFETY RELATED TO HUMAN IMPACT

7.1 General

The provisions herein are limited to the behaviour of glass when subjected to various kinds of human impact, precautions against risk of fall and falling glass. Conditions outside of 'human impact' are not covered under the scope of this Section.

This Section does not assume that the glass used in accordance to this Section will not be broken under all human impact conditions, rather,

a) it will not be broken under most likely forms of human impact; and
b) even if it breaks, the likelihood of cutting or piercing injuries will be minimised by virtue of the protection given to the glass, or by the limited size, or by the fracture characteristics of the glass.

Further, this Section does not deal with the safety and security of people or goods in relation to risks of,

1) vandalism, riots, burglary or break in protection;
2) fire arm protection;
3) protection from explosion (terrorist attack);
4) natural disasters like earthquakes, cyclone, fire, etc; and
5) plastic glazing material, safety and security glazing, etc.

In circumstances wherein the requirements of any referred standard(s) exceeds the requirements of this Section, in such cases the higher requirement shall become applicable.

The use of this Section shall also be in conformity with all other relevant standards on fire safety, structural stability, natural disasters, safety and security, etc, in force.

7.2 Safety Glass

Glazing material that are constructed, treated, or combined with other materials so as to reduce, in comparison with ordinary sheet/ float/ plate glass, the likelihood of injury to persons by objects from exterior sources or by these safety glasses when they may be cracked or broken.

The following are the products in the scope of this Section that may be used in safety glazing provided they meet the conformity requirements of accepted standard [6-8(5)]. Safety glass according to this Section shall be of following types:

a) Toughened safety (Tempered) glass, and
b) Laminated safety glass.

7.2.1 All heat-treated/heat strengthened glasses, laminated, toughened, coated glasses and annealed glasses are not classified as safety glasses unless laminated to meet the requirement of tests specified in accepted standard [6-8(5)] for safety glass.

7.2.2 In atria where there is no impact loads above 10 m, suitable toughened glass is adequate. *See* **4.2.9,** in case of use of glass fins as a structural member.

7.3 Critical Location

Where any glazing is within 1.5 m above the floor level of a building, it is considered likely to be subjected to human impact and hence, shall comply with the human impact safety requirements of this Section. Safety glazing should also be used,

a) where there is danger of falling infill glass material(s) from overhead glazing;
b) the danger of falling due to a change in floor level; and
c) in case of balustrades, stairs and floors.

Based on typical accidents in glazed buildings, certain locations in buildings are found to be more vulnerable to human impact than others. Some of such critical locations are shown in Fig. 15, where necessary precautions given below should be followed:

1) In-and-around doors, low windows;
2) Door side panels;
3) Panels mistaken for a doorway or opening;

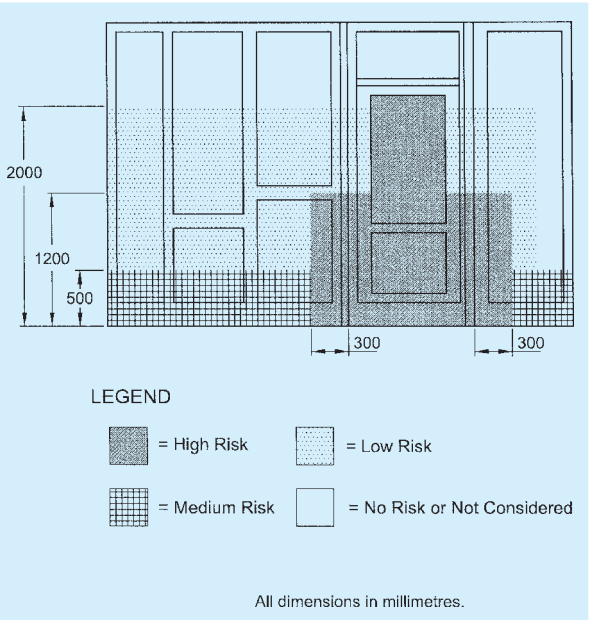


FIG. 15 CRITICAL LOCATIONS

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4) Panels at low levels in walls and partitions;
5) Bathrooms;
6) Building associated with special activities, for example, gymnasia, enclosed swimming pools, etc;
7) Schools and child care facilities; and
8) Nursing homes and care facilities for the aged and infirmed.

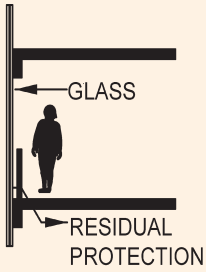
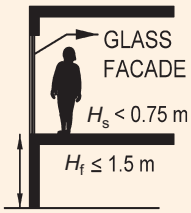
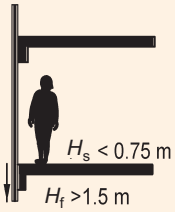
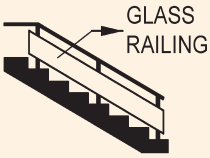
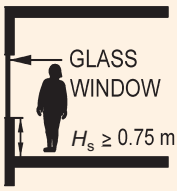
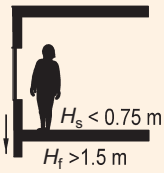
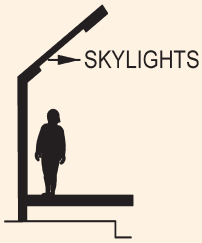
Suitable precautions should be taken to reduce the injuries that can result from glass breakage by,

i) selecting glass of a suitable type, thickness and size;
ii) enhancing a person's awareness of presence of glass by making glass visible (manifestation of glass); and
iii) minimizing manual handling of large pieces of glass during installation.

Based on the above, a comprehensive Table 30 is provided for information.

Table 30 Type of Glass Suggested for Use at Different Critical Locations/Cases in Buildings

(*Clause* 7.3)

CASE 1 **Vertical Walls with Residual Protection or $H_s \geq 0.75$ (not Likely to be Subjected to Human Impact)** (1)	CASE 2 **Vertical Walls H_s<0.75m and $H_f \leq 1.5$m (Human Impact but no Risk of Fall)** (2)	CASE 3 **Vertical Walls H_s<0.75m and H_f>1.5m (Human Impact and Risk of Fall)** (3)	CASE 4 **Horizontal or Sloped Glazing Glass (Risk of Fall)** (4)	CASE 5 **Glass Acting as a Balustrade/ Railing (Human Impact and Risk of Fall)** (5)
				
				
Type of glass: Any glass[1)]	Safety glass	Safety glass[2)]	Laminated safety glass	Laminated safety glass
Examples: Residual protection is the safeguard provided to avoid the impact of human being on glass. It is provided on the side of the glass where there are chances of human impact. It can be achieved by providing protection in the form of a sill structure or transom, chair rail or grill work inside	a) Doors b) Side panels c) Curtain walls d) Glazed area e) Doors in bathroom 1) Fully framed 2) Partially framed 3) Frameless f) Façade g) Windows h) Internal partitions and doors j) External facade and doors on ground floor, above floor with terrace outside.	a) Curtain walls b) Façade c) Spandrels d) High activity area e) High risk area f) To avoid risk	a) Roof (Skylights) b) Ceilings c) Bus shelters d) Floors e) Stairs f) Sloped facade	a) Balustrades b) Balcony c) Railings

[1)] Safety glass is not mandatory.
[2)] Laminated float glass is preferred.

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Table 30 — (*Concluded*)

NOTES

1 'H_f' corresponds to height of fall of human being or glass in case of change in level and 'H_s' corresponds to the sill height with reference to floor height.

2 In case of mirror glazing, it should conform to the requirements of other safety glasses unless it is fully backed by a solid material.

3 In Case 2 and Case 3, if the smaller dimension of the pane is 250 mm or less and its area is 0.5 m^2 or less, glass other than safety glass may be used, provided that its nominal thickness is not less than 6 mm (applicable to vertical glazing).

4 Toughened or laminated safety glass should meet respective test requirements as given in respective Indian Standard specifications.

5 The effective toughened safety glass thickness and/or laminated safety glass configuration shall be determined case by case with regard to,

a) other solicitations (wind load, snow load, dead load, and human load);

b) the overall dimension (length, width of surface);

c) the aspect ratio of the glass; and

d) the glazing fixing type (framing, bolted system, structural system, etc).

6 Precautions against chances of injuries due to broken glass falling on people include:

a) Broken annealed glass falling on people can cause grievous or even fatal injuries; hence it is recommended to use safety glass in locations other than defined in case 1 where the risk of people getting hurt by falling glass is high.

b) Toughened safety (tempered) glass has a safe breakage pattern, as it breaks and disintegrates into small and relatively harmless particles. However, thick toughened glass particles may stay interlocked, and fall as lumps of these multiple particles and can cause a minor or medium injury mainly due to the weight of the cluster.

c) Laminated safety glass shall generally not fall out of fixing. However, where laminated glass with both glasses toughened, used for horizontal or sloped glazing, in case of failure of both toughened glasses, it may crumble as a blanket and fall out of fixing. This factor needs to be considered while designing horizontal and sloped glazing. Further, when the slope is acute, inner pane facing the floor should be laminated; and when the slope is obtuse, the outer pane facing the ground / floor should be laminated and all obtuse angle sloped glazing shall be continuously capped for safety reasons.

d) Any broken glass in any glazing should be removed immediately on breakage.

e) Strength of the glazing system should be such that it has the ability to hold glass in place and prevent it from falling out as a whole.

f) For over-head applications like skylights, canopies for the safety of maintenance workers and people underneath, the broken laminated glass shall be capable of sustaining a load of 100 kg for a minimum duration 30 min.

7 In case of external laminated glass facades, openable portions have to be left at regular distances for fire fighting and smoke exhaust. This portion should be of toughened (safety tempered) glass and clearly indicated by suitable visible marking. *See also* Part 4 'Fire and Life Safety' of the Code.

8 If insulating glass unit (IGU) is used in situations mentioned in this Section, then one of the following shall apply:

a) If IGU is installed in areas subjected to human impact on either side, then both the panes of the unit shall meet the requirements of this Section.

b) In situations where access is restricted to one side of the unit, then only the accessible side should meet the requirements of this Section.

9 Enhance person's awareness of presence of glass by making visible manifestation.

10 For specific provisions relating to smoke evacuation, Part 4 'Fire and Life Safety' of the Code may be referred.

7.4 Manifestation (Making Glass Visible)

7.4.1 Presence of glass in a door, side panel or a panel capable of being mistaken for a doorway or opening, which is not made apparent by transoms, colonial bars, door frames, large door handles, stall or other components of glazing system, should be made apparent by some form of manifestation. Decorative treatment, such as being opaque, or patterned are the other common manifestation options.

The manifestation employed should be of a sufficient size to make it immediately obvious. The manifestation should preferably be permanent, for example etching of the glazing; alternatively, if applied materials are used, they should be durable and not easily removed.

Manifestation shall be in the form of an opaque band in accordance with **B-5.3.13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

7.4.2 A band or marking may not be required, where any one of the following applies:

a) Width of the glass is not greater than 500 mm at any part (this applies to overall panel assembly — not individual glass pieces as in faceted glazing).

b) Glass is provided with at least one fixed glazing bar, firmly attached to the styles to locate and protect each face of the glass. At least one transom (glazing bar) shall be located with its upper edge not less than 500 mm and its bottom edge not more than 1 000 mm above the floor level. The glazing bar shall have a face of width 40 ± 3 mm; and

c) Alternatively, patterns may be used as an acceptable form of marking provided it meets the other criteria in this Section.

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7.5 Identification

All safety glasses shall be procured from certified manufacturers and the product shall conform to relevant Indian Standards and shall carry all relevant information through the approved label/permanent (indelible) markings on the glass surface.

7.6 Test Requirements

7.6.1 Safety glass shall conform to all the requirements when tested as per the test methods mentioned in the relevant Indian Standards or as listed in Table 31.

7.6.2 *Mechanical Strength*

The required mechanical strength values (*see* Table 32) apply to quasi-static loading over a short time like wind loading relate to 5 percent probability of breakage at the lower limit and 95 percent confidence intervals.

Table 31 Test Requirement

(*Clause* 7.6.1)

Sl No.	Requirements	Laminated Safety Glass	Toughened Safety Glass	Test Requirement as per
(1)	(2)	(3)	(4)	(5)
i)	Impact/ Resistance to shock	YES	YES	Accepted Standard [6-8(5)]
ii)	Fragmentation test	—	YES	
iii)	Warp test	—	YES	
iv)	Boil test	YES	—	
v)	Fracture and Adhesion test	YES	—	
vi)	Light stability test	YES	—	
vii)	UV light test	YES (for glass used in the exterior portions and subject to natural light)	—	
viii)	Shot bag impact test	YES	YES	*see* Annex E

NOTES

1 Bake test (high temperature) and humidity test may also be carried out as an option to determine the characteristics of laminated safety glass.

2 Surface compression test, four point bending test and waviness may also be carried out to determine such characteristics.

Table 32 Minimum Mechanical Strength Required for Fully Toughened Glass

(*Clause* 7.6.2)

Sl No.	Type of Glass	Mechanical Strength
		N/mm^2
(1)	(2)	(3)
i)	Float (Clear/ Tinted/ Coated/ Mirror)	120
ii)	Enameled flat (Based on enamelled surface in tension)	75
iii)	Patterned glass	90

If the glass satisfy the relevant impact test performance requirements (or fragmentation test for toughened glass), in addition to all other appropriate tests mentioned in available Indian Standards or as listed in Table 32, these materials can be classified as safety glass.

8 GLAZING SYSTEM

8.1 The provisions relating to glazing system are covered hereunder. The details and procedure for selection, design, fabrication, installation, testing and maintenance of glazing system and its materials, considering the performance factors, including structural, seismic, acoustic insulation, fire resistance and energy efficiency are covered here under.

8.2 Design and Selection

This performance criteria and parameters for the design and selection of a glazing system and the components involved, along with its associated materials used in buildings are listed below.

8.2.1 *Performance Criteria*

The performance criteria to be satisfied by the glazing system are:

a) Structural stability and safety,
b) Energy efficiency (performance),
c) Visual comfort (light transmittance and reflection),
d) Fire protection (ability to resist/withstand fire),
e) Sound insulation,
f) Air infiltration (wind pressure, stack pressure, fan pressure), and
g) Water penetration (static, dynamic and cyclic pressures).

See Annex F for general guidance on the above.

8.2.2 *Design Parameters*

To achieve the performance criteria, care should be taken so that components in the system are selected and designed for the following parameters, such that the necessary performance criteria is met both individually and as a system

a) Loading,
b) Deflections and allowable stress,
c) Movements,
d) Impact resistance,
e) Acoustic and sound insulation, and
f) Energy performance.

8.2.2.1 *Loading*

Wind load, live load, dead load, load combinations as per good practice [6-8(11)], seismic load as per

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good practice [6-8(8)], and other consequential loading may be considered.

8.2.2.2 *Deflections and allowable stress*

The deflection of framing members, members supporting brittle materials, metal panels, glass panels and the allowable stress shall be in accordance with **6.3.6.2**. The allowable stress shall be in accordance with [6-8(11)].

8.2.2.3 *Movements*

The glazing system (and its framing elements) shall be able to accommodate the movements caused due to wind loads, seismic loads, live loads, dead load deflection, thermal expansion and contraction of members, and slab deflection, etc.

8.2.2.4 *Impact resistance*

Any glazing (in the glazing system) within 1 500 mm above the floor level of a building is considered likely to be subjected to human impact and hence, shall comply with the human impact safety requirements given in **7**.

8.2.2.5 *Acoustics and sound insulation*

The recommendations on acoustics and sound insulation given in Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code shall be applicable.

8.2.2.6 *Energy performance*

The recommendations on the principal energy performance characteristics of the glazing system shall meet the provisions given in **5**.

The primary characteristics required in general are reducing thermal losses and solar gains. For additional reference to visible light transmittance (VLT), solar heat gain coefficient (SHGC) and thermal transmittance (U factor) features, Part 11 'Approach to Sustainability' of the Code shall be referred.

8.2.3 *Types of Structural Frame Materials*

For the framed/semi-framed systems, materials such as aluminium, stainless steel, uPVC and timber, which are commonly employed are listed hereunder.

8.2.3.1 *Aluminium alloy*

Extruded aluminium alloy used for structural framing members, shall be fabricated from the most appropriate grade of alloy complying with the relevant standard(s). The thickness of the aluminium sections should be in accordance with structural and hardware fastening requirements and shall be capable enough to meet the design requirements and satisfy the performance requirements.

Such extrusions in framing members and trims shall preferably be extruded aluminium grade 6063-T5, 6063-T6, 6060-T66, similar or stronger. Where 6063-T5 is to be used in shaped structures, supporting structural calculations particularly the stress criteria be ensured. Extrusion alloy 6061 or 6105 are commonly used for higher strength. Aluminium brackets shall be extruded aluminium grade 6061-T6 or approved equivalent. All aluminium alloys used as extruded rods/ bars, tubes and profiles shall be compliant with accepted standard [6-8(12)].

Sheets and plates may be obtained from the following alloys of aluminium which also lists their primary characteristics:

a) 1100 — A low strength alloy suitable for applications requiring a high degree of formability.
b) 1135 — Brighter finish when anodized.
c) 3003 — General purpose sheet alloy with fair mechanical properties and excellent formability, susceptible to structural streaking when anodized (noticeable in large flat areas).
d) 5005 — Excellent workability, weldability and corrosion resistance.
e) 5052 — Slightly better mechanical properties and excellent corrosion resistance and weldability.

Other alloys can be used provided that they meet the required physical properties and the specified performance requirements.

8.2.3.2 *Stainless steel*

Mullions, panels, fascia, column covers, windows, doors, trim, roofing, gutters, flashing, hardware and other items where minimum maintenance is anticipated, shall be of austenitic stainless steels of Type 301, 302 and 304 complying with accepted standard [6-8(13)] and employed for their mechanical properties as they are highly corrosion resistant for all normal exposures.

For interior decorative applications, where regular maintenance will be provided, Type 430 may be used as it has lesser corrosion resistance properties. For external applications like in coastal regions where maximum resistance to corrosion is required, stainless steel shall be of Type 316. Particular attention shall be paid to the direction of the rolling grain on self-finished stainless steel components where the finish is aesthetically important. All screws, nuts, bolts, washers, self-tapping screws and other fastenings, including those used for the hardware, shall be of stainless steel Type 304, 316, 430 complying with accepted standard [6-8(13)]. Type 316 based steel fasteners, etc, shall be preferable when they are used in coastal regions on the exposed side.

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8.2.3.3 *uPVC*

A relatively flexible material, PVC which is internally reinforced with steel or aluminium to give it the required strength and stiffness may also be used. The inherent ability to make a variety of profiles, easier maintenance, corrosion resistance ability and heat resistance when used may be considered when choosing uPVC sections.

8.2.3.4 *Timber*

Timber frames are relatively stiff and particularly treated timber combined with good design and workmanship give an acceptable life. They are adopted for their inherent thermal insulation property, light weight and improved sound insulation. Tenderness to absorb moisture, if not carefully treated prior to use can lead to possible rotting or even warping resulting in air and water infiltration and regular painting and maintenance are the factors to be considered while choosing timber as the framing material.

8.2.4 *Surface Finishes*

The commonly employed surface finishes are listed hereunder:

a) *Aluminium frame* — The main types of aluminium frame coatings are as follows:
   1) Anodized finish,
   2) Powder paint finish, and
   3) PVDF coating.

b) *Steel frames* — Surface finish on stainless steel frames plays a major role in its resistance to corrosion and hence it is an important design aspect to be clearly specified. The types of surface finishes listed here shall be in accordance with applicable relevant standards:
   1) Mill,
   2) Ground,
   3) Brushed,
   4) Polished,
   5) Bead blasted,
   6) Electro polished,
   7) Coloured, and
   8) Patterned.

   Electro polishing of steel frames shall be done in accordance with available standards.

c) *Timber frames* — The function of finishes on timber is two-fold, first to improve the durability of the frame and second to add to the aesthetics. Unfinished, unprotected timber weathers as a result of gradual changes to its physio-chemical structure brought about by temperature and moisture content variations. The finishes may be of the following types:
   1) *Conventional opaque systems* — Water and solvent borne,
   2) *Natural finishes* — Semi-transparent and opaque, and
   3) Water repellent preservatives, wood primers, undercoats and finishing coats (gloss, semi-gloss, flat and low sheen).

Based on the application, the appropriate type of finish shall be chosen.

8.2.5 *Types of Anchorages*

Anchorages are used primarily to join the mullions and transoms to the beam or slab through an appropriate bracket. The two basic types of anchors commonly used are:

a) *Stud anchors* — Used where the mullions have to be fixed to the face of the beam or slab.

b) *Flush anchors* — Used where the mullions have their start point or termination at a slab/ beam or skirting.

Factors influencing the selection of anchors and to ensure proper performance of the anchor during its service life are:

1) *Diameter* — The following parameters shall be calculated for the selection of the anchor diameter:
   i) Dead load acting on the anchor,
   ii) Live load incident to the anchor (wind load- tensile or shear), and
   iii) Weight of bracket, aluminium channels and other associated components.
2) *Length* — The length of the anchor is primarily based on the thickness of the glazing components which have to be fastened to the base material. Insufficient length shall lead to pull out failure.
3) *Material* — Stainless steel and galvanized iron are the two main types of materials used in the manufacturing of anchors.
4) *Coating* — The following type of coating shall be used based on the specific environmental condition met with:

Environmental Condition	*Coating to be Used*
Particular influence of moisture	Zinc plated
Occasional exposure to condensation and in coastal areas/slightly corrosive	Hot-dip galvanized
Heavy condensation/ corrosion and in coastal areas	Stainless steel

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5) *Load direction* — Based on the orientation of the anchor, they are incident to shear loading, tensile loading and combined loading of force and hence the proper diameter and depth of anchorage shall be selected.
6) *Base material* — The material characteristic of the base material also plays a major role in avoiding failure in the anchorage. The material shall be of suitable grade, have minimum thickness, shall be properly cured and have the necessary compressive stress.
7) *Anchor spacing and edge distance* — Anchor spacing is the minimum distance between two anchor centre lines without an influence on the tensile or shear failure load of either anchor. The load bearing capacity of an anchor is influenced by an adjacent anchor and thus the minimum anchor spacing specified by the manufacturer shall be adhered. Due to reduced material volume, a minimum edge distance shall be maintained to prevent the edge from breaking away prematurely when the anchor is installed, and also to achieve the full load bearing capacity of the anchor.
8) *Embedment depth* — A critical factor in determining load capacity. Anchors installed less than minimum depth will stress the base material above its limits and may cause failure during installation or expansion of the anchor.
9) *Environmental condition* — Environmental conditions like temperature, humidity, salinity, etc, will affect the performance of the anchors and may lead to premature failure. Hence, careful selection of the material and coating should be done when selecting anchors which are to be installed in location subjected to adverse environmental impact such as coastal region.

8.2.6 *Hardware Materials*

The material, geometry and finish of all the hardware materials shall be as per the requirement and should not affect the performance of the glazing system. All materials and finishes shall be as per relevant Indian Standards and tested before installing into the system in accordance to relevant Indian Standards.

8.3 Fabrication

8.3.1 *Factory*

The manufacturer shall ensure that proper internal control, documentation including records of test results performed be maintained about the production. The above shall enable quality assurance of the materials and process involved.

8.3.2 *Handling of Materials on Site*

The following lists among others, the important features to be considered:

a) All materials shall be handled by workers who have been provided appropriate training and awareness on the techniques to handle the materials and shall operate with a full set of PPE (Personal Protection Equipment).
b) Large glass panes or panels shall be handled with vacuum cups. Care shall be taken to ensure that the vacuum cups and the glass are perfectly clean.
c) All materials shall be handled with dry, clean, gloves and shall not come in contact with rough surfaces or hard objects, in order to avoid scratches, dents or breakage.
d) Labels and marking shall not be put on the coated side of glass, and any relative movement of the coating with the next glass pane shall be avoided.

8.3.3 *Transportation and Logistics*

While transporting materials from vendor to factory, within the factory, to and from surface finish coater, finished goods to site and movement of finished goods at site care should be taken to ensure the following:

a) Finished surface is adequately protected with a protective tape which can be easily removed without leaving any residue.

   NOTE — Most protective tapes either peel off or adhere to the substrate when exposed to UV for more than three months.
b) Suitable blocking, edge protection, crating, etc, are done to avoid dents and gouges.
c) Hardware is secured and not damaged in transit.
d) Material is adequately secured in the truck/ container especially when the goods are sent as loose container load (LCL) or partial shipment avoiding any damages.
e) Lifting equipment's shall be adequately engineered for capacity, safety and balance (especially when units are very heavy).
f) Suitable 'A' frames or customized transport support shall be used.
g) Recommendations from glass supplier towards the protective film shall be followed.

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8.4 Installation

8.4.1 *Site Survey of Building*

a) Measuring the elevation width and height, ascertaining the grid pattern including position of vision and spandrel frames, the levels of concrete and masonry in x, y and z axis, checking and recording the presence of any difference in plumbness of jambs, beam and column fascia and steel structures are the key activities necessary in deciding the final fabrication measurements.

b) Levelling (setting x-axis, common sill level for all elevation and adjustment in bracket depth) and surveying (measuring x-axis distance and setting the width and height for all elevation) are involved in the process of site survey of building. The key processes are listed below:

   1) *Processes in levelling:*
      i) The sill bottom level of all the glazing elevations is to be checked by fixing a common benchmark and the reading should be recorded at minimum one metre distance.
      ii) After taking the reading we can locate the highest and lowest point and then we can decide upon common level of all glazing elevations.
      iii) The benchmark shall be a permanent mark, hence we shall be using oil paint mark in form of upside triangle
      iv) The levels of all beam bottoms and up stand, if any, coming across the glazing elevations at all floors are to be measured.
      v) Any other point that can affect fabrication drawings to be noted.
   2) *Processes in surveying:*
      i) The total width shall be measured using a theodolite and recorded at one plane.
      ii) It shall be cross checked by measuring existing column to column (at other plan) distance.
      iii) The two end point RCC shall be measured for plumbness. If any difference is observed, adjust the reading of first two steps.

8.4.2 *Installation Tolerance*

The effect of installation tolerance is vital for any type of glazed system to perform as per the requirement and the specified performance. For structural glazing, the installation tolerances shall be strictly followed in order to assure that the sealant joint opening meets the specified minimum and maximum joint opening dimensions.

8.4.3 *Good Installation Practices*

The good practices involved in installing a glazing system have been categorized hereunder.

8.4.3.1 *Anchorage*

a) Anchor installation shall be carried out by appropriately qualified personnel and under the supervision of the person responsible for technical matters of the site.

b) Installation shall be in accordance with the manufacturer's specifications and drawings using the tools indicated in the technical documents.

c) Use of the anchor shall be only as per that supplied by the manufacturer and without changing/exchanging the components of an anchor.

d) Checks before placing the anchor to ensure that the strength class of the concrete in which the anchor is to be placed is in the range given and is not lower than that of the concrete to which the characteristic loads apply.

e) Edge distance and spacing shall be not less than the specified values without minus tolerances.

8.4.3.2 *Sub-structures*

a) In order to avoid physical contact with the panels and frames during sealant application, which might cause adhesion loss, use of powder-free latex gloves shall be used, during panel placement.

b) Proper alignment and setting out of the sub-frame is critical in ensuring the ease of operation of the window/door.

c) Anchor/bolt heads and joints between external wall and sub-frame should be sealed with sealant for effective water tightness.

d) Prior to fixing the main frame, the sub-frame should be checked for any physical damages and any damaged sub-frame should be repaired or replaced.

e) Setting out of the sub-frame should also be verified before the installation of the main frame.

f) Dust and debris accumulated in the sub-frame could affect the alignment and fixing of the main frame and may also cause blockage to the weep holes, resulting in overflow of any

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incidental water into the interior, and so it shall be properly cleaned before assembly.

8.4.3.3 *Sealants*

a) All components (glass and framing member such as aluminium) receiving the structural glazing silicone sealant shall be wiped thoroughly with a clean cloth dampened with a cleaner recommended by the manufacturer, and immediately followed by a dry wipe, using clean cloth.

b) All surfaces once cleaned/primed shall be handled carefully so as not to contaminate the surface.

c) The substrates shall be kept free from moisture, condensation, dust and other impurities.

d) An application temperature range of +10°C to +40°C (or as specified by the manufacturer) is recommended and shall be adhered to.

e) Substrate temperatures in excess of +50°C will adversely affect curing process and also the adhesion of the sealant to the substrate.

f) Minimal time shall be taken for cleaning, placement and sealing of panels since environment conditions at job site cannot be controlled.

g) Temporary fasteners may be used to keep the joints stable during the curing process of the sealants and they shall be removed only after complete cure and adhesion has been achieved by the sealant.

h) Tooling of the sealant shall be done with light pressure, within 5 to 10 min, before a skin forms on the sealant.

j) Avoid the use of wet tooling aids such as soaps and solvents. Dry tooling is appropriate.

k) Masking tape shall be used in ensuring neat straight-line application and avoiding smears.

m) The masking tape shall be removed immediately after tooling has taken place and before the sealant starts to cure.

n) The general recommendation for the application of structural sealant required for a 4 sided system, bonding the glass to the aluminium frame should be done in a factory atmosphere.

p) Complete quality control process with respect to surface preparation, storage, sealant application and quality check are to be implemented in the factory with full traceability. In most cases sealant manufacturers have quality requirements and documentation process related to warranties which need to be followed.

q) *In-situ* application may be required for 2 sided system, retrofit, repair and small areas in a façade. Sealant manufacturers should be contacted to get job specific recommendation on sealant application for *in-situ* application.

8.4.3.4 *Installation*

The framing and fixing system of the panel should, in no case, cause shear stresses in the panel, either under the impact of external forces or due to differential expansion of components. The following shall be taken care of:

a) All framing shall be checked prior to glazing to assure that the opening is square, plumb and secure so that the uniform sealant bite, face and edge clearances are maintained.

b) Inspect all butt and mitre joints and if found open, they shall be sealed using sealants prior to glazing.

c) Minimum edge clearances shall be maintained between glass and sash, as mentioned by the manufacturer.

d) Setting blocks shall be used to support the glass unit which shall prevent the addition of stress applied on the structural tensile bead due to the self-weight of glass.

e) Adhesion tests shall be performed by the contractor/agency at the beginning and during the installation process.

8.5 Testing

8.5.1 *Laboratory Testing*

The glazing system is subjected to various adverse environmental conditions and impacts during its service life. A properly designed and installed glazing system may be able to resist any major damage to its stability or performance under any condition within its effective life time. The glazing system and its component materials shall be tested for the required parameters and performance.

8.5.2 *Field/On-Site Testing*

Testing of the glazing system as a whole unit in site (the field) subject to loads and effects such as water infiltration, wind (air) infiltration, acoustic insulation, fire insulation, thermal performance, structural performance, etc, may be carried out for specific cases as mutually agreed to between the parties concerned, to ensure homogeneity.

The following performance tests are to be conducted on structural glazing system, if area of structural glazing exceeds 2 500 m^2 from the certified laboratories, as per the specialist literature:

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a) Performance Laboratory Test for Air Leakage Test (–50 Pa to –300 Pa) and (+50 Pa to +300 Pa) for a range of testing limit 1 to 200 mVh.

b) Static Water Penetration Test (50 Pa to 1 500 Pa) for a range up to 2 000 ml.

c) Dynamic Water Penetration (50 Pa to 1 500 Pa) for a range up to 2 000 ml.

d) Structural Performance Deflection and deformation by static air pressure test (1.5 times design wind pressure without any failure) for a range up to 50 mm.

e) Seismic Movement Test (up to 30 mm).

8.6 Maintenance and Durability

8.6.1 *Maintenance Infrastructure*

Regular maintenance of the building facades plays an important role in the holistic building maintenance. The access systems shall provide sufficient approach which enables all parts of the façade to be reached safely for the purpose of cleaning, inspection and maintenance and also offer high work efficiency to the maintenance workers, without also hindering the aesthetics of the building. The provisions of Part 12 'Asset and Facility Management' of the Code may also be referred.

The means of access and supporting infrastructure should be established at the design stage so that the loads are properly envisaged for.

Façade access requirements come in many varieties and may present challenges. Powered access cradles for facade access, cleaning of the glass directly from the ground, hoists based access and window based cleaning/access from inside the building are some of the common techniques employed. Recently, access techniques using ropes have been used for facade access and are generally considered to be safe, provided the workers have been trained and are using all the correct safety equipment and precautions.

In nearly all cases, façade access and maintenance requires a worker to be exposed to working at height with its associated risks. Therefore, use of height safety equipment, anchor point attachments (like the fall restraint or fall arrest system) and those given below should be employed:

a) *Roof guardrails* — When choosing equipment for working at heights, collective protection like roof guardrails may also be considered. Roof guardrails ensure that all users are protected from falling without the need for specialised training and/or equipment. They also eliminate the need for rescue procedures to be put in place. Roof guardrails are available in fixed, free standing, straight upright, cranked upright or collapsible.

b) *Fall arrest systems and fall prevention cable systems* — Fall arrest systems allow safe access to roof areas for maintenance and inspections to be carried out by workers. Users of the fall arrest systems require wearing of full body harnesses and attachment to the cable/fall arrest system via a lanyard (rope) and shuttle device which allows them to walk the full length of the system without having to detach from the system. Fall arrest systems shall be of types horizontal, overhead, sloping and vertical lifeline type and shall comply to the relevant/available standards.

Depending on the project requirement, the maintenance infrastructure shall consist of the following systems:

1) *Roof trolley/Cradles* — Fixed or adjustable jib, telescopic jib, cradle with pantograph.

2) *Rail systems* — Hooked, anchored, turntables, rotary plates.

3) *Other systems* — Additional winches for glass replacement, parking positions/lifting platforms.

8.6.2 *Maintenance of Materials*

The glazing system and the associated materials require a suitable degree of maintenance, if they are to fulfill their intended working life. Early detection of defects can mitigate expensive repairs or replacement later. The degree of inspection and maintenance required will depend on the type of glazing system and its intended design life.

8.6.3 *Common Practices for Maintenance*

The common principle maintenance practices to be followed shall be as given below:

a) When using the cleaning equipment or carrying out maintenance on the exterior of the building, the risk to personnel and property, prior to the start of work shall be assessed at first.

b) Where applicable, qualified personnel to carry out routine or complex maintenance shall be employed.

c) Power supplies may need to be isolated prior to maintaining electrically operated equipment such as motors to opening vents, roller blinds to atrium roof and main entrance pass doors.

d) While accessing the external façade, fall arrest systems shall always be used even while working in the house cradle.

e) Manufacturer's instructions shall be followed when using cleaning fluids and shall not be mixed up with drinking water or the like. To

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deal with instances of contact with eyes, skin, etc, necessary eyewash arrangement and first aid equipment shall be at place.

f) Loosened fixing or bolts shall be identified, reported and attended to immediately, and shall never be tampered with.

g) Unauthorized loosening or removing of the fixings may prove dangerous and can result in structural damage and displacement of the system.

h) When lifting equipment such as hoists and sucker machines are used, it shall be ensured that they are capable of lifting the loads required. Further, the recommended safe working loads of any equipment shall never be exceeded.

j) When handling any insulation of firebreak material, ensure gloves, goggles and masks are worn as fibrous materials (if any) may cause irritation.

k) Prior to the commencement of work involving glues or sealants (particularly in confined spaces), manufacturer's advice/special instructions shall be adhered to before exposing the product to air. Such materials shall preferably be worked with, in a well-ventilated area.

m) In the case of coated glass, the following precautions shall particularly be adhered to:

1) Any scratching will penetrate the surface of the coating and cannot be repaired.

2) Any excessive mechanical treatment might remove the coating in localised areas.

3) Avoid all contact with metal objects.

4) Avoid all chemicals that may attack the surface and damage it irreparably.

ANNEX A

(*Clause* 5.1.1)

MINIMUM PERFORMANCE REQUIREMENT OF GLAZING FOR EXTERIORS

A-1 The panel size design of the exterior glass for the building is done in accordance with this Section considering the effect due to wind load, other imposed load, seismic design. The type of glazing to be installed is determined considering human safety in **7**.

In the determination of the energy and thermal performance of the glazing, the three compliance approaches prescriptive in nature, defines the minimum glazing/glazing system requirement to be met.

The prescriptive values are specified with respect to the geographic climatic zone and glazing area of the building.

A-2 BUILDING FENESTRATIONS

The fenestration shall comply with the maximum glazing area weighted on *U*-value and solar factor as given in Table 34.

The window wall ratio (WWR) is defined by the total fenestration area to the total gross area of the building envelope which is limited to 70 percent. The corresponding minimum visible light transmission is given below. For fenestration area greater than 70 percent, *see* other specialist literature.

WWR	*Minimum Visible Light Transmission* Percent
0 – 0.3	27
0.31 – 0.4	20
0.41 – 0.5	16
0.51 – 0.6	13
0.61 – 0.7	11

Table 34 *U*-Value Requirement for Glazing System

(*Clause* A-2)

Sl No.	Climate	Maximum *U*-Value $W/m^2 K$	Maximum SHGC	
			WWR ≤ 40 Percent	40 Percent < WWR ≤ 60 Percent
(1)	(2)	(3)	(4)	(5)
i)	Composite	3.30	0.25	0.20
ii)	Hot and dry	3.30	0.25	0.20
iii)	Warm and humid	3.30	0.25	0.20
iv)	Moderate	6.90	0.40	0.30
v)	Cold	3.30	0.51	0.51

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A-3 WEATHER PERFORMANCE

Air infiltration from the fix litres shall be permitted within 1.5 $m^3/h.m^2$ and from operable sash 2 $m^3/h.m$.

Water should be contained in the gutter and drained back to the exterior. Any uncontrolled water in excess of 15 ml or more on the top surface of any exposed interior shall be considered as leakage.

ANNEX B

[*Clause* 5.1.2.4.2(c)]

TEST REQUIREMENTS FOR COATED GLASS

B-1 The coated glass that is used for the exterior building of commercial and non-commercial (residential building) should meet the test requirement listed in this Annex.

B-2 MEASUREMENTS OF PERFORMANCE

The performance factors and spectral details of the coated glass shall be determined using standard accepted spectrophotometer equipment. The actual size shall be dependent on the type of equipment being used for the measurements. The transmittance of the measurement sample shall be measured with radiation of normal incidence at the following wavelengths:

a) 550 nm (representative wavelength for light and solar transmittance); and
b) 900 nm (representative wavelength for solar transmittance).

For glass claiming to have a low emissivity coating, a measurement of the reflectance shall be made at 8 µm using radiation of nearly normal incidence.

B-3 CONDENSATION RESISTANCE TEST

B-3.1 This test consists of subjecting the coated glass to a water saturated atmosphere at constant temperature. The samples have condensation continually forming on them and it is this condensation that may cause surface degradation.

B-3.2 Test apparatus should have a provision of four test pieces and the materials used for the inner walls shall be corrosion-resistant and shall not affect the test pieces.

B-3.3 Procedure

a) The water tank shall be filled with demineralized water, having conductivity lower than 30 µS/cm and a *p*H higher than 5. The internal temperature of the cabinet shall be controlled by means of the reference thermocouple keeping a temperature of the reference glass piece of 40 ± 1.5°C.
b) The test cabinet shall be in a room with an ambient temperature of 23 ± 3°C. Care shall be taken to ensure that draughts, dust, moisture and solar radiation do not interfere with the test cabinet.
c) The reference temperature shall be reached within 2 h of commencing heating. Condensation shall be seen to form on the glass pieces. The test is continued without interruption for the required time. Both the internal reference and the external air temperature shall be regularly checked.

B-3.4 Requirements

a) No defect, greater than 3 mm length.
b) Maximum one defect between 2 mm and 3 mm length.
c) Maximum five defects between 1 mm and 2 mm length.
d) No scratches, staining of the coating or clusters of pinholes greater than 1 mm.
e) When compared with the reference test piece, in both reflection and transmission, there shall be no significant colour change. This observation shall be made within 20 s.
f) The transmittance measured at 550 nm and 900 nm shall differ by no more than ±0.03 from the corresponding measured value on the reference test piece.

B-4 ACID RESISTANCE TEST

B-4.1 This test consists of subjecting the coated glass to a sulphur dioxide saturated atmosphere at constant temperature. The samples shall have condensation continually forming on them. It is this condensation together with the quantity of sulphur dioxide that may cause surface degradation. Test apparatus should have

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a provision of four test pieces and the material used for the inner walls shall be corrosion-resistant and shall not affect the test pieces.

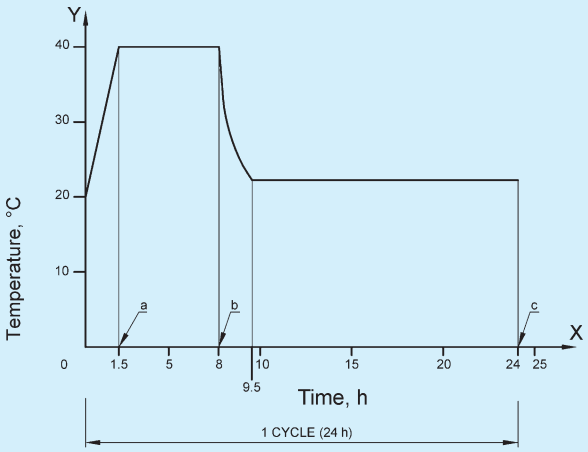
B-4.2 Procedure

a) The test cabinet contains 2 litre of demineralized water having conductivity lower than 30 µS/cm When the cabinet is closed 0.2 litre of SO_2 shall be added and the heating system switched on.

b) The test consists of a repetition of 24 h cycles (*see* Fig. 16).

c) Each cycle consists of high temperature plus condensation period and an ambient temperature without condensation period.

d) The temperature shall increase to 40 ± 1.5°C in less than 1.5 h. During the next 6.5 h the test pieces shall be subjected to condensation in the SO_2 atmosphere.



a – Maximum time to reach 40°C
b – Cessation of heating the cabinet and ventilation of the cabinet
c – Solution removal rinsing of cabinet

FIG. 16 24-HOUR CYCLE OF HEATING

B-4.3 Requirement

The transmittance measured at 550 nm and 900 nm shall differ by no more than ±0.03 nm from the corresponding measured value on the reference test piece.

B-5 NEUTRAL SALT SPRAY

B-5.1 This test consists of subjecting the coated glass to neutral, water saline atmosphere at constant temperature. It is the water saline spray that may cause surface degradation.

Test apparatus should have a provision of four test pieces and the material used for the inner walls shall be corrosion-resistant and shall not affect the test pieces.

B-5.2 Procedure

a) The test cabinet shall be prepared and run for a minimum period of 24 h before the test pieces are placed within it. The neutral salt solution is made up by dissolving NaCl, in demineralized water having conductivity lower than 30 µS/cm, to produce a concentration of 50 ± 5 g/l at 25 ± 2°C.

b) The compressed air supplied to the spray nozzle shall be passed through a filter to remove all traces of oil or solid matter and shall be at an absolute pressure of 70 kPa to 170 kPa through a saturator at 40 ± 1.5°C. The spray nozzle shall be made of inert material, with baffles to prevent direct impact of spray on the test pieces.

B-5.3 Requirements

a) No defect, greater than 3 mm length;

b) Maximum one defect between 2 mm and 3 mm length;

c) Maximum five defects between 1 mm and 2 mm length;

d) No scratches, staining of the coating or clusters of pinholes greater than 1 mm;

e) When compared with the reference test piece, in both reflection and transmission, there shall be no significant colour change. This observation shall be made within 20 s; and

f) The transmittance measured at 550 nm and 900 nm shall differ by no more than ± 0.03 nm from the corresponding measured value on the reference test piece.

B-6 ABRASION RESISTANCE TEST

B-6.1 This test consists of subjecting the coated surface of the coated glass to rubbing with a felt pad in dry condition. It is the type of pad, the loading on it and the number of strokes that may cause surface degradation.

B-6.2 Procedure

a) The metal finger shall be approximately 15 mm to 20 mm in diameter and shall be driven so as to produce a frequency of 60 strokes/min + 6 strokes/min alternating forwards and backwards. The stroke length shall be 120 ± 5 mm. The strokes shall be parallel and ensure a constant pressure over the zone to be tested.

b) A circle shape with a diameter of 14.5 ± 0.5 mm.

c) The test sequence shall commence within 30 min of the sample being cleaned.

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d) The metal finger containing the felt pad shall be lowered on to the glass surface and a load of 4 N applied perpendicular to the glass surface *via* the felt pad.

B-6.3 Requirements

a) Ensure that the abraded area is uniform.

b) The transmittance measured at 550 nm and 900 nm shall differ by no more than ± 0.03 nm from the corresponding measured value on the reference test piece.

B-7 DURATION OF TESTS

The duration of tests shall be as per the following:

Sl No.	*Test*	*Test Duration for Class*		
		A	B	S
(1)	(2)	(3)	(4)	(5)
i)	Condensation resistance	21 days	4 days	14 days
ii)	Acid resistance	5 cycles	1 cycle	5 cycle
iii)	Neutral salt spray	21 days	10 days	—
iv)	Abrasion resistance	500 stokes	50 stokes	500 stokes

NOTES

1 *Class A* — The coated surface of the glass can be positioned on the outer or the inner face of the building.

2 *Class B* —The coated glass can be used as monolithic glazing but the coated surface shall be on the inner face of the building.

3 *Class S* — The coated surface of the glass can be positioned on the outer or the inner face of the building but these types of coated glasses can only be used in specifically defined applications.

ANNEX C

(*Clause* 6.1.9)

PROCEDURE FOR CALCULATING THE APPROXIMATE DEFLECTION AT CENTRE OF GLASS PANEL

C-1 Maximum glass deflection as a function of plate geometry and load may be calculated using the following:

Deflection, $w = t \cdot \exp(r_0 + r_1 X + r_2 X^2)$

where

$X = \ln\{\ln[q(a.b)^2/Et^4]\}$

$r_0 = 0.553 - 3.83(a/b) + 1.11(a/b)^2 - 0.069(a/b)^3$

$r_1 = -2.29 + 5.53(a/b) - 2.17(a/b)^2 + 0.206\ 7\ (a/b)^3$

$r_2 = 1.485 - 1.908(a/b) + 0.815(a/b)^2 - 0.082\ 2\ (a/b)^3$

where

E = Young's modulus of glass, N/mm^2;

q = net pressure on the pane, N/mm^2;

a = longer dimension, mm;

b = shorter dimension, mm; and

t = thickness of the glass pane calculated.

Example:

Lateral deflection calculation — Determine the maximum lateral deflection (w) of a vertical 1 200 mm × 1 500 mm × 6 mm rectangular glass plate subjected to a uniform lateral load of 1.80 kPa. The actual thickness of the glass is 5.60 mm as determined through direct measurement.

$a = 1\ 500$; $b = 1\ 200$

$r_0 = -2.689$

$r_1 = 2.011$

$r_2 = 0.213$

$q = 1.80 \times 10^{-3}$ N/mm^2

$E = 71.73 \times 10^3$ N/mm^2

$t = 5.60$

$X = 1.490$

Therefore maximum deflection at the centre of glass is:

$w = 5.6 \times \exp(-2.689 + 2.111 \times 1.490 + 0.213 \times 1.490^2)$

$w = 12.2$ mm

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ANNEX D

(*Clause* 6.1.9)

MODEL CALCULATION OF GLASS THICKNESS

D-1 MODEL CALCULATION

D-1.1 Glass panel dimension width 1 200 mm and height 1 800 mm for location Chennai for annealed glass type.

D-1.1.1 *General Checks has to be Done for Safety Performance*

a) The maximum area of glass panel is restricted to 15 m^2.

b) The maximum span of window is restricted to 4 m.

c) Applicable to normal, reflective, laminated, tempered and insulating glass.

d) Applicable to rectangular panels properly fixed.

The procedure for calculating glass thickness is described below:

1) *Step 1* — Calculate aspect ratio (AR_{max}) from Table 16.

Aspect ratio (AR_{max}) = Longer side/shorter side of glass

Aspect ratio = 1 800/1 200 = 1.5

2) *Step 2* — Wind load calculation

$P_z = 0.6\ V_z^2$

$V_z = V_b.k_1.k_2.k_3$

where

V_b = basic wind speed based on location {*see* Fig. 1 of good practice [6-8(7)]}.

k_1 = risk co-efficient factor taken as per good practice [6-8(7)].

k_2 = terrain factor {*see* Table 2 of good practice [6-8(7)]}.

k_3 = topography factor {*see* Table 3 of good practice [6-8(7)]}.

V_z = design wind speed.

P_z = design wind pressure, N/m^2, at height, *h.*

Design wind pressure for Chennai location {Basic wind speed = 50 m/s taken from good practice [6-8(7)]} = 1 750 N/m^2

3) *Step 3* — Strength factor

Based on the types of glass (Laminated/ Tempered/Insulating Glass) pressure factor is calculated. To determine the thickness of laminated/tempered/insulating glass, the design wind pressure P_{net} is modified as below:

$P_{net} = P_z/P_f$

where

P_f = pressure factor dependent on the type of glass.

The values of the pressure factor P_f can be taken from Table 2.

For annealed units, $P_f = 1.0$, therefore,

P_{net} = 1 750/1.0 = 1 750 N/m^2

At this stage the glass thickness value shall be calculated from the table and then the deflection and stress check be done as described below:

4) *Deflection check* — The deflection of the glass can be calculated using the formula in Annex C. Actual deflection for the pane shall be obtained as below:

Deflection, $w = t.\ \exp(r_0 + r_1X + r_2X^2)$

$X = \ln\{\ln[q(a*b)^2/Et^4]\}$

$r_0 = 0.553 - 3.83(a/b) + 1.11(a/b)^2 - 0.069(a/b)^3$

$r_1 = -2.29 + 5.53(a/b) - 2.17(a/b)^2 + 0.206\ 7(a/b)^3$

$r_2 = 1.485 - 1.908(a/b) + 0.815(a/b)^2 - 0.082\ 2(a/b)^3$

where

E = Young's modulus (71.7 × 10^3 N/mm^2),

q = net pressure on the pane (N/mm^2),

a = longer dimension (mm),

b = shorter dimension (mm), and

T = thickness of the glass pane calculated.

The actual deflection is, 4 mm < 11 mm maximum allowable.

Result: 1 800/175 = 10.3 mm, which is the maximum allowable deflection.

Hence the glass thickness calculated is safe against deflection.

Glass thickness calculation:

$P_{net}.A = 200.0\ T^k$ (let $T \leq 6$ mm)

P_{net} = 1 750

A = 2.16 m^2

K = 1.765

T = 5.28 mm, therefore choose the thickness of glass as 6 mm.

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ANNEX E

(*Table* 31)

SHOT BAG IMPACT TEST

E-1 OBJECTIVE

The shot bag impact test addresses the capability of glass rails, guards, and balustrades in one, two, three and four sided support systems to continue in their function as a barrier by remaining in the designed framing system after impact or glass breakage.

E-1.1 Glazing Retention

The property of maintaining the glass or glazing material, post breakage, in a system, such that the glass is held in the framing system with no opening sufficient to pass a 75 mm solid steel sphere through the system using a horizontally applied force of 18 N.

E-2 APPARATUS

E-2.1 Instrumentation

Load and time-measuring devices with an accuracy of 62 percent or the full scale shall be incorporated in the test setups. The scale ranges used shall assure that the performance levels are within an accuracy of 65 percent.

E-2.2 Load Attachments

Brackets, fasteners, or other devices used in performing these tests shall be designed and attached so as to minimise their influence on the test results.

E-2.3 Shot Bag, Traction and Release System

The test apparatus shall be capable of supporting a 45.4 kg shot bag and allowing unimpeded swinging of the shot bag from a drop height of 1 220 mm. The impactor system consists of the impactor, traction, release, and suspension devices. The impactor shall consist of the leather bag described in Fig. 17, a commercial punching bag with its bladder left in place,

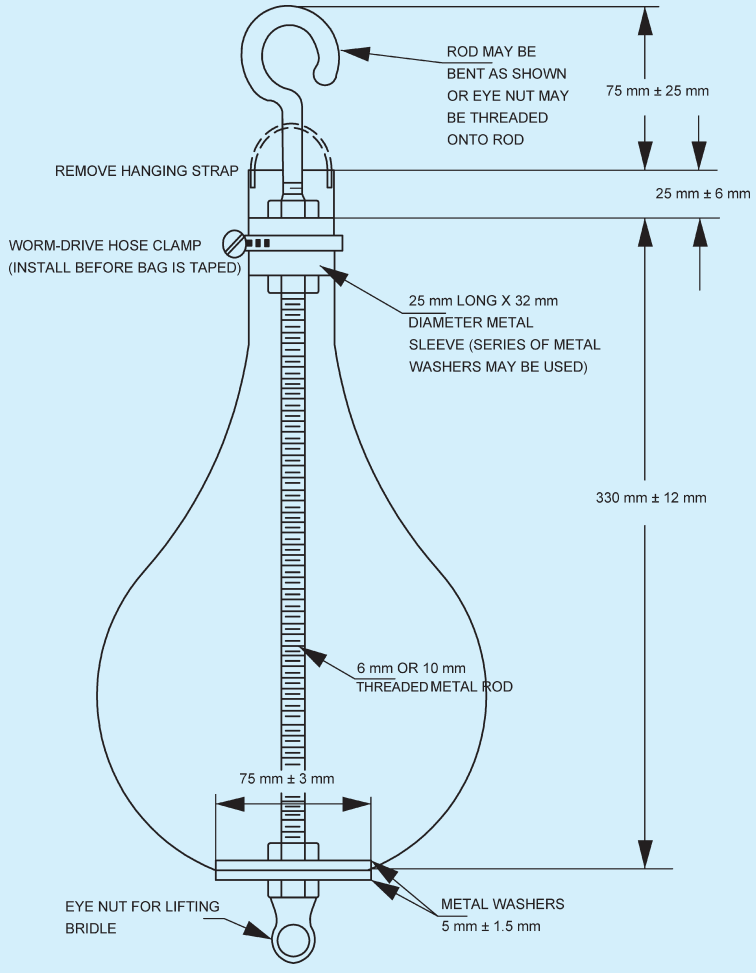


FIG. 17 SHOT BAG IMPACTOR

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or any other leather bag of nominally identical shape and size. The bag shall be filled with lead shot of $24^{+0.1}_{0}$ mm diameter and taped. After filling with lead shot, the top shall be either pulled over the metal sleeve and tied with a cord; or twisted around the threaded eyebolt shaft and tied below the metal sleeve, or both. To reduce bag damage during testing, the exterior of the leather bag surface shall be completely covered with glass filament reinforced pressure sensitive polyester adhesive tape, 12 to 15 mm in width and 0.15 mm thick. Tape the entire bag, using three rolls or 165 m total length, and taping in a diagonal overlapping manner. Tape the neck of the bag separately, with additional glass filament reinforced tape of the same kind. The total mass of the impactor assembly shall be $45.4^{+0.1}_{0}$ kg excluding traction system attachments. A traction system shall be used which enables the impactor to be brought into its launch position. The launch position depends on the drop height selected. The traction cable shall be connected to the impactor traction system by a release mechanism, with provisions for rotating the impactor.

E-3 SHOT BAG IMPACT TEST

E-3.1 Procedure

Any protective masking or decorative components shall be removed from the glazing material. To position the impactor at the selected drop height, a traction force shall be applied to raise the impactor such that the axis of the impactor shall be aligned with the suspension cable, with the cable remaining taut. To ensure this, the top and bottom ends of the impactor shall be connected to the release device by a suitable link. To reduce bag deformation during testing, the bag shall be rotated about the axis of its suspension device before each specimen or sample set, by no less than 30°, and by no more than 90°. To reduce bag damage during testing, a thin homogeneous or non-woven plastic film no more than 0.13 mm thick or a loosely draped woven cloth towel weighing no more than 0.005 kPa shall be permitted to be suspended vertically from its top edge directly in front of the surface of the specimen at a distance no more than 10 mm. When at rest the maximum diameter of the impactor shall be located no more than 12 mm from the surface of the specimen and no more than 50 mm from the centre of the specimen. The impactor shall be suspended from an overhead support, located so when at rest, it will, at its maximum diameter, be no more than 12 mm from the surface of the specimens and no more than 50 mm from the centre of the specimen. Raise the impactor to the required height (460 or 1 220 mm) and stabilize it. The suspension device shall be taut and the axes of the impactor and cable shall be aligned. The impactor, stabilized in the launch position in a vertical plane normal to the test specimen, shall be released and falls without initial velocity or axial rotation. One impact with a force of 1.8 kN shall occur on each glazing configuration of the test specimen. Each test specimen shall be inspected after each impact and report condition of specimen.

E-3.2 Reporting of Results

Impact performance shall be classified as: (a) unbroken, (b) broken and retained, or (c) infill broken and not retained (*see* Fig. 18). Retention of the product in the frame is based on the definition of glazing retention given in **E-1.1**.

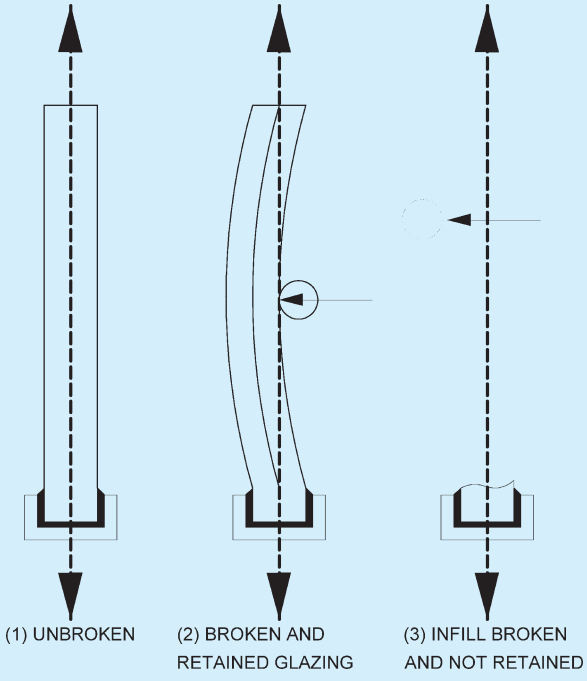


FIG. 18 GLAZING RETENTION

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ANNEX F

(*Clause* 8.2.1)

PERFORMANCE TESTS FOR GLAZING SYSTEM

F-1 The following enlists the performance tests for glazing systems. The test specimen size and direction facing the pressurised chamber shall be mutually agreed to between the parties concerned or specifed without ambiguities in the tender documents.

F-2 AIR INFILTRATION/EXFILTRATION TEST

Permissible air leakages shall be 1.5 m^3/h.m^2 for fix area and 2 m^3/h.m for crack length of operable panel. The crack length is the maximum height of the shutter per interlock or per meeting stile in a slider or per overlap joint in a double leaf door or vent, in addition to the jambs. Along the width, crack length is the maximum width of the shutter at top and bottom. All operable panels shall be opened and closed 5 times prior to commencement of test.

For facade, strip glazing, skylights and insert vents in facades, the pressure differential shall be ±150 Pa for up to buildings of height 70 m and shall be ±300 Pa for buildings of height beyond 70 m.

For strorefront, operable windows, sliding windows, sliding doors and doors, the pressure differential shall be +150 Pa.

NOTE — Preload of 50 percent of design load for 10 s to be applied before commencement of the test.

F-3 STATIC AND DYNAMIC WATER PENETRATION TEST

If water is observed in the operable vent drainage path and the same is drained through slots after the spray is stopped it shall be considered as pass. Any water on the top surface of any exposed interior shall be considered as leakage. For sliders, only water overflowing to the interior is considered as failure. In case of leakage the remedy needs to be carried out and the retest shall be conducted. The rate of water spray shall be 3.4 litre/min.m^2 for a period of 15 min. The spray shall be located at a distance of 400 mm from the glass and 700 mm centre-to-centre horizontally and vertically. The pressure differential up to 35 m height shall be 300 Pa, beyond 35 m up to 70 m shall be 450 Pa and beyond 70 m shall be 600 Pa.

NOTES

1 Cyclic water penetration is optional and the parameters are to be agreed mutually between the relevant stakeholders. However, cyclic water penetration is not applicable to sliding doors and windows.

2 Between each test, water should be drained and if required 450 Pa pressure applied for a period of 2 min to flush out the water from the system. There should also be a minimum of 10 min at zero pressure between tests.

F-4 STRUCTURAL LOAD TEST (100 PERCENT DESIGN WIND LOAD)

The deflection criteria of glass and framing members shall be as specified in **6.3.6.2**.

No damage or harmful permanent deformation of any parts except sealing materials shall be found at the maximum testing pressure. Residual displacement of structural member shall not exceed span/1 000. The slippage at supports and fixing shall not exceed 1 mm.

F-5 SEISMIC RACKING TEST

Criteria shall be the movement of the sub-structure in the horizontal (+/–) directions. Optional testing for vertical movements (+/–) shall be based on sub-structure movement to accommodate live load, long term creep, column shortening and thermal elongation or contraction. No glass breakage or fall out is allowed. Any damage shall be easily reparable without any part replacements required. No wall component fallout is allowed.

F-6 BUILDING MAINTENANCE UNIT (BMU) PULL OUT TEST (WHEN APPLICABLE)

A tensile load of minimum 1.5 kN shall be applied on the BMU restraint in the following directions:

a) Horizontally to the right and held for a period of 1 min.
b) Horizontally to the left and held for a period of 1 min.
c) Vertically upward and held for a period of 1 min.
d) Vertically downward and held for a period of 1 min.

After each step the BMU restrain should not fail or have permanent deformation.

NOTE — If the load on the BMU restraints required by the BMU supplier is higher, the higher load shall apply.

F-7 OPERATING FORCES TEST (OPTIONAL)

Maximum force required to initiate opening of a sliding door is 180 N and the maximum force to maintain the motion of a sliding door or window is 115 N. For a projected top hung or parallel open vent the maximum force to maintain motion is 135 N.

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F-8 STRUCTURAL PROOF LOAD TEST (150 PERCENT DESIGN WIND LOAD AND SEISMIC FORCE, IF APPLICABLE)

Under proof load test there shall be no collapse which means any one or any combination of the following:

a) Dislodgement of any glass.
b) Dislodgement of any frame, panel or any component thereof.
c) Failure of any fixing that connect the façade to the building structure, such that the test sample is unstable.
d) Failure of any stop, locking device, fastener or support which may allow an opening light to come through.

The permanent deformation in framing members in excess of span/1 000 is not permissible and considered as failure.

NOTE — For on-site testing, the parameters shall be tested for two/third of the laboratory values.

ANNEX G

(*Foreword*)

INSTALLATION OF MIRRORS

G-1 This annex provides general guidelines, which is to be followed during the installation of mirror. Mirrors (Piece of glass silvered on one side, with a protective paint coating) are used in shops, gymnasiums, etc, where it is predominantly used as wall cladding. The mirror panels in such application use large panel size and it is recommended to follow the installation procedure in accordance with this Section.

G-1.1 The mirror should always be mounted on a perfectly flat, clean and dry surface free from acids and aggressive substances such as acid, solvent and cement mortar.

G-1.2 The mirror shall be mounted on wall or plywood and care is taken that the mirror is never stuck over unstable support (painted paper, paint or old plaster). It is recommended that the mirror installation is not done directly on the mirror supports. In order to have good ventilation, the following spacing behind the mirror is recommended depending on the height of the mirror panel:

a) A space of 5 mm for a mirror less than 1 m height.
b) A space of 10 mm for a mirror greater than 1 m height.

Figure 19 gives typical details of the installation of mirrors. During the installation of mirror panels at several levels that is, one above the other, it is recommended to provide a space of 10 mm at the top and at the bottom for circulation of air. The side of the mirror is designed with a minimum 1 or 2 mm of interleaving space. When mirror is fixed in a profile (frame), care is to be taken to maintain perfectly dry and clean frame. It is recommended that mirror is supported on hard non-metallic/plastic wedges of at least 3 mm, to raise the mirror and thus avoid contact with the condensed water which could accumulate in the profile. If the mirror is screwed on, the screws of a suitable dimension is designed, with the interleaving and washers (*see* Fig. 20) made of plastic to avoid any direct glass-metal contact. To minimise the risk of breakage, cracks and splinters during screw-mounting the mirror, it is recommended to use synthetic protective collars.

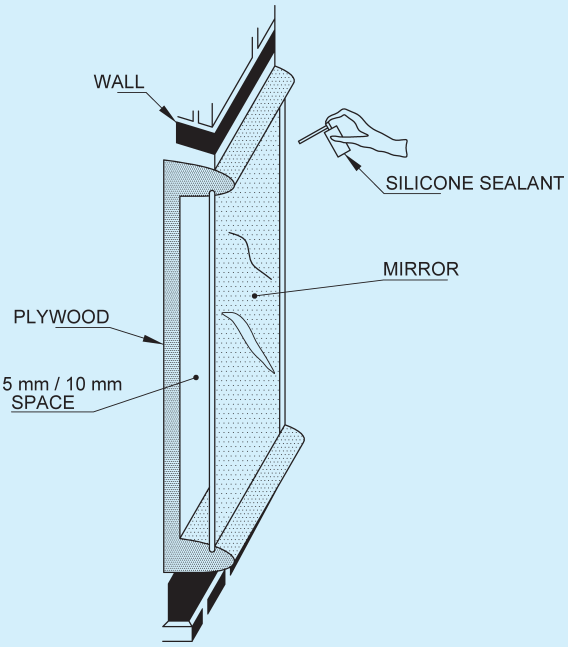


FIG. 19 INSTALLATION OF MIRRORS

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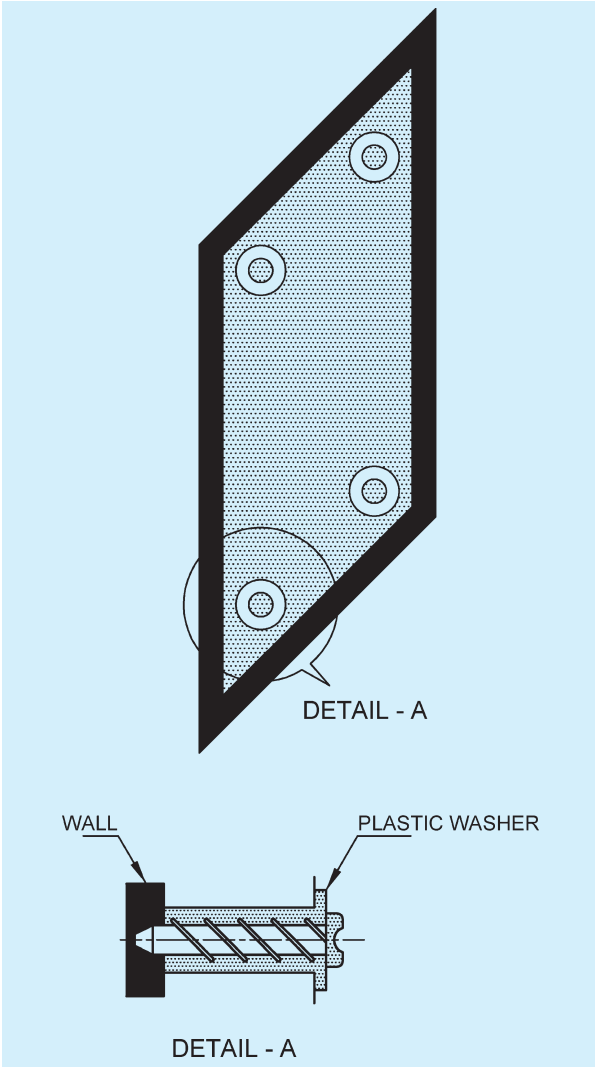


FIG. 20 DETAILS OF USE OF SCREWS AND INTERLEAVING WASHERS FOR INSTALLING MIRRORS

G-1.3 The adhesive used to mount mirrors, care should be taken to ensure that the adhesive is compatible with the protective coatings on the mirror. It is recommended to use only neutral binding agents such as alkoxy silicone, oxime silicone, etc. Avoid use of acid silicones, such as acetoxy silicones which contain acetic acid or water/rubber/polyurethane-based glues.

G-1.4 In the high humidity areas (for example bathrooms), it is recommended to seal the edges with neutral silicone to protect the backing paint from damage due to moisture and enhanced protection from moisture. It is recommended to use double sided adhesive tapes to fix the mirror on the mounting surface (*see* Fig. 21). The adhesive tapes used for installation shall be certified to be compatible with the mirror and the adhesive or the adhesive tapes shall always be fixed vertically.

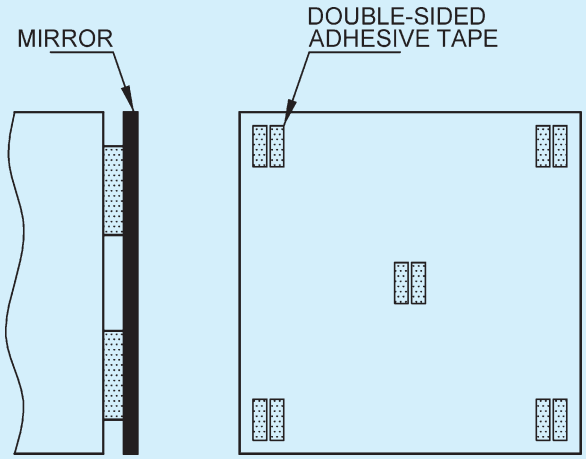


FIG. 21 DETAILS OF USE OF DOUBLE SIDED ADHESIVE TAPES FOR INSTALLING MIRRORS

ANNEX H

(*Foreword*)

GLASS RAILINGS

H-1 GENERAL

Glass railings are generally sought in commercial applications (such as in malls) and in certain domestic villas, etc. Glass of appropriate thickness when used as a railing can provide transparency and when engineered properly can provide structural performance too.

The basic requirement of a parapet which a glass railing (if so used) intends to substitute shall be met with. This includes protecting people from falling and in some cases to control movement. Careful consideration including in design shall be made where glass railings are used.

NOTE — Notwithstanding the above, the potential benefits including safety (through psychological aspects) of regular railings shall be borne in mind.

H-2 PRELIMINARY CONSIDERATIONS

In the assessment of the need for a railing and the type

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of railing to be provided, the designer should give consideration to the likely hazards, the building use and the risks to building users. Where, in a building, more than one use of the building is anticipated, either the railing design should be chosen to suit the worst case, or more than one type of railing should be provided, as appropriate, to the location. Generally when there is a change in adjacent levels (600 mm in dwellings, 380 mm in other buildings) a railing is needed to restrict movement of people.

The railing adopted should be designed so as to minimise the risk of persons falling, rolling, sliding or slipping through gaps in the railing. In dwellings and other buildings which can be accessed by children, gaps in railing or infill should not be large enough to permit a sphere of 100 mm diameter to pass through, making due allowance for deflection under load.

The designer should ensure all the elements of the railing system satisfy the criteria given in available relevant standards.

For general safety, the finished barrier should have no sharp edges or projections that could cause injury to persons or clothing. Infill panels and balusters are intended to provide support and protection to users, and should be designed to restrain people without causing additional injury from sharp edges, thin sections, open-ended tubes, projecting details, etc.

The design shall be based on the horizontal UDL (uniformly distributed load) should be applied at a notional height of 1.1 m above finished floor level, even though the minimum permissible height of the railing may be less (The notional design height of 1.1 m is chosen as being representative of the height of the centre of gravity of a human being above the datum level).

H-3 GLASS RAILING TYPES

There are four common types of railing that used to fix glass.

a) *Full height railing* — Where glass forms part or whole of a wall element, the railing should be carefully designed as per the relevant existing standards and as per this Section, if any part of the glass comes below the minimum railing height (*see* Table 35).

b) *Railings with a glass infill panel* — In this type of railing, the main frame of the railing (that is, top rail and baluster) should be designed to withstand the loads applied to the top rail and the glass should be used to form infill panels. It should be noted that the glass provides no support to the main frame. This can be further sub-categorized into 4 types:

1) *Glass supported on vertical edges only* — This may involve the vertical edges of the glass being supported in a rebate into the side of each vertical post. The top and bottom edges of the glass are exposed. The glass may also be supported by patch fittings fixed to the posts. In all cases a handrail is required.
2) *Glass supported on horizontal edges only* — This may involve a handrail at the top, and a channel or a rail at the base of the glass. In this case the handrail should be designed to carry the railing load with the glass designed to carry the infill load.
3) Glass supported on all four edges.
4) *Glass fixed by patch/bolted fittings* — This system requires the use of two rows of bolts (commonly) to provide a stiff fixing which minimises panel deflection. There are a variety of bolt fixing types available in the market so design and performance information should be sought for each type. The purpose of these fixings is to transfer the force applied to the railing into the support structure. These fixings occupy a small surface area on the glass which can produce high stresses in the glass, so careful analysis is required to determine suitable glass thickness, fixing spacing and size.

c) *Free standing glass protective railing* — In this type of railing, the glass should be designed to withstand the design loads. Each glass plate should be rigidly clamped to the structure along its bottom edge, the handrail attached to the top edge of the glass and there should be no balusters. In the event that a free standing railing is supplied without a handrail, each panel should be able to withstand the entire appropriate design load. This applies to vertical glazing and glass within 15° of vertical. Adequate provision for drainage of water should be made in the base structure to avoid any water ponding which may cause delamination issue

d) *Bracket systems* — These systems are an extension of the bolt fixed system where the bolts are part of a bracket and the bracket is fixed to the floor or the face of a concrete slab, steel or timber structure. The use of these systems shall be investigated carefully as they can develop very high stresses in the glass where the brackets are located. The design shall balance glass thickness and bracket location to produce an adequate system. Some systems may be designed to produce test data,

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to justify their use. This data shall be studied carefully as there have been some cases where such data has been shown to be inadequate. Proper interpretation of these test data shall also become necessary.

Table 35 Minimum Barrier Heights

[*Clause* H-3 (a)]

Sl No.	Use	Position	Heights mm
(1)	(2)	(3)	(4)
i)	Single family dwelling	a) Barriers in front of a window up to 10 floors	800
		b) Barriers in front of a window from 11th floor to 20th floor	1 100
		c) Barriers in front of a window above 21st floor	1 200
		d) Stairs, landings, ramps, edges of internal floors	900
		e) External balconies including *balconet*, edges of roofs:	
		1) up to 20th floor	1 100
		2) 21st floor and above	1 200
ii)	All other uses	a) Barrier in front of a window	800
		b) Stairs	900
		c) Balconies and stands, etc, having fixed seating within 530 mm of the barrier	800
		d) Balconies and stands, etc, having fixed seating within 530 mm of the barrier, provided the sum of the barrier width and the barrier height is greater than 975 mm	750
		e) Other positions including *balconets*	1 100

H-4 DESIGN CONSIDERATIONS

The designer shall first determine the purpose of the railing. Once this is done, the appropriate load requirement can be derived. Typical values (minimum requirements) of railing loads to be chosen are given in Table 36. (If so desired by the designer, higher values than that in the Table 36 may also be chosen.)

H-4.1 General

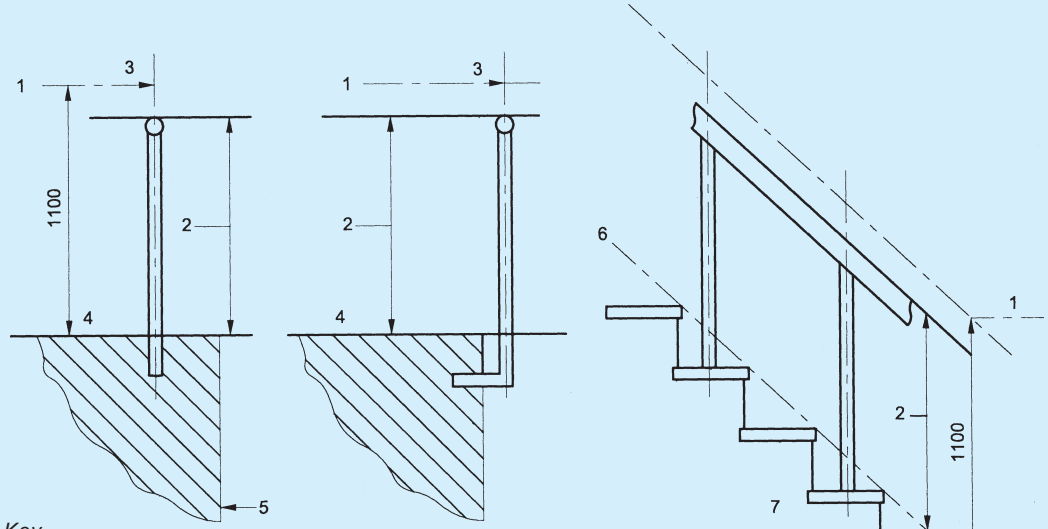
Railings should be designed to resist the most unfavourable likely imposed loads and wind loads separately without unacceptable deflections or distortions. Heights of railings shall be same as that for parapet walls as per other Parts of the Code. The railing height above datum is defined in Fig. 22. The minimum heights for each railing location shall be as given in Table 35.

The height of glass railings installed on top of low parapet walls should be measured from the top of the parapet and not at walk level.

For railings, either permissible stress or limit state design procedure should be used, according to the recommended procedures. When using limit state design, the partial safety factors for loads and materials should be those recommended by the appropriate standard for relevant materials. The deflection of the railing shall be determined as per serviceability limit state.

H-4.2 Loadings

Minimum horizontal imposed loads appropriate to the design of parapets, railings, balustrades and other



Key
1 Design level
2 Barrier height
3 Horizontal load
4 Datum = FFL
5 Edge of floor
6 Datum = pitch line
7 Stairs

NOTE — In design, the horizontal uniformly distributed line load acts at a height of 1.1 m above datum level, irrespective of the actual height of the element.

FIG. 22 DATUM, BARRIER HEIGHT AND DESIGN HEIGHT

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elements of structure intended to retain, stop or guide people, should be determined in accordance with Table 36, which recommends a uniformly distributed line load for the railing and a uniformly distributed and point load applied to the infill.

NOTE — These are not additive and should be considered as three separate load cases, all loads being determined according to the type of occupancy which reflects the possible in-service conditions.

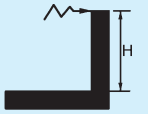
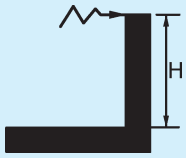
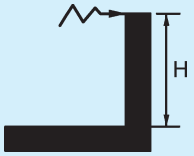
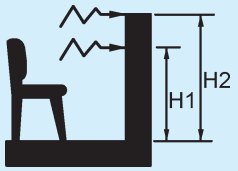
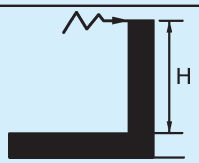
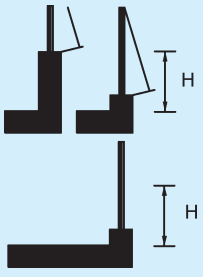
Horizontal uniformly distributed line load should be applied at design height as presented in Table 36 or at design level (1 100 mm) for railings higher than the design height.

Uniformly distributed load should be applied to the area below the design height.

Point load should be applied at the most onerous point anywhere on the railing structure.

NOTE — For clarity, the design level (the level at which the horizontal uniformly distributed line load ought to be considered to act) is shown in Fig. 23.

In general, the load combinations as described in **H-4.2.1** to **H-4.2.3** should be applied.

Building	Element		Strength	Height (H)
Single family dwelling	Stairs landings, ramps edges of internal floors	0.36 kN/m	900 mm for all elements	
	External balconies and edges of roofs	0.74 kN/m	1 100 mm	
Factories and warehouses (light traffic)	Stairs, ramps	0.36 kN/m	900 mm	
	Landing and edges of floor	0.36 kN/m	1 100 mm	
Residential institutional, educational, office and public building	All location	0.74 kN/m	900 mm for flights otherwise 1 100 mm	
Assembly	Within 530 mm in front of fixed seating	1.5 kN/m	800 mm (H1)	
	All other locations	3.0 kN/m	900 mm for flights elsewhere 1 100 mm (H2)	
Retail	All locations	1.5 kN/m	900 mm for flights otherwise 1 100 mm	
All buildings	At opening windows		800 mm	
	At glazing to changes of level	To provide containment	Below 800 mm	

NOTE — *H* is the height at which the applied load (horizontal design load) is located and it need not be the height of the barrier itself.

FIG. 23 HEIGHT LIMIT FOR THE UNIFORM LOADING FOR VARIOUS CATEGORY OF BUILDINGS

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Table 36 Minimum Horizontal Imposed Loads for Parapets, Barriers and Balustrades

(*Clauses* H-4.2 *and* H-4.4)

Sl No.	Type of Occupancy for Part of the Building or Structure	Examples of Specific Use	Horizontal Uniformly Distributed Line Load	Uniformly Distributed Load Applied to the Infill	A Point Load Applied to Part of the Infill
			kN/m	kN/m^2	kN
(1)	(2)	(3)	(4)	(5)	(6)
i)	Domestic and residential activities	a) All areas within or serving exclusively one single family dwelling including stairs, landings, etc, but excluding external balconies and edges of roofs	0.36	0.5	0.25
		b) Other residential, that is, houses of multiple occupancy and balconies, including Juliette balconies and edges of roofs in single family dwellings	0.74	1.0	0.5
ii)	Offices and work areas not included elsewhere, including storage areas	a) Light access stairs and gangways not more than 600 mm wide	0.22	—	—
		b) Light pedestrian traffic routes in industrial and storage buildings except designated escape routes	0.36	0.5	0.25
		c) Area not susceptible to overcrowding in office and institutional buildings, also industrial and storage buildings except as given above	0.74	1.0	0.5
iii)	Areas where people might congregate	Areas having fixed seating within 530 mm of the barrier, balustrade or parapet	1.5	1.5	1.5
iv)	Area with tables or fixed seatings	Restaurants and bars	1.5	1.5	1.5
v)	Areas without obstacles for moving people and not susceptible to overcrowding	a) Stairs, landings, corridors, ramps	0.74	1.0	0.5
		b) External balconies including *balconets* and edges of roofs. Footways and pavements within building curtilage adjacent to basement/sunken areas	0.74	1.0	0.5
vi)	Areas susceptible to overcrowding	a) Footways or pavements less than 3 m wide adjacent to sunken areas	1.5	1.5	1.5
		b) Theatres, cinemas, discotheques, bars, auditoria, shopping malls, assembly areas, studio. Footways or pavements greater than 3 m wide adjacent to sunken areas.	3.0	1.5	1.5
vii)	Retail areas	All retail areas including public areas of banks/building societies or betting shops	1.5	1.5	1.5
viii)	Vehicular	Pedestrian areas in car parks, including stairs, landings, ramps, edges or internal floors, footways, edges of roofs	1.5	1.5	1.5

H-4.2.1 *Free Standing Glass Protective Railing (Without any Balusters)*

It requires five design loadings to be taken into account:

a) Line load (Horizontal UDL), in kN/m
b) UDL (Infill UDL), in kN/m^2.
c) Concentrated load, in kN.
d) Impact force.
e) Shot bag test load (*see* Annex E).

H-4.2.2 *Railing with Glass Infill Panel*

It requires three design loadings to be taken into account:

a) UDL (Infill UDL), in kN/m^2.
b) Concentrated load, in kN.
c) Impact force, in kN.

H-4.2.3 *Full Height Railing*

It requires three design loadings to be taken into account:

a) Line load (Horizontal UDL), in kN/m.
b) UDL (Infill UDL), in kN/m^2.
c) Concentrated load, in kN.

H-4.3 Wind Loads

External railings should be designed to resist the wind loads given in good practice [8-5(7)].

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H-4.4 Deflection

Railings for the protection of people should be of adequate strength and stiffness to sustain the applied loads given in Table 36. In addition, a railing that is structurally safe should not possess flexibility to such an extent so as to create a false alarm to building users when subject to normal service conditions. Therefore, for serviceability considerations, the limiting condition for deflection appropriate for a railing for the protection of people is that the total horizontal displacement of the railing at any point from its original unloaded position and should not exceed the deflection limits determined from the relevant structural design code (where applicable) for the material used, or 25 mm, whichever is the smaller. Where the infill of a railing is subjected to the imposed loads given in Table 36, or if appropriate, other calculated design loads, the displacement of any point of the railing should not exceed H/65 or 25 mm, whichever is lower.

H-4.5 Fixings, Attachments and Anchorage

The strength of fixings, attachments and anchorage securing the railing to a substrate should be adequate to sustain a loading greater than that to which the railing will be subjected. All joints should be designed to provide the full strength of the members being joined. To that end, where any uncertainty exists with regard to the strength of any component in the fixing, the design loading factors should be increased by 50 percent.

While designing fixings, particular care should be taken to account for the material into which the fixing is placed, the spacing between fixings, the edge distance, and where the substrate is concrete, the position of reinforcement. Designs based on the pull out capacity of a single fixing should be avoided.

NOTES

1 The recommendation of an additional load factor of 1.5 is intended to ensure that under an extreme load condition, railings give an indication of failure by deflection distortion and not by total collapse, as may be brought about by a failure of the fixing, attachment or anchorage system. Where the design strength of a proposed system of fixing to an existing substrate cannot be determined with reasonable accuracy by theoretical consideration, load testing should be used to validate the design.

2 A factor greater than 1.5 on railing load design might also be chosen based on the importance desired by the designer/parties concerned.

H-4.6 Testing

The standard tests, performance criteria of glass in permanent glass railing systems, guards and balustrades shall be mutually decided between the parties concerned.

H-5 GLASS

The use of glass in railings, the type and thickness of glass required for various support conditions shall be as given below. If designed properly, glass can form a structural component of the railing, or the railing may be designed to have a structural component made from another material such as steel or aluminium, with glass acting as an infill panel only. This places a lesser load on the glass as the major load is taken by the structural component.

NOTE — There are certain situations, particularly under some lighting conditions, where the presence of transparent glass is not readily evident and suitable manifestation should be provided.

H-5.1 Types of Glass

For the purpose of this annex, safety glass used in railing shall be any of the following:

a) Laminated glass,
b) Heat strengthened laminated glass, and
c) Toughened laminated glass.

The designer shall ensure that in the case of accidental or deliberate damage, there is no glass fallout to rule out any kind of danger to public. In these situations, it is recommended to use a toughened laminated glass or fully framed laminated glass. Exposed edges of laminated glass are not recommended unless it is with a non-hygroscopic layer.

It is recommended that all monolithic toughened glass used in frameless or bolted structural railings be specified as heat soak treated.

The type of glass should be chosen to suit the design of the railing. For the use of laminated glass, where the glass is not fully framed, the manufacturer should be consulted. Toughened glass and laminated toughened glass should be used for all railings where the glass is fully or partially framed or is free standing. The selection of glass should include consideration of the post breakage behaviour.

NOTES

1 Laminated safety glass can be used for all railings, where the glass is used, fully framed.

2 Monolithic toughened glass might fall from its retention system if broken in free-standing and infill railings. In such cases, additional protection shall be required if this type of glass is used above areas of fixed seating.

H-5.2 Working of Glass

The size, position and shape of holes and notches in toughened glass, and the production of shapes other than rectangles, should be decided in consultation with

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the manufacturer, as shaping, drilling, cutting, etc, should be undertaken prior to toughening.

H-5.3 Fixing of Glass

Contact between glass and any other hard material (including other glass parts) should be prevented. Rubber gaskets or other glazing materials should be used with frame sections. The frame section should give a minimum of 15 mm edge cover to the glass unless it can be shown by test or calculation that the frame will retain the glass under load while conforming to design requirements.

The frame and/or fastenings should be designed so that they do not tend to distort the glass panel. This is particularly important with bolted connections, which can exert considerable forces on the glass, where particular attention should be paid to the alignment and position of the fasteners in order to avoid unnecessary stresses being developed.

H-5.3.1 *Bolt Fixing of Infill Panels*

At the bolted connections there should be clamping plates and gaskets on both sides of the glass that provide a minimum of 50 mm diameter cover to the glass. These plates should be not less than 6 mm thick in steel or 10 mm thick in other suitable metals.

Where the length of a glass pane is greater than the span between the bolted connectors, giving rise to a cantilevered portion of the pane, the cantilevered portion should be less than one-quarter of the span between the bolted connectors.

Under the design loads, the railing should be designed so that the relative in plane movement of the bolted connections in the same panel is not greater than 2 mm.

The glass, framing system and connections of railings and infill panels should be capable of sustaining and safely transmitting the design loads to the supporting structure.

H-5.4 Design of Glass

H-5.4.1 *Design of Glass in Full Height Protective Railings*

Glass partly or totally below the minimum railing height should be designed to satisfy the appropriate design criteria. Any part of a glass pane below the minimum railing height should sustain the infill loads. Where there is glass at the minimum railing height given in Table 36, the glass should also sustain the line load applied at the design level.

For any specific information on the glass size relative to the glass type, support system, loadings and thickness, available standards or the manufacturer recommendations should be sought.

H-5.4.2 *Design of Glass Infill Panels*

Infill panels should be designed to satisfy the appropriate design criteria as below:

a) *Fully framed infill panels* — The deflection of the glass in fully framed infill panels should be as per recommended deflections.

b) *Two-edge framed infill panels* — The deflection of the glass in two edge framed infill panels should be as recommended under **H-4.4** taking L as the distance between the supports.

c) *Clipped infill panels* — The clips should be positioned around the periphery of the infill panel, at a maximum spacing of 600 mm. Each clip should be not less than 50 mm in length and should give a minimum depth of cover to the glass of 25 mm.

d) *Bolt fixing of glass infill panels* — Where glass is supported by bolted connections through holes in the glass, toughened/ toughened laminated glass should be used.

e) *Position of infill panels relative to the main frame* — Infill panels should be fully contained within the supporting structure. In order not to apply unintended loads to the infill panels, they should have handrails above the glass or attached to the side to which the public have access.

H-5.4.3 *Design of Free Standing Glass Protective Railings*

The glass should be designed to satisfy the appropriate design criteria given in **H-4**. The deflection of the glass should not be more than 25 mm at any point.

H-5.4.3.1 *Handrail attachment*

Where the railing protects a difference in level greater than 600 mm, a handrail shall be used unless a laminated toughened glass construction is used that remains *in-situ*, if a panel fails. Continuous fixing should be used for fixing the handrail to the glass, or individual fixings where calculations or tests demonstrate that component failure will not occur.

Where handrail is not desired, the laminated toughened glass should have a stiff interlayer such as ionoplast interlayer or structural PVB interlayer.

The handrail should be attached to the glass in such a manner that, should a glass panel gets fractured, the handrail,

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a) will remain in position; and
b) will not fail if the design load is applied across the resulting gap.

NOTE — The above condition (b) can be relaxed where the glass pane is an end pane and protects a difference in level of 600 mm or less, for example at the foot of a flight of stairs. In cases where an end pane protects a difference in level greater than 600 mm, there may normally be some adjacent structure to which the handrail could be attached, thus enabling it to meet condition (b).

H-5.4.4 *Base Fixing of Free Standing Railings*

H-5.4.4.1 *Point of fixing clamps*

The fixing clamps on each side of the glass should be not less than 100 mm to 150 mm and should be made of a suitable metal of minimum thickness 12 mm. There should be not less than two fixing clamps for every 1 m length of railing.

H-5.4.4.2 *Continuous fixing clamps*

The fixing clamps on each side of the glass should be not less than 100 mm wide and should be made of a suitable metal of minimum thickness 12 mm. The clamps should be continuous for the entire length of the glass pane and have a maximum bolt spacing of 500 mm.

H-5.4.4.3 *Other clamping systems*

Different clamping methods could be used, provided they cater for an effective continuous clamping over the length of the glass pane. Where a clamping system that does not rely on bolts through the glass is used, the depth over which the clamping force operates should be not less than 75 mm, unless specific tests have been carried out to prove the integrity of the system and that it meets the design criteria given.

H-5.4.4.5 *Structural movement*

The structural movement due to live or dead loads or creep of the structure to which a railing pane is clamped should be not greater than 2 mm over the length of any railing panel, if more than two bolts are used to clamp that panel.

H-5.4.4.6 *Fixing clamps*

The attachment of the fixing clamps to the structure should be capable of withstanding the turning moment induced at the fixing clamps.

H-6 IMPACT RESISTANCE AND CONTAINMENT

H-6.1 General

In addition to resisting the design loads given, glass below the minimum railing height (*see* Table 1) should also be able to resist impact forces appropriate to whether the railing indicates a route or protects people from a hazard.

H-6.2 Glass in Full Height Railings

The glass in full height railings should be selected to resist the appropriate design loads given and for its impact performance in accordance with the safety glazing recommendations.

H-6.3 Railing with Glass In-Fills or Free-Standing Balustrades

The glass in railings with glass in-fills or free-standing should be selected to resist the appropriate design loads given, and to provide containment, that is, it should meet the recommended impact class without penetration.

H-7 INSTALLATION

The installation of a railing should be supervised by a suitably qualified person or persons, who should ensure that the design assumptions have been effectively implemented. Inspections and investigations should be carried out as necessary to establish the integrity of the materials and the elements of construction used.

H-7.1 Fasteners and Fittings

Fasteners and fittings should be of stainless steel, or should be hot-dip galvanized. Thin zinc plated or cadmium plated coatings should not be used for external exposure without additional protection.

H-8 MAINTENANCE

All glass should be regularly cleaned and fixings should be checked for corrosion and loosening. Maintenance recommendations, and the frequency with which railings should be inspected, are governed by environment, usage, incidence of malicious damage and the protection applied. Protective railings assembled entirely from metal-coated steel and situated in normal environments should not require any maintenance for a very long period. They should, however, be inspected regularly and the residual coating thickness should be measured.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Section:

	IS No.	*Title*
(1)	14900 : 2000	Specification for transparent float glass
	2553 (Part 1) : 1990	Specification for safety glass: Part 1 General purpose (*third revision*)
(2)	3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(3)	2835 : 1987	Specification for flat transparent sheet glass (*third revision*)
(4)	14900 : 2000	Specification for Transparent float glass
(5)	2553 (Part 1) : 1990	Specification for safety glass: Part 1 General purpose (*third revision*)
(6)	5437 : 1994	Specification for figured rolled and wired glass (*first revision*)
(7)	875 (Part 3) : 2015	Code of Practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind Loads (*third revision*)
(8)	1893 (Part 1) : 2016	Criteria for earthquake resistant design of structures: Part 1 General provisions and buildings (*sixth revision*)
(9)	875 (Part 2) : 1987	Code of Practice for design loads (other than earthquake) for buildings and structures: Part 2 Imposed loads
(10)	3809 : 1979	Fire resistance test for structures (*first revision*)
(11)	875	Code of Practice for design loads (other than earthquake) for buildings and structures
	(Part 1) : 1987	Dead loads — Unit weights of building material and stored materials (*second revision*)
	(Part 2) : 1987	Imposed loads (*second revision*)
	(Part 3) : 2015	Wind loads (*third revision*)
	(Part 5) : 1987	Special loads and combinations (*second revision*)
(12)	733 : 1983	Specification for wrought aluminium and aluminium alloy bars, rods and sections (for general engineering purposes) (*third revision*)
	738 : 1994	Specification for wrought aluminium alloys, drawn tube for general engineering purposes (*third revision*)
(13)	6911 : 1992	Specification for stainless steel plate, sheet and strip (*first revision*)

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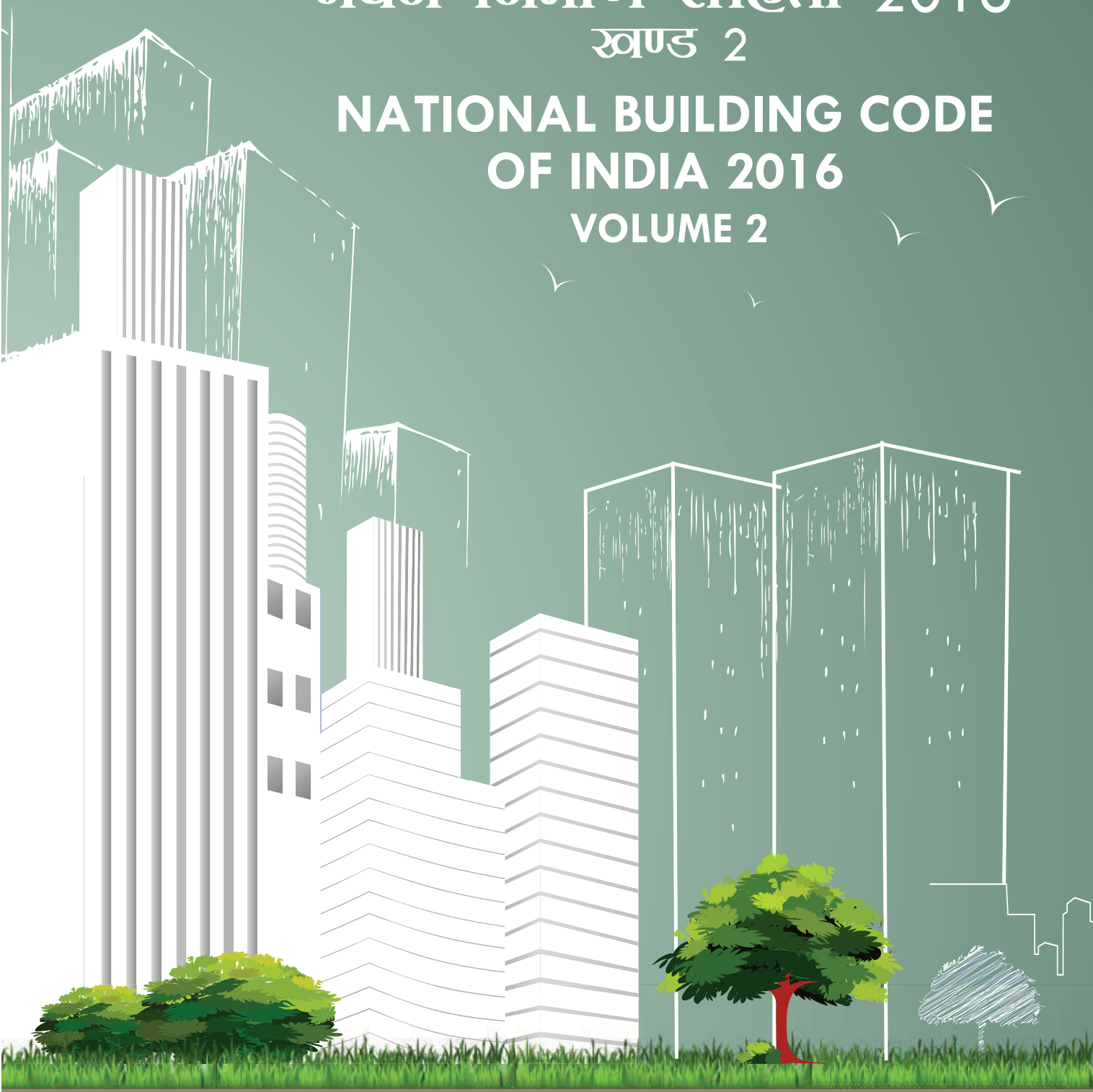
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Important Explanatory Note for Users of the Code

In any Part/Section of this Code, where reference is made to 'good practice' in relation to design, constructional procedures or other related information, and where reference is made to 'accepted standard' in relation to material specification, testing, or other related information, the Indian Standards listed at the end of the Part/Section shall be used as a guide to the interpretation.

At the time of publication, the editions indicated in the standards were valid. All standards are subject to revision and parties to agreements based on any Part/Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the list of standards given at the end of a Part/Section, the number appearing within parentheses in the first column indicates the number of the reference of the standard in the Part/Section. For example:

a) Good practice [7(2)] refers to the Indian Standard given at serial number (2) of the list of standards given at the end of Part 7, that is, IS 16416 : 2016 'Construction project management: Project formulation and appraisal — Guidelines'.

b) Good practice [8-1(6)] refers to the Indian Standard given at serial number (6) of the list of standards given at the end of Section 1 of Part 8, that is, IS 3362 : 1977 'Code of practice for natural ventilation of residential buildings (*first revision*)'.

c) Good practice [8-3(16)] refers to the Indian Standard given at serial number (16) of the list of standards given at the end of Section 3 of Part 8, that is, IS 4831 : 1968 'Recommendation on units and symbols for refrigeration'.

d) Accepted standard [8-5A(6)] refers to the Indian Standard given at serial number (6) of the list of standards given at the end of Subsection 5A of Part 8, that is, IS 14665 (Part 3/Sec 1 and 2) : 2000 'Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts'.

e) Accepted standards [8-6(2)] refers to the Indian Standards given at serial number (2) of the list of standards given at the end of Section 6 of Part 8, that is, IS 9537 (Part 3) : 1983 'Specification for conduits for electrical installations: Part 3 Rigid plain conduits for insulating materials' and IS 3419 : 1989 'Specification for fittings for rigid non-metallic conduits (*second revision*)'.

f) Accepted standard [9-1(1)] refers to the Indian Standard given at serial number (1) of the list of standards given at the end of Section 1 of Part 9, that is, IS 10446 : 1983 'Glossary of terms relating to water supply and sanitation'.

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INFORMATION FOR THE USERS ABOUT AVAILABILITY OF THE CODE IN GROUPS

For the convenience of the users, the National Building Code of India 2016 is available as a comprehensive volume as well as in the following five groups, each incorporating the related Parts/Sections dealing with particular area of building activity:

Group 1	**For Development/ Building Planning and Related Aspects**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 1	Definitions
		Part 2	Administration
		Part 3	Development Control Rules and General Building Requirements
		Part 4	Fire and Life Safety
		Part 5	Building Materials
		Part 10	Landscape Development, Signs And Outdoor Display Structures
			Section 1 Landscape Planning, Design and Development
			Section 2 Signs and Outdoor Display Structures
		Part 11	Approach to Sustainability
Group 2	**For Structural Design and Related Aspects**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 6	Structural Design
			Section 1 Loads, Forces and Effects
			Section 2 Soils and Foundations
			Section 3 Timber and Bamboo
			3A Timber
			3B Bamboo
			Section 4 Masonry
			Section 5 Concrete
			5A Plain and Reinforced Concrete
			5B Prestressed Concrete
			Section 6 Steel
			Section 7 Prefabrication, Systems Building and Mixed/ Composite Construction
			7A Prefabricated Concrete
			7B Systems Building and Mixed/ Composite Construction
			Section 8 Glass and Glazing
		Part 11	Approach to Sustainability
Group 3	**For Aspects Relating to Construction, and Asset/ Facility Management**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 7	Construction Management, Practices and Safety
		Part 11	Approach to Sustainability
		Part 12	Asset and Facility Management
Group 4	**For Aspects Relating to Building Services**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 8	Building Services
			Section 1 Lighting and Natural Ventilation
			Section 2 Electrical and Allied Installations
			Section 3 Air Conditioning, Heating and Mechanical Ventilation
			Section 4 Acoustics, Sound Insulation and Noise Control
			Section 5 Installation of Lifts, Escalators and Moving Walks
			5A Lifts
			5B Escalators and Moving Walks
			Section 6 Information and Communication Enabled Installations
		Part 11	Approach to Sustainability
Group 5	**For Aspects Relating to Plumbing Services and Solid Waste Management**	Part 0	Integrated Approach — Prerequisite for Applying Provisions of the Code
		Part 9	Plumbing Services (including Solid Waste Management)
			Section 1 Water Supply
			Section 2 Drainage and Sanitation
			Section 3 Solid Waste Management
			Section 4 Gas Supply
		Part 11	Approach to Sustainability

The information contained in different groups will serve the concerned professionals dealing with the respective areas. However, it is advisable that professionals essentially dealing with any of the above groups should also refer the other groups.

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NATIONAL BUILDING CODE OF INDIA

PART 7 CONSTRUCTION MANAGEMENT, PRACTICES AND SAFETY

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 7) covers construction project management; construction planning, site management and building construction practices; storage, stacking and handling of materials; and safety of personnel during construction operations for all elements of a building and demolition of buildings; and habitat and welfare requirements for workers. It also covers guidelines relating to repairs, retrofitting and strengthening of buildings.

The principles enunciated in the various sections of this Part are to be ultimately utilized and implemented in the physical construction of the buildings with the required infrastructure. This would require sound construction practices and efficient management thereof in order to ensure that the implementation of the project is carried out within the estimated cost and planned period to the required quality standards and in a safe and sustainable manner. Workers in large number, both skilled and unskilled, are engaged in the innumerable construction works. Due to increased tempo of such a building activity and large scale mechanization, hazards of accidents could increase considerably. It is, therefore, imperative that adequate safety rules are laid down for every phase of construction work. It is also important to give due cognizance to habitat and welfare requirements of workers at construction site. This Part also deals with these aspects.

Planning the various construction operations before hand and making adequate arrangements for procurement and storage of materials, and the machinery to get work done is as important as carrying out these construction operations in accordance with good practice. Lack of planning or defective planning may result in avoidable delay in the completion of work and consequently increased hazards from the point of view of fire, health and structural soundness. This Part covers provisions in this regard.

A construction project is an endeavour undertaken by a project team on behalf of owner/client to create a built facility suited to the defined functional objectives. From inception to commissioning, the project goes through various distinct stages leading to progressive achievement of project objectives. Each stage involves specific inputs, processes (both technical and managerial) and deliverables. Typically, the life cycle of a project from commencement to completion involves the following stages:

a) *Project formulation and appraisal* — Inception, feasibility and strategic planning;
b) *Project development* — Project brief development, planning and design, finalization of proposals, procurement strategy, construction documentation including tender drawings, working drawings, specifications, cost estimates, bills of quantities, procurement documents;
c) *Planning for construction* — Sequencing of project components, planning tools, resource planning and time cost trade off;
d) *Tender action* — Open competitive bidding/pre-qualification of agencies, issue of tender documents, evaluation of bids, negotiation if required and award of work;
e) *Construction* — Execution, monitoring, control, work acceptance; and
f) *Commissioning and handing over* — Contractual closeout, financial closeout, defect liability commencement, facility handing over.

The distinct features of a construction project include the temporary nature of the organizations involved, the evolutionary process of project deliverables during project development stages and the unique output of the built facility. As a result of these features, unless there is efficient and effective project management, a construction project is faced with challenges of uncertainties leading to time over-runs, cost over-runs, changes in project parameters, loss of quality and inability to meet the functional objectives. While technical soundness of a proposal is an important aspect of a construction project, the management aspects, which involve techno-legal, financial and other issues, have also a significant role in the success of a project. Therefore, management functions and technical processes in a construction project need to be integrated towards achieving project objectives. Top management commitment plays an important role in harmoniously achieving these project objectives. In some of the public sector projects, it may be necessary to share relevant information with public at large through appropriate

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means. The overall management of a building construction project is very important to ensure that the objectives of such a project are achieved through scope management, procurement management, time management, cost management, quality management, risk management, communication management, human resources management, safety, health and environment management and integration management. This Part, therefore, gives guidelines on these areas.

The first version of this Part was formulated in 1970, which was subsequently revised in 1983 and 2005. In the first revision, information regarding handling operations that is unloading, stacking, lifting, loading and conveying of building materials, was also given along with the storage practices. Additional information regarding the use of ladders; safety requirements for floor and wall openings, railings and toe boards; piling and other deep foundations; constructions involving use of hot bituminous materials; and erection of structural steel work and concrete framed structures, etc, were included.

In the second revision, the Section 1 'Construction Practices' of this Part, had been revamped to include the planning and management aspects. Further, provisions on construction using bamboo were also incorporated. The other important modifications incorporated in the second revision included comprehensive updating of the provisions with regard to stacking and storage of building materials and components, which were comprehensively covered in line with the revised IS 4082 : 1996 'Recommendations on stacking and storage of construction materials and components at site (*second revision*)'; addition of provisions of safety requirements of hoists/lifts for worker during construction; incorporation of aspects like preventive measures such as falling material hazards prevention, fall prevention, disposal of debris, fire protection, etc, with regard to safety at work site; addition of provisions regarding safety management at work sites; addition of a new section on 'Maintenance management, repairs, retrofitting and strengthening of buildings', covering aspects like maintenance management, prevention of cracks, and repairs and seismic strengthening of buildings; and updating of safety provisions with respect to demolition of buildings.

As a result of experience gained in implementation of 2005 version of this Part and feedback received as well as in view of formulation of new standards in the field of construction project management and construction practices and revision of some existing standards, including those on safety, a need to revise this Part was felt. This revision has, therefore, been prepared to take care of these aspects. This Part has been divided into six sections as follows, under which all technical provisions relating to their subject areas, have been given:

Section 1 Construction Management
Section 2 Construction Planning and Site Management
Section 3 Construction Practices
Section 4 Safety in Construction
Section 5 Repairs, Retrofitting and Strengthening of Buildings
Section 6 Habitat and Welfare Requirements for Workers

The significant changes incorporated in this revision include:

a) This Part has been divided into six Sections under which the provisions have been rearranged in a logical sequence;
b) Provisions on construction project management have been detailed which also now includes project formulation and appraisal.
c) Safety provisions with respect to scaffolding, piling and other deep foundations, blasting and related drilling operations, and construction involving use of hot bituminous materials have been updated;
d) A new clause on habitat and other welfare requirements for construction workers has been introduced;
e) A new clause on urban/city roads planning and construction, has been added;
f) A new clause on temporary works has been included;
g) Provisions on construction using bamboo has been shifted to Part 6 'Structural Design, Section 3B Bamboo, and a reference to the same has been given in this Part;
h) Provisions on maintenance management has been shifted to Part 12 'Asset and Facility Management' of the Code and a reference to the same has been given in this Part; and
j) References to all the concerned Indian Standards have been updated.

Users are encouraged to employ suitable construction management software as an aid to implement provisions of

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this Code. The guidelines may be applicable in general to all construction projects. However, for smaller projects, the applicability of various provisions may be decided appropriately by the parties concerned.

Provisions on sustainable building construction practices are covered in Part 11 'Approach to Sustainability' of the Code.

The information contained in this Part is largely based on the following Indian Standards and Special Publications:

IS 3696	Safety code for scaffolds and ladders:
(Part 1) : 1987	Scaffolds
(Part 2) : 1991	Ladders
IS 3764 : 1992	Code of practice for excavation work (*first revision*)
IS 4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
IS 4130 : 1991	Safety code for demolition of buildings (*second revision*)
IS 4912 : 1978	Safety requirements for floor and wall openings, railing and toe boards (*first revision*)
IS 5121 : 2013	Code of safety for piling and other deep foundations (*first revision*)
IS 5916 : 2013	Safety code for construction involving use of hot bituminous materials (*first revision*)
IS 7205 : 1974	Safety code for erection of structural steel work
IS 7969 : 1975	Safety code for handling and storage of building materials
IS 8989 : 1978	Safety code for erection of concrete framed structures
IS 13415 : 1992	Safety code for protective barrier in and around buildings
IS 13416	Recommendations for preventive measures against hazards at work places:
(Part 1) : 1992	Falling material hazards prevention
(Part 2) : 1992	Fall prevention
(Part 3) : 1994	Disposal of debris
(Part 4) : 1994	Timber structures
(Part 5) : 1994	Fire protection
IS 13430 : 1992	Code of practice for safety during additional construction and alteration to existing buildings
IS 15883 (Part 1) : 2009	Guidelines for construction project management: Part 1 General
IS 16601 : 2016	Guidelines for habitat and welfare requirements for construction workers

A reference to SP 62 : 1992 'Handbook on building construction practices (excluding electrical works)' and SP 70 : 2001 'Handbook on construction safety practices', may also be made.

All standards, whether given herein above or cross-referred to in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Code is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part.

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NATIONAL BUILDING CODE OF INDIA

PART 7 CONSTRUCTION MANAGEMENT, PRACTICES AND SAFETY

1 SCOPE

1.1 This Code (Part 7) covers construction project management; construction planning, site management and building construction practices; storage, stacking and handling of materials; and safety of personnel during construction operations for all elements of a building and demolition of buildings; and habitat and welfare requirements for workers. It also covers guidelines relating to repairs, retrofitting and strengthening of buildings.

1.2 The provisions in respect of sustainable building construction practices are covered in Part 11 'Approach to Sustainability' of the Code which shall be used in conjunction with this Part.

1.3 Provisions relating to maintenance management are covered in Part 12 'Asset and Facility Management' of the Code which has been referred to in this Part.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply, and for other terms those given in the accepted standards [7(1)] shall apply.

2.1 Authority Having Jurisdiction

The authority which has been created by a statute and which for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.2 Definitions Relating to Safety in Construction

2.2.1 *Construction Equipment* — All equipment, machinery, tools and temporary retaining structures and working platforms, that is, tools, derricks, staging, scaffolds, runways, ladders and all material, handling equipment including safety devices.

2.2.2 *Floor Hole* — An opening measuring less than 300 mm but more than 25 mm in its least dimension, in any floor, platform, pavement, or yard, through which materials but not persons may fall; such as, a belt hole, pipe opening or slot opening.

2.2.3 *Floor Opening* — An opening measuring 300 mm or more in its least dimension, in any floor, platform, pavement or yard through which person may fall; such as hatch way, stair or ladder opening, pit or large manhole.

2.2.4 *Guard Railing* — A barrier erected along exposed edges of an open side floor opening, wall opening, ramp, platform, or catwalk or balcony, etc, to prevent fall of persons.

2.2.5 *Materials Handling Hoists* — A platform, bucket or similar enclosure exclusively meant for the lifting or lowering of construction material, the hoists being operated from a point outside the conveyance.

2.2.6 *Pile Rig* — The complete pile driving equipment comprising piling frame, leader, hammer, extractor winch and power unit. Complete pile driving rig may be mounted on rafts or pontoon or rails. Pile rig may also be a mobile unit mounted on trailers or trucks, or a special full revolving rig for raking piles.

2.2.7 *Platform* — A working space for persons, elevated above the surrounding floor or ground, such as balcony or platform for the operation of machinery and equipment.

2.2.8 *Scaffold* — A temporary structure consisting of standards, putlogs, ledgers, generally of bamboo, *Ballies*, timber or metal to provide a working platform for workers and materials in the course of construction, maintenance, repairs and demolition, and also to support or allow hoisting and lowering of workers, their tools and materials.

2.2.9 *Toe Board* — A vertical barrier erected along exposed edge of a floor opening, wall opening, platform, catwalk or ramp to prevent fall of materials or persons.

2.2.10 *Wall Hole* — An opening in any wall or partition having height of less than 750 mm but more than 25 mm and width unrestricted.

2.2.11 *Wall Opening* — An opening in any wall or partition having both height of at least 750 mm and width of at least 450 mm.

3 GENERAL

3.1 A general overview of construction project management and information regarding the applicable tools and techniques are covered in Section 1 'Construction Management' of this Part, which also demarcates various stages of a construction project and activities thereunder. Section 1 gives brief guidelines on project formulation and appraisal, and various construction project management functions; and for detailed guidelines on each of these, gives reference to the available good practices.

Construction planning and site management, plays an

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important role in smooth progress of a building construction activity and are covered in Section 2 'Construction Planning and Site Management'. The knowledge of actual technical provisions in regard to practices relating to various building components starting from sub-structure to super-structure, play a key role in achieving the quality of building construction. Also, temporary enabling works; proper stacking and storage of materials; and well planned handling operations, have important role in proper, safe and smooth progress in construction work at site. The provisions in respect of these are covered in Section 3 'Construction Practices'.

The objectives of sound construction of buildings having requisite quality, durability and finish has to be duly dovetailed with the goals of safety whether during construction of a new building or addition/alteration to an existing building part thereof or during demolition of an existing building. Section 4 'Safety in Construction' covers provisions to these effects.

Section 5 'Repairs, Retrofitting and Strengthening of Buildings' covers repair, retrofitting and strengthening of existing buildings and Section 6 'Habitat and Welfare Requirements for Workers' deals with habitat and other welfare requirements for construction workers at site.

3.2 The objective of universal design and accessibility is to ensure that all users, including those with disabilities and elderly people are able to access all the facilities within the built environment including in the public buildings, on an equal basis. Requirements for accessibility in built environment for the elderly and for persons with disabilities as given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code shall be complied with at all stages of the construction project.

SECTION 1 CONSTRUCTION MANAGEMENT

4 CONSTRUCTION PROJECT MANAGEMENT

4.1 General

4.1.1 A project is generally a non-recurring task having a definable beginning and end, with a definite mission and has a set of objectives and achievements. Project management is application of knowledge, skills, tools and techniques to achieve the objectives of a defined project with the aim to ensure that a project is completed within the scheduled time, authorized cost and to the requirement of quality standards. Construction project management refers to such project management when applied to construction of built facility. Project objectives depend on the requirements of the built facility. From the point of view of construction project management, project objectives may be defined in terms of scope, time, cost and quality. This may usually take place in project appraisal stage and shall be done in accordance with the good practice [7(2)]. Information and guidelines given under **4.1.2** to **4.1.6** shall be appropriately utilized under different stages of construction project.

4.1.2 *Stakeholder*

Stakeholder is a person, group of persons or organizations who are actively involved in the project or those who have an interest in the success of a project and its environment. Generally in a construction project, besides the owner/client, the project manager, consultants, construction agencies and the users are the stakeholders. In addition, depending on the nature of the project, there may be other stakeholders such as financer, government and public at large.

4.1.3 *Construction Project Life Cycle*

Construction project life cycle consists of project formulation and appraisal, project development, planning for construction, tender action, construction, and commissioning and handing over, as main stages. These stages involve defined decisions, deliverables and completion of mile-stones for control of project, ensuring that the adverse impact of uncertainties is overcome at each stage in the progress. Accordingly, the responsibilities of project team should be defined and measured for acceptance, and liabilities determined objectively.

Project objectives, drawn out of feasibility established in the appraisal stage, are achieved progressively through each of the project life cycle stages. The stage-wise break-up of project objectives, tasks, compliance and authorization to proceed further in the next stage should be structured comprehensively through various stages of life cycle. Each stage of construction project life cycle may be considered as a subproject, thus making overall complexities of a project more manageable.

A typical construction project life cycle is given in Fig. 1.

4.1.4 *Construction Project Delivery Models*

Project delivery model determines the manner in which the project is planned, designed, executed and contract administration carried out. It also determines the contractual relationships between the owner/client, design consultants and construction agency. The delivery model shall define the span of control and role and responsibilities of each of the above parties. The main types of project delivery models that are in vogue in construction projects are: (a) Traditional design-bid-build, (b) Design-build with variants, (c) Turn-key and (d) Build, operate and transfer and its variants. Each

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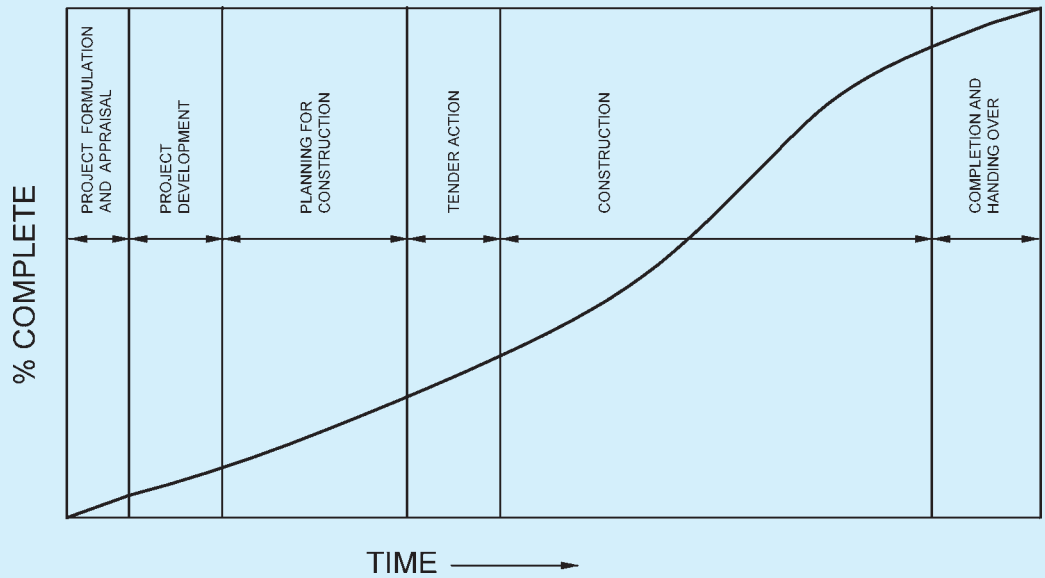


FIG. 1 TYPICAL CONSTRUCTION PROJECT LIFE CYCLE

of the delivery models can adopt different types of contracts depending upon the suitability of the contract type in relation to the nature and type of projects, project objectives and other project specific considerations.

4.1.5 *Construction Methodologies and Techniques*

Suitable construction methodologies and techniques, such as, conventional, prefabrication, systems building approach, mixed/composite construction, mechanization in construction and other innovative technologies, shall be defined considering design principles adopted and also considering the project objectives in terms of factors, like, scope, time, cost and quality requirements. Method statement may be made for all critical items of work.

4.1.6 *Organizational Structures*

Organizational structure depends on the project delivery model. As an example, a typical organization chart for Design-Bid-Build model is given in Fig. 2.

4.1.6.1 *Construction project management organizational teams*

For any given project delivery model, an appropriate organizational structure shall be selected so as to facilitate constitution of teams across various agencies involved. Such teams are fundamental functional units generally specific to each of the life cycle stages of a project.

Health, Safety and Environment (HSE) and quality set up shall directly report to the Project Manager.

4.2 Stages of a Construction Project

4.2.1 Typically a construction project (whether small or large) may be considered to involve the following distinct broad stages:

a) Project formulation and appraisal stage:
   1) Inception,
   2) Feasibility, and
   3) Strategic planning.
b) Pre-construction stage:
   1) Project development,
   2) Planning for construction, and
   3) Tender action.
c) Construction stage, and
d) Commissioning and handing over stage.

4.2.2 *Project Formulation and Appraisal Stage*

For successful management of construction projects, the earlier stages when the construction project is conceived, formulated and its feasibility assessed, leading to decision to implement the project, are equally important. The guidelines given in the good practice [7(2)] should be employed during project formulation and appraisal stage of a construction project.

NOTE — This stage of a construction project is basically the preliminary stage covering activities up to the stage of preparation of proposals for obtaining approval for implementing the project including financial approval and includes inception, pre-feasibility, feasibility, related project strategic planning and viability assessment and review prior to approval of project.

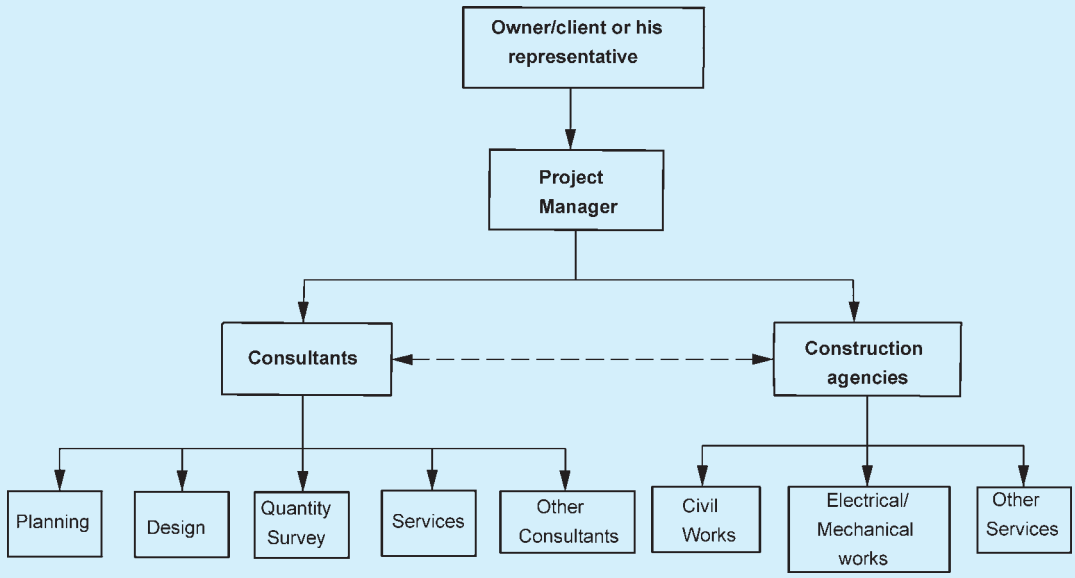
For all other above stages, the relevant construction management function guidelines given in **4.3** should be employed for achieving the intended objectives.

4.2.3 *Pre-Construction*

4.2.3.1 *Project development*

This shall involve the following:

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NOTE — 'Consultants' may cover in-house teams or outside consultants.

FIG. 2 TYPICAL ORGANIZATION STRUCTURE FOR DESIGN-BID-BUILD MODEL

a) Formalization of design brief;
b) Site survey and soil investigation;
c) Hazard risk vulnerability analysis;
d) Alternative concept designs with costing and finalization;
e) Preliminary designs and drawings;
f) Development of design of each discipline and their integration;
g) Obtaining statutory approvals;
h) Selection of construction methodology;
j) Preliminary cost estimates;
k) Detailed planning and design of each discipline;
m) Construction working drawings and related specifications with integration of engineering inputs of all concerned disciplines;
n) Detailed cost estimates;
p) Detailed specifications and bills of quantities; and
q) Tender documents.

Peer review/proof checking of the drawings/designs/ estimates shall be done in case of important projects, depending upon their complexity and sensitivity. Environment impact analysis and social impact analysis shall be done in applicable cases.

4.2.3.2 *Planning for construction*

The following aspects shall be considered:

a) Sequencing of project components,
b) Planning tools:
   1) Work breakdown structures (WBS),
   2) Bar charts, and
   3) Network techniques and scheduling.
c) Resource planning, and
d) Time cost trade off.

4.2.3.2.1 *Sequencing of project components*

Methodology of construction shall be detailed before the start of the project. Sequencing of project components shall be done on the basis of methodology adopted and availability of resources. This shall be reviewed during the progress of the project and revised, if necessary.

4.2.3.2.2 *Planning tools*

The planning tools described below may be employed for effective management of a construction project:

a) *Work breakdown structure (WBS)* — The WBS shall identify the total scope of works involved in the project and shall form the basis for the development of detailed project schedule. Through WBS, the project shall be subdivided into major subdivisions (work packages) and each major subdivision shall be further subdivided into additional levels as required up to the level of activities that could form the basis for monitoring and control of project performance in terms of time, cost and quality parameters. WBS shall provide activity listing with associated cost account codes for the preparation of project schedule either by bar charts or by network diagramming methods.
b) *Bar chart* — Bar chart is the simplest form of

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project scheduling and used for small and complex projects and in preliminary planning and tender-stages of major projects. A typical bar chart form of project schedule depicts the various activities on a calendar time scale in the form of bars in their relative positions with start and finish dates and length of bar indicating probable activity duration. Linked bars represent the interdependencies between the activities. Bar chart type of schedule shall be used to comprehend, summarize and display the results of complex project network analysis and further monitoring and controlling process.

c) *Network techniques* and *scheduling*

1) *Network diagramming methods* — Network based project schedule shall be used for major and complex projects. In this method, the network of project activities identified through WBS is developed incorporating their logical relationships and interdependencies. The two available approaches for network diagramming techniques are arrow diagramming method (ADM) and precedence diagramming method (PDM).

2) *Network analysis and scheduling* — The project network incorporating the activity durations and logical relationships shall be analyzed with forward and backward pass schedule calculations to establish early and late start and finish time of activities with their available floats, critical activities, critical path and overall project duration. The project schedule is prepared in terms of calendar dates of start and finish of activities with available floats. The network schedule shall also be presented in the form of linked bar chart or in tabular format.

For details on network preparation and analysis, reference shall be made to good practices [7(3)]. Network schedule shall be prepared for all disciplines and they shall be integrated into a master control schedule.

4.2.3.2.3 *Resource planning*

This shall involve the following:

a) *Resource allocation* — The feasibility of the network shall be checked with respect to manpower, equipment, materials, other resources required at the site.

b) *Resource levelling* — It shall be done by re-allocating the slack resources from non-critical path to critical path activity in order to obtain a reduction of time or by shifting the activities within the floats available with them, to obtain optimum uniform resource requirements.

c) *Resource schedule* — Schedule of following resource requirements with respect to time shall be prepared on the basis of network developed and kept in the database for project control purposes:

1) Technology,
2) Manpower:
   i) Technical staff,
   ii) Skilled labour,
   iii) Unskilled labour,
3) Machinery,
4) Materials, and
5) Cash flow.

Resource schedule shall be prepared separately for client, consultant and construction agency.

4.2.3.2.4 *Time cost trade off*

Time cost trade off analysis shall be done to obtain a minimum total cost of the project within the specified time. This shall be done taking into consideration direct cost and indirect cost of the project.

4.2.3.3 *Tender action*

4.2.3.3.1 *Preparation of tender documents*

The bill of quantities, specifications, drawings and conditions of contract should be prepared on the basis of design and details finalized in project proposal development stage (*see* **4.2.3.1**) keeping in view the construction project delivery model selected. The format, terminologies and terms and conditions should be as per the standard engineering practices. In case of any special item or condition, the same shall be described clearly to avoid any ambiguity.

4.2.3.3.2 *Selection of construction agency*

Selection of construction agency shall be done by either:

a) *Open competitive bidding* — In this case, tender notice should be publicized adequately to obtain competitive tenders from competent agencies for the project; or

NOTE — Electronic tendering could also be considered.

b) *Limited competitive bidding* — In large, specialized and important works, prequalification of contractors shall be done considering their financial capability, bid capacity, experience of similar type of works, past performance, technical staff, and plants and machinery available.

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4.2.3.3.3 *Bid evaluation, negotiation and award of work*

After due evaluation and negotiation with the bidders, if required, the work shall be awarded to the construction agency based on competitive technical and financial bids.

4.2.4 *Construction*

This is one of the most important stages of construction management where pre-construction stage outputs are realized into physical tangible form within the constraints of time and cost. The intent or need for functional and physical characteristics, defined in the pre-construction stage outputs through specifications, drawings and consolidated project brief is realized through various construction project management functions described in **4.3** and particularly through procurement management, time management, cost management, quality management and health, safety and environment management.

4.2.5 *Commissioning and Handing Over*

After all construction activities of the project are complete as per specifications and designs, project commissioning and handing over stage follows. It shall need the compliance of the following:

a) Clearing of site,
b) Removal of all defects at the time of completion and during defect liability period,
c) Preparation of list of inventories,
d) Certification and settlement of construction agency's final bills for payment,
e) Obtaining completion certificate from local government bodies/departments,
f) Preparation of maintenance manual,
g) Performance compliance verification of built facility,
h) Handing over all other required documents, including guarantees, to the client/owner,
j) Restoration of surroundings, and
k) Preparation and handing over all as-built drawings.

4.3 Construction Project Management Functions

Construction project management consists of number of processes and these can be grouped under the following management functions:

a) Scope management,
b) Procurement management,
c) Time management,
d) Cost management,
e) Quality management,
f) Risk management,
g) Communication management,
h) Human resources management,
j) Health and safety management,
k) Sustainability management,
m) Integration management, and
n) Other management processes.

The project management functions briefly described below may be employed for effective management of construction project during its different stages as applicable. Some of the processes may, however, overlap more than one function.

4.3.1 *Scope Management*

It should be ensured that project concept, details and functions which are established and recorded during the finalization stage, remain same except minor changes and/or authorized variations. Scope management includes the processes of scope planning, scope definition, scope verification, scope monitoring, and change control.

Scope planning, scope definition and scope verification are associated with the preconstruction phase of the project. Scope monitoring and change control are critical to the construction/installation stage in order to control time and cost over-runs. The work break down structure of the project shall be the basic tool for defining the scope baseline. Scope control should aim to identify factors influencing scope change, determine the impact of scope changes and establish the system for scope change approval and revision of scope baseline. Accordingly, a detailed scope management plan should be drawn to lay down all the necessary practices including technical and organizational interfaces.

For detailed guidelines, reference shall be made to good practice [7(4)].

4.3.2 *Procurement Management*

Procurement management includes processes for purchase of materials, equipment, products, soliciting services of consultants and engaging agencies for execution of works under a contract. Project procurement processes, which depend on type of project delivery model include identification of procurement needs, preparation for procurement, soliciting proposals, selection of suppliers/consultants/ works contractors, administering of contract, contract management and closure of contract. Project manager is charged with the responsibility to help structure and develop contract to suit the specific needs of the project. As contract, which is an output of project procurement management processes, is a legal document, the procurement processes should follow detailed

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procedures with adequate review and stakeholder appraisal opportunities.

One of the fundamental issues in construction projects, managed through project managers, is to determine what needs may be met by procuring products, services and works from external agencies and what should be accomplished by the project team. This decision is best arrived at the earlier stages of the project (so that the opportunities of procurement initiation at earlier stages is not lost) and reviewed at each of the subsequent life cycle stages of the project. Such decisions should draw inputs from the time, cost, quality and scope management processes. Various procurement routes should be analysed on their suitability to both time and cost criteria of project. As a strategy for procurement, a project procurement management plan should be developed to document: contract types to be used; procurement documents; coordination of procurement with schedules; constraints and assumptions; risk mitigation activities (performance bonds, insurances, etc); and pre-qualification of suppliers. In addition, specifications, quality standards, performance data at work locations, etc, which are part of project scope statement, should be described. Inventory management plays an important role in the procurement management process.

Provision of establishment of suitable dispute redressal system should be inbuilt to take care of any disputes that may arise.

For detailed guidelines, reference shall be made to good practice [7(5)].

4.3.3 *Time Management*

Time management aims to complete the project within the stipulated time period. Time management essentially involves the following processes:

a) Defining project scope in the form of work breakdown structure to generate activity identification and listing,
b) Activity duration estimating,
c) Activity sequencing with interactivity dependencies,
d) Project schedule development, and
e) Project schedule control.

Work breakdown structure should be used as a tool to prepare the project schedule by defining the project scope and identifying and listing of the activities in the work packages. For the quantum of work involved in the activities, the activity durations are estimated based on the standard productivity norms for different trades of work. Past-documented experience and expertise should also be used for determination of the activity durations with the construction technology adopted and manpower and equipment resources used. Based on the construction methodology proposed with the consideration of project specific constraints, the sequencing and interdependencies of the activities are determined and the graphical representation of activities in the form of network should be prepared. The network thus prepared should be analysed to develop the project schedule with information on early and late start and finishing of activities with their available floats and the critical path/critical activities on the network. Incorporating the calendar dates, the baseline schedule may be finalized with the incorporation of milestones for subsequent schedule monitoring and control processes.

During the construction stage, schedule monitoring involves methods of tracking and comparing the actual schedule with the baseline schedule and schedule control activities should ensure to remove deficiencies and slippages corrected to acceptable levels.

Project scheduling and monitoring is a dynamic process and periodic schedule updating should be done for effective monitoring and control process. In the process, the status of each activity should be examined. For completed activities, actual durations utilized, are incorporated; and for activities in progress, balance to complete revised durations and estimated finish dates are determined and incorporated. If the actual schedule lags behind the baseline schedule, various options should be considered to control and bring back the schedule to acceptable levels. The possible control actions, which may be considered, are: possible reduction in activity duration of future activities with alternate technology options, increasing the resources, alteration in the construction logic and activity sequencing, etc.

For detailed guidelines, reference shall be made to good practice [7(6)].

4.3.4 *Cost Management*

The objective of the project cost management is to ensure that the project is completed within the authorized budget. The major processes involved in the cost management are: resource planning, cost estimation, cost budgeting/cost planning and cost monitoring and control. The resource planning involves determination of various types of resources, such as appropriate technology, workforce, materials, equipment and infrastructure facilities, their quantum and their requirements during different stages of the project. Preliminary cost estimate with defined scope of work is required for obtaining the project sanction. Detailed item wise cost estimates with bill of quantities and specifications should be made for tendering and subsequent project execution. The type of contract

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adopted such as item rate, percentage rate, lump sum and cost plus, influences the cost management strategy.

Most of the cost optimization techniques through value engineering studies are achieved during the preconstruction stage of the project. Value engineering is a useful technique for application in cost management. It is a systematic multi-disciplinary effort directed towards analyzing the functions of project or item for the purpose of achieving the best value at the lowest overall life cycle project cost. It is an established technique for determining value based decisions rather than cost reduction based on change in specifications. Suitability of construction techniques, selection of equipment for specific purposes, considering alternative materials and other design changes are some of the areas of application of value engineering.

During construction stage, the efforts are more on control mode for adherence to the budgeted cost. For the purpose of cost control during execution, the time based cost baseline of the project which forms the basis for the measurement and monitoring of cost performance, should be generated. The cost baseline is generated by allocating the overall cost estimate to individual project activities based on the project schedule. Using the cost baseline, the cost control, which comprises the following, should be exercised:

a) Periodical cost reporting,
b) Comparison of the actual cost against the planned cost,
c) Obtaining early warning for corrective actions,
d) Control and monitoring cost changes,
e) Forecasting of final cost at completion based on cost trend and cost changes, and
f) Modification of the cost baseline for authorized cost changes and preparation of revised estimates.

For detailed guidelines, reference shall be made to good practice [7(7)].

4.3.5 *Quality Management*

Quality management in construction aims to achieve required functional and physical characteristics of a constructed facility through management actions including planning, direction and control. Quality is the key determinant of requirements which is expressed through drawings and specifications. Main function of quality management is to achieve quality objective of satisfying requirements through performance evaluation of construction processes and ensure that they are directed towards overall quality. Quality management during construction stage assumes that the design and specifications comprehensively incorporate requirements of users and other stakeholders. Prior to setting out for the construction, the client should completely understand the implications of changes to the design and specifications during the construction stage, which may affect quality.

Although quality is an all-encompassing concept which also has bearing on time and cost aspects, the specific scope of quality management may be limited to its key functions of quality planning, quality assurance and quality control. Quality planning refers to the identification of relevant quality standards and determining how to satisfy them. Quality assurance activities include consistent evaluation of project performance to provide confidence that the project satisfies the relevant quality standards. Quality control monitors project results related to the compliance to quality standards and identifying means to eliminate non-conformity.

On-site operations constitute most of the construction processes. Scope of quality management for on-site operations may be categorized broadly in three distinct stages. In the receiving stage, materials and supplies are inspected and tested for conformance to the specified standards. During 'in-process stage', materials and supplies are processed to form project product components wherein process control ensures conformance to the specified standards. In the 'final stage', inspections and tests monitor the functional and physical performance of the product/service to ensure that they satisfy the requirements.

Planning being an integral part of the quality management, may also consider efficient site layout and its management for on-site operations. In addition to time and cost implications of the site management, the quality performance improves by efficient organization of activities by way of providing adequate and appropriate conditions for the work processes. Site management needs to consider construction technology constraints with reference to aspects related to space availability such as permanent services, access to site, temporary services, location of material stores, stacking and storage areas and plants, fencing and other temporary structures.

The various organizations connected with the project should have their own quality management systems.

For detailed guidelines, reference shall be made to good practice [7(8)].

4.3.6 *Risk Management*

Project risks have an impact on the project objectives and need a planned response. Project risk management processes ensure proper planning, identification, analysis, monitoring and control to the best interest of the project.

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Risk management planning processes develop an approach to risk management activities which include planning, execution and monitoring. A risk management plan should define lead and support role responsibilities of project team in relation to management, budgeting, risk responsive scheduling, classification of risk activities based on risk break-down structure and explanation of probability and impact for risk context.

Risk response planning determines actions required for reducing impact of risks. Risk responses are established and assigned to appropriate project participants. Suitable risk mitigation measures should be evolved for identified risks.

For detailed guidelines, reference shall be made to good practice [7(9)].

4.3.7 *Communication Management*

For communication management, Management Information System (MIS) is used as an important tool for systemized approach to furnish information. It comprises a system that collects, stores, sorts and analyses data to generate and communicate information. It may be a combination of manual and computerized systems.

At the construction stage of a project, there are many agencies involved like client, architect, engineer, project manager, various consultants, material suppliers, construction agencies and sub-contractors. Each agency is divided into top level management taking policy decisions, middle level management monitoring the project and lower level management involved in day to day operations of the project.

Each level of management requires information of varying details, at different periodicities and in different formats. Project progress information flows from lower level to the top level management and policy decisions flow from top level to the lower level management.

MIS integrates the work and information flow within each agency and flow of information between different agencies.

In construction stage of the projects, the information may be in the form of data reflecting status of project in terms of actual execution time for each activity, cost incurred, resources used, quality control, material management, bills, organization management and other administrative aspects like disputes that may come up. This data should be analysed to understand the overall progress achieved and to update schedules of the project.

Basic objectives of MIS of a construction project may be summarized as:

a) Providing benchmark against which to measure or compare progress and costs, like time network schedules, cost estimates, material and labour schedules, specifications, working drawings.
b) Providing an organized and efficient means of measuring, collecting, verifying and reflecting the progress and status of operations on the project with respect to progress, cost, resources and quality.
c) Providing an organized, accurate and efficient means of converting the data from operations into information.
d) Reporting the correct and necessary information in the required format and at the required level of detail to managers at all levels and to the supervisors.
e) Identifying and isolating the most important and critical information at various stages to be communicated to the managers and supervisors for taking decisions.
f) Communicating the information to the managers and supervisors in time so that decisions may be taken at the right time.

Total MIS configuration of the construction project may be divided into the following modules:

1) Planning and scheduling module,
2) Cost control and accounting module,
3) Trend and forecast module,
4) Project administrative and financial module, and
5) Historical and documentation module.

All modules should be interlinked in flow of information and generation of reports.

For large public projects, suitable mechanism may be established for communication of relevant information to public at large.

For detailed guidelines, reference shall be made to good practice [7(10)].

4.3.8 *Human Resource Management*

All construction projects involve large number of skilled/unskilled persons. Human resources in a project should be adequately qualified, trained and competent.

Quality of construction work depends on the quality of labour resource. For skilled and un-skilled labour, the requirement for technical knowledge, skill and general awareness are varied for different construction processes. Labourers are required to understand their respective responsibilities especially towards the work. Therefore, construction management practices should emphasize on development of competence of this critical human resource through training programmes.

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The critical activities should be identified from the point of view of technological innovations, workmanship and environmental conditions which determine labour behaviour and performance. In each construction project, there are certain work related peculiarities which call for job specific orientation. There should be a clearly defined competence requirement for the workers. Progressively, a formal training or a certified course undertaken should be a preferred selection criterion for the workers. All efforts should also be made to impart on site skilling/training of construction workers for specific tasks. A periodic review of the performance may be made to establish the nature of training required and methods for imparting training. There is a need to address the motivational aspects, for better performance.

For detailed guidelines, reference shall be made to good practice [7(11)].

4.3.9 *Health and Safety Management*

4.3.9.1 Health management issues include looking into the risk factors to health of construction personnel and providing hygienic conditions at construction sites and methods of their management. It includes managing,

a) occupational/physical health hazards.
b) short term as well as long-term ill effects of the activities and the working environment of the construction sites.
c) provision of personal protective equipment required for specific health hazards.
d) laying down of construction hygiene control methods.

4.3.9.2 Safety management issues include managing work processes, equipment and material handling at site for striving to achieve zero accident status at site. For prevention and management of accidents, a proper organizational and administrative mechanism is required. Following steps should be taken for achieving the same:

a) Laying down of safety regulations or mandatory prescriptions concerning different work processes.
b) Standardization of work processes and management actions.
c) Regular and stipulated inspection of works and machinery/equipment for enforcement of mandatory regulations.
d) Providing education and training to workers on safety issues.
e) Publicity and appeal to develop safety consciousness.
f) Insurance of built facilities, construction personnel and third party.
g) Regular safety audit of construction sites and post audit actions.
h) Effective post-accident action including accident analysis and reporting.
j) Effective post-accident management including corrective measures to avoid repetition of such accidents.

Safety Officer shall be appointed in accordance with the concerned provisions of the *Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act*, 1996. Safety officer who is posted at a medium to major construction site shall:

1) Look after the safety of the personnel, safe handling of materials and machinery, safe work practices and standard operating procedures.
2) Be responsible for compliance of all statutory obligations of the employer in regard to safety of personnel and structures.
3) Guide and assist the site managers/engineers to make their sites safe and accident free.
4) Train personnel in construction safety, conduct safety surveys and design suitable documents for recording and promoting safety on sites and in the construction industry.
5) Arrange for safety briefing for all the persons entering the construction area.

For detailed guidelines, reference shall be made to good practice [7(12)].

4.3.10 *Sustainability Management*

4.3.10.1 Sustainability management issues include the following:

a) Minimizing adverse environmental impact of activities, products and services.
b) Limiting any adverse impact within the laws/ prescribed norms and their monitoring.
c) Safety of environment while working with hazardous materials and maintaining material safety data sheets.
d) Management of disposal of waste from the construction sites.
e) Considering positive environmental contribution particularly after completion of construction.
f) Mechanism to review concerns of interested parties.

For detailed guidelines, reference shall be made to good practice [7(13)].

4.3.11 *Integration Management*

Integration management aims to provide processes

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necessary for coordination amongst various organizations and their teams involved. It ensures that various organizational teams perform in an integrated manner, with their actions coordinated to the mutual interests towards the project. Integrated management processes provide opportunities for resolving conflicts and competing interests through appropriate tradeoffs. Integration is necessary where processes interact, especially when process responsibilities belong to different organizational groups. Such process interactions need organizational interfaces to be defined and resolved at an overall level.

Integration management may also be required for specific situations when impact of one management function is a cause for concern for other management functions. For example, if there is a time delay in performing a particular construction process, it may often have impact on the cost aspects of not only that process but other processes involving other organizational groups; the rescheduling may affect coordination amongst performing groups in the down-stream processes and activities.

For detailed guidelines, reference shall be made to good practice [7(14)].

SECTION 2 CONSTRUCTION PLANNING AND SITE MANAGEMENT

5 PLANNING ASPECTS

Construction planning aspects aim to identify and develop various stages of project execution on site which should be consistent with the management considerations. Planning aspects evolve out of the objectives of project and requirements of the final completed constructed facility. These objectives could relate to the time constraints, cost considerations, quality standards, safety standards, environmental considerations and health considerations. Construction practices would, then have to satisfy these objectives during construction phase of the project.

Having established objectives of the construction phase, planning determines processes, resources (including materials, equipment, human and environmental) and monitoring system to ensure that the practices are appropriately aligned. Adequate knowledge about preconstruction phase evolution of project, especially related to customer's requirements, is an essential prerequisite for construction planning.

5.1 Preconstruction Phase

5.1.1 Besides the design aspects, preconstruction phase should also address all the issues related to the implementation of the design at the site through suitable construction strategy. During the design stage, the site conditions should be fully understood with anticipated difficulties and avoid the risk of subsequent delays and changes after the construction has started.

5.1.2 The selection of construction methods, building systems and materials, components, manpower and equipment and techniques are best done in the preconstruction phase. Such selection is influenced by the local conditions like terrain, climate, vulnerability for disasters, etc.

5.1.3 Construction in busy localities of cities needs special considerations and meticulous planning due to restricted space, adjoining structures, underground utilities, traffic restrictions, noise and environmental pollution and other specific site constraints.

5.1.4 The constructability aspects of the proposed construction methods needs to be carefully evaluated at the planning stage to ensure ease of construction besides optimizing the construction schedule and achieving quality, reliability and maintainability of the constructed facilities.

5.1.5 Construction practices in hilly regions needs to take into considerations the problem of landslides, slope stability, drainage, etc, besides ensuring no adverse impact on the fragile environmental conditions.

5.1.6 Durability of constructions in corrosive atmospheric conditions like coastal regions and aggressive ground situations with high chlorides and sulphates should also be taken care of with appropriate construction practices.

5.1.7 Construction practices in disaster prone areas need specific planning. The type of construction, use of materials, construction techniques require special considerations in such areas.

5.1.8 Adverse weather conditions have strong bearing on construction phase. Situations wherein constructions are to be carried out in adverse weather conditions, such as heavy and continuous rain fall, extreme hot or cold weather, dust storms, etc, the practices have to address the relevant aspects. Accordingly, suiting the site conditions, the design and field operations should be adapted or redefined based on considerations, such as the following:

a) Site layout which enables accessibility in adverse weather.
b) Adequate protected storage for weather sensitive materials/equipment.
c) Protection to personnel from extreme hot/cold conditions.
d) Scheduling to allow maximization of outdoor activities during fair weather conditions.
e) Special design and construction provisions for

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activities in extreme temperature conditions like hot or cold weather concreting, stability of false work in extreme wind conditions (gusts).

f) Adequate lighting for shorter days in winter/ night work.

g) Design for early enclosure.

5.2 Resource Planning

Resource planning aims to identify requirement, availability and regulatory/control processes related to resources. Resource planning is a generic expression but the actual process of planning is specific to the resources considered (*see also* **4.2.3.2.3**).

In construction phases, the resources could be categorized as materials, manufactured products, equipment for construction, installation and fabrication, human resources as a part of overall organization, information resources such as reference standards and other practice documents, environmental conditions for work on site, infrastructure facilities and cash flow. Therefore, the resource planning encompasses identification, estimation, scheduling and allocation of resources. Resource planning needs to establish a control system for controlling consumption monitoring, corrective action and resource reappropriation in the event of favourable deviation. Organizational capability, commitment to the project requirements and other constraints such as time and cost, need to be considered as inputs while planning resources. Techniques of management and planning such as Programme Evaluation and Review Technique (PERT) and Critical Path Method (CPM) may be used.

Non-availability of basic building materials (brick, stone, aggregate, etc) within reasonable lead would influence the construction practice by alternative materials. The construction practices also get decided by the local skills of the manpower for construction activities. The equipment selection would also be governed by the site constraints. Source of funding of the project and its timeliness with reference to requirement of cash flow should also merit consideration. Therefore, as, the resource planning is critical to the project viability itself, the inputs to the resource planning need to be validated appropriately and established for such management. Resource planning should establish a proper system of data collection so as to facilitate effective resources control mechanism. Resource planning responsibility has to be specifically defined in the overall organizational setup.

5.3 Construction Phase

5.3.1 *Organizational Structure*

The site management should be carried out through suitable site organization structure with roles and responsibilities assigned to the construction personnel for various construction related functions.

5.3.2 *Site Management*

5.3.2.1 *Site layout*

The layout of the construction site should be carefully planned keeping in view the various requirements of construction activities and the specific constraints in terms of its size, shape, topography, traffic, and other restrictions, in public interest. A well planned site layout would enable safe smooth and efficient construction operations. The site layout should take into considerations the following factors:

a) Easy access and exit, with proper parking of vehicle and equipment during construction

b) Properly located material stores for easy handling and storage.

c) Adequate stack areas for bulk construction materials.

d) Optimum location of plants and equipment (batching plants, etc).

e) Layout of temporary services (water, power, power suppression unit, hoists, cranes, elevators, etc).

f) Adequate yard lighting and lighting for night shifts.

g) Temporary buildings; site office and shelter for workers (*see* **14**) with use of non-combustible materials as far as possible including emergency medical aids.

h) Roads for vehicular movement with effective drainage plan.

j) Construction safety with emergency access and evacuations and security measures.

k) Fabrication yards for reinforcement assembly, concrete precasting and shuttering materials.

m) Fencing, barricades and signages.

5.3.2.2 *Access for firefighting equipment vehicles*

Access for firefighting equipment shall be provided to the construction site at the start of construction and maintained until all construction work is completed. Free access from the street to fire hydrants/static water tanks, where available, shall be provided and maintained at all times. No materials for construction shall be placed within 3 m of hydrants/static water tanks. During building operations, free access to permanent, temporary or portable first-aid firefighting equipment shall be maintained at all times.

5.3.2.3 *Access to the upper floors during construction*

In all buildings over two storeys high, at least one

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stairway shall be provided in usable condition at all times. This stairway shall be extended upward as each floor is completed. There shall be a handrail on the staircase.

5.3.2.4 *Electrical installations*

Electrical installations, both permanent and temporary, for construction and demolition sites, including electrical installations for transportable construction buildings (site sheds) shall be in accordance with **12** of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

5.3.3 *Construction Strategy and Construction Sequence*

Construction strategy and construction methods are to be evolved at the planning and design stage specific to the conditions and constraints of the project site and implemented by the site management personnel to ensure ease of construction and smooth flow of construction activities. Sites of high water table conditions with aggressive chemical contents of subsoil needs special design considerations. Buildings with basement in sites of high water table should be planned with dewatering scheme with appropriate construction sequence. Duration of dewatering should continue till sufficient dead loads are achieved to stabilize the buoyancy loads with adequate factor of safety. The construction sequence should be planned taking into consideration the following aspects:

a) Availability of resources (men, material and equipment);
b) Construction methods employed including prefabrication;
c) Planned construction time;
d) Design requirements and load transfer mechanism;
e) Stability of ground like in hilly terrain;
f) Ensuring slope stability with retaining structure before the main construction;
g) Installation and movement of heavy equipment like cranes and piling equipment;
h) Effect of weather; and
j) Minimum time to be spent on working below ground level.

SECTION 3 CONSTRUCTION PRACTICES

6 CONSTRUCTION CONTROL AND PRACTICES

6.1 Professional Services and Responsibilities

The responsibility of professionals with regard to planning, designing and supervision of building construction work, etc and that of the owner shall be in accordance with Part 2 'Administration' of the Code. All applications for permits and issuance of certificates, etc shall be as given in Part 2 'Administration' of the Code. Employment of trained workers shall be encouraged for building construction activity.

6.2 Site Preparation

6.2.1 While preparing the site for construction, bush and other wood, debris, etc, shall be removed and promptly disposed of so as to minimise the attendant hazards.

6.2.2 Temporary buildings for construction offices and storage shall be so located as to cause the minimum fire hazards and shall be constructed from non-combustible materials as far as possible.

6.3 Habitat for Construction Workers at Site

The habitat and other welfare measures for construction workers shall meet the requirements specified in **14**.

6.4 Construction of All Elements

6.4.1 Construction of all elements of a building shall be in accordance with good practice [7(15)]. It shall also be ensured that the elements of structure satisfy the appropriate fire resistance requirements as specified in Part 4 'Fire and Life Safety' of the Code, and quality of building materials/components used shall be in accordance with Part 5 'Building Materials' of the Code.

6.4.2 Construction of all accessibility features/elements in a building and its built environment shall be as per the requirements given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

6.4.3 All mechanical, electrical and plumbing (MEP) and other services in a building shall be installed in accordance with approved designs as per Part 8 'Building Services' of the Code and Part 9 'Plumbing Services including Solid Waste Management' of the Code. Proper sequencing of installation of various services shall be done for ensuring smooth construction activities.

6.4.4 Necessary temporary works required to enable permanent works, shall be executed in accordance with **7**.

6.5 Low Income Housing

For low income housing, appropriate planning and selection of building materials and techniques of construction have to be judiciously done and applied in practice. Requirements of low income housing specified in Part 3 'Development Control Rules and

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General Building Requirements' of the Code shall be followed. However, all requirements regarding structural safety, health safety and fire safety shall be in accordance with this Part.

6.6 Use of New/Alternative Construction Techniques

The provisions of this Part are not intended to prevent use of any construction techniques including any alternative materials, not specifically prescribed by the Code, provided any such alternative has been approved. The Authority may approve any such alternative, such as, ferrocement construction; stretcher bond in filler slab; glass fibre reinforced gypsum (GFRG) panel system using composite of GFRG panel and reinforced concrete; pre-engineered steel structures with reinforced concrete expanded polystyrene core based panel/other in-fill walls; light gauge steel framed structures with suitable water resistant wall panels like cement bonded particle board, provided it is found that the proposed alternative is satisfactory and conforms to the provisions of relevant parts regarding material, design and construction and that material, method, or work offered is, for the purpose intended, at least equivalent to that prescribed in the Code in quality, strength, compatibility, effectiveness, fire and water resistance, durability and safety.

6.7 Urban Roads/City Roads Planning and Construction

6.7.1 The urban roads, which are commonly known as city roads/streets have been under constant development. The emphasis has been primarily on providing essentially required width of metalled surface for the movement of vehicles (both motorized and non-motorized). Footpaths of various widths and heights are required to be provided.

The space between the buildings and the city roads should be treated as valuable and important space allowing for a comfortable and safe use by the pedestrians, hawkers, cyclists including non-motorized vehicle (NMV) drivers, and adequate space for drainage, utilities, street lighting poles, transformers and trees. Thus, the objective should be to create urban streets/roads that are efficiently planned, safe for vehicles as well as pedestrians, universally user friendly, and sustainable.

The elements required in an efficiently planned street, such as, kerb stones; kerb channels; kerb ramps; tactile ground surface indicators; silt chambers with manhole cover; drain cover slabs; drain manhole covers; service pipes; manhole covers for electrical services; manhole covers for telecom services; cycle tracks (NMV); bollards across pedestrian paths; tree gratings; lighting poles on main roads and service roads; table tops on free left turns; pedestrian paths at intersections/ T-junctions; pedestrian paths on traffic islands; pedestrian paths across central verge; pedestrian paths near rotaries (un-signaled); pedestrian paths below flyovers; signages; traffic signals; cable ducting by discoms; central verge irrigation system; central verge, footpath and traffic islands plantation; street furniture; bus queue shelters; public art, public toilets, etc. should be identified. These elements should be integrated at the planning stage, indicating the methodology of execution, taking care of the following while complying with the relevant rules/regulations:

a) Road cross-section planning based on land-use with emphasis on smooth vehicular movements.

NOTE — This may be achieved by rationalizing lane widths based on norms laid down by Indian Roads Congress.

b) Design of road intersections, fixing of geometrics of roads, providing provision of entry and exits from the service roads.

c) Coordination between the traffic police, transport authorities and the executing agencies to be ensured for efficient location of traffic signals, zebra crossings and the bus queue shelters and the pickup stands for the para-transport.

d) Standardization of kerb stones, kerb ramps and kerb channels.

e) Appropriate selection of materials, like, paver blocks, tiles, stone slabs or plain cement concrete for footpaths, plazas, etc, so that they add to aesthetics of buildings and roads.

f) Standardization of access manhole covers for various utilities.

g) Providing footpath at one level by adjusting the drain cover slab levels.

h) Integration of bus queue shelters with the footpath.

j) Pedestrian friendly access across the roads to the foot-over bridges, subways and public toilets.

k) Access to gates of residential/commercial properties integrated with the road through the footpath in front.

m) Sharing of NMV with footpath necessary at many locations.

n) Adequate provision of public conveniences and dust bins.

p) Street lighting for proper illumination of roads and service roads including modifications of street lighting along with central verge and the service roads blocked by existing trees.

q) Low height plantation on central verges, avoiding plantation of trees.

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r) Removal of crooked trees on footpaths for proper and safe utilization of footpath.

s) Removal of trees obstructing the carriage ways and their replantation, wherever feasible.

t) Freeing of trees embedded in the compound wall/dwarf walls on footpaths to save both the trees and the walls.

u) Providing planters in the central verge in the deck portion of flyover to ensure proper glare cutting during night hours and improving aesthetics during the day.

w) Proper location of signage boards so as to be safe from moving traffic near the footpath edges and give clear visibility.

y) Selection, procurement and installation of street furniture.

z) Selection, procurement and installation in respect of accessibility features as per the requirements given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

NOTE — The relevant standards/publications of Indian Roads Congress may be referred to.

6.7.2 The road work zones are areas of conflict between normal operating traffic, construction workers, road building machineries and construction traffic. If it is a construction of new road, normal operating traffic will not be there but the care has to be taken to avoid and or remove conflicts between workers and construction machineries and construction traffic. Problem becomes more serious if it is an urban road with significant proportion of vulnerable road users. The road work zones and the traffic around them should be so planned and managed so as to ensure traffic safety, facilitate smooth and efficient flow of traffic and also provide safe working environment for the workers.

NOTE — For guidance on management of pedestrians/cyclists/ vehicles near road construction sites, reference may be made to IRC SP 55 : 2014 'Guidelines on traffic management in work zones'.

6.8 Measures against pollution and hazard due to dust, smoke and debris, such as screens and barricading shall be installed at the site during construction. Plastic/ tarpaulin sheet covers shall be used for trucks transporting fine materials liable to cause environmental pollution.

7 TEMPORARY WORKS

7.1 The construction of most types of permanent works requires the use of some form of temporary works. Temporary works are the parts of a construction project that are needed to enable the permanent works to be built. Usually the temporary works are removed after use, for example, access, scaffolds, props, shoring, excavation support, false work and formwork, etc. Sometimes the temporary works are incorporated into the permanent works, for example, haul road foundations and crane or piling platforms which may be used for hard standing or road foundations. The same degree of care and attention should be given to the design and construction of temporary works as to the design and construction of the permanent works. Considering that as temporary works may be in place for only a short while, there is a tendency to assume they are less important, which is incorrect. Lack of care in design, selection, assembly, etc, leaves temporary works liable to fail or collapse. While organizing the temporary works, aspects as given below should be followed:

a) The person organizing the temporary works should be aware of the problems that can occur at each stage of the process and how to prevent these. They need to coordinate design, selection of equipment, appointment of contractors, supervision of work, checking completion, authorization to load and removal.

b) If so required, a temporary works co-ordinator (TWC) may be employed in case of medium and large projects, whose requisite qualification and experience should be specified. The role of TWC and supervisor should be decided. The coordinator shall have adequate field training for temporary works. The contractor shall ensure that work is allocated and carried out in a manner that does not create unacceptable risk of harm to workers or members of the public. On projects with relatively simple temporary works needs, a TWC may be avoided, however, it shall be ensured that temporary works are properly managed.

c) The cost of any temporary works is generally included in the build-up of the tender.

d) Temporary works are often taken from site to site and re-used and it is important to consider the robustness of components in their design. However, temporary works that are designed only to be used during construction shall not be removed until the satisfactory safety criteria for their use has been met.

e) Proper planning and co-ordination should be done in respect of sequence and timely execution of temporary works, as also for ensuring that they are correctly installed, used, checked and maintained.

f) In each of the cases of temporary works, the person organizing the temporary works should assess the soil conditions to be sure that it is

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suitable for the equipment involved, and check that any assumptions made in the calculations for the standard solution are valid for this particular situation and the conditions on site. On a simple job, the supplier's data will allow an experienced person to consider the necessary issues without further calculation.

g) Propping using standard equipment such as screw props (acrows) needs careful consideration. To select the type, size, number and decide spacing, information is needed about the loads that will act on the props. This will include the wall above and the additional load from any other floor or roof beams, etc, that enter the wall above or close to the opening. Even with proprietary equipment, the support system shall be worked out.

h) A local failure within the temporary works should not initiate a global collapse of the structure. Therefore, additional care should be taken while removing temporary works.

The different types of temporary works can be scaffolding, crane supports, falsework, formwork, and trench support. Detailed knowledge about each type of temporary work is necessary for safe construction. The requirements as given in **7.2** to **7.6** shall be satisfied in case of temporary works.

Proprietary equipment supplier should be identified and approved. It should be ascertained, whether following has been performed:

1) They have designed the foundations,
2) Any assumption made that have to be confirmed/investigated,
3) Independent checking done and by whom,
4) Status of drawings, and
5) Procedures checked at site.

In management of temporary works, the owner/client has to ensure,

i) checks on competence on designers;
ii) steps taken to ensure co-operation between the permanent and temporary works designers;
iii) coordination at site meetings; and
iv) advise clients on the suitability of the initial construction phase plan, that is, the arrangements for controlling significant site risks.

7.2 Scaffolding

Scaffolding includes providing a temporary safe working platform for erection, maintenance, construction, repair, access, and inspection. Scaffolding and their erection shall be in accordance with the good practice [7(16)].

7.3 Tower Cranes

Tower cranes are usually supplied on a hire basis, with the client being responsible for the design and construction of the base upon which the crane is erected. Details of loading are provided by the crane supplier and the base is most commonly designed as a temporary structure, though sometimes a crane base is incorporated into the permanent structure to save on cost and time.

Loads are given in two forms, 'in service' loads, where the crane is functioning and wind speeds are restricted (that is, cranes will not operate at high wind speeds), and 'out of service' loads, where the crane is not being used but maximum wind speeds may occur.

The location for a crane should be carefully selected to provide a maximum working radius, and when two cranes are being used on the same site, mast heights and jib lengths shall be considered.

Cranes should typically be structured around two rails at their base between 4.5 m and 10 m apart with wheels in each corner. Cranes should not normally be tied down, so sufficient kentledge should be provided so as to ensure that vertical loading from the crane passes through the rails and into the foundation. The foundation shall be so designed that the unfactored loading from the crane and the unfactored pressure is less than the allowable bearing pressure of the soil.

Various foundation types can be selected depending on the ground conditions. Where possible a structural fill can be compacted and used to support a crane with the load spreading through layers of track support at 45° in to the soil strata below. When loads from the crane increase, reinforced concrete foundations may be required. This can involve a series of reinforced concrete beams used to support line loads as a result of the crane loading.

When ground conditions are particularly poor, pile foundations may be necessary. The design shall ensure that reinforcement at the top of the pile top should not cause problems for positioning the mast base section of the crane.

Tower cranes shall embody all fundamental principles of design in accordance with the good practice [7(17)] so as to secure reliability and safety in operation. The particular requirements for controls for tower cranes and the arrangement of basic control used for positioning loads shall be in accordance with the good practice [7(18)].

7.4 Falsework

Falsework involves a temporary structure used to

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support other permanent structures until they can support themselves. Falsework shall be designed and erected in accordance with the good practice [7(19)].

7.5 Formwork

Formwork is the term used for a temporary mould into which concrete is poured and formed. Traditional formwork is fabricated using timber, but it can also be constructed from steel, glass fiber reinforced plastics and other materials.

Timber formwork is normally constructed on site using timber and plywood. It is easy to produce, although it can be time consuming for larger structures. Re-usable plastic formwork is generally used for quick pours of concrete. The formwork is assembled either from interlocking panels or from a modular system and is used for relatively simple concrete structures. It is not as versatile as timber formwork due to the prefabrication requirements and is best suited for low-cost, repetitive structures such as mass housing schemes.

Stay-in-place structural formwork is generally assembled on site using prefabricated fibre-reinforced plastic. It is used for concrete columns and piers and stays in place, acting as permanent axial and shear reinforcement for the structural member. It also provides resistance to environmental damage to both the concrete and reinforcing bars. Proprietary systems are used to support vertical formwork while concrete cures, consisting of series of tubes and ties.

When selecting formwork the type of concrete and temperature of the pour are important considerations as they both effect the pressure exerted on the formwork. Striking of formwork shall be governed by Part 6 'Structural Design, Section 5 Concrete: Subsection 5A Plain and Reinforced Concrete' of the Code.

High quality workmanship and inspection are necessary to ensure a high standard of work including finish.

7.6 Trench Support

A trench is defined as an excavation when its length greatly exceeds its depth. Shallow trenches are usually considered to be less than 6 m deep and deep trenches have depth greater than 6 m. Depending on the dimensions of a trench, excavation can either be carried out by hand or by using a mechanical digger. Trenches are commonly required to allow services, pipelines or foundations to be laid.

Water ingress into the trench is often a major issue and ground water table locations and soil strata should be investigated before any extensive excavation takes place. Over short periods of time, for relatively shallow depths most soil types will stand almost vertically without any problems. However, trenches other than those which are relatively shallow may require a trench support scheme. Traditionally, trenching involved using timber to support horizontal and vertical soil loads and this technique is still used today. Timber trenching is generally used for low risk, narrow trenches, shafts or headings. The timber solutions require good workmanship and are reasonably labour-intensive; however, they are versatile and the equipment required is easy to handle and transport.

Trench boxes are suitable for low-risk situations in stable, dry ground and can be placed in pre-excavated trenches or installed using the 'dig and push' technique. The system requires at least two struts at each panel for stability which should be considered when access is required for construction work or piping.

Trench sheets are the most adaptable of the systems available, and are most commonly used to retain poorer soil. They can support deeper trenches with larger surcharges and provide a continuous support. They require multiple levels of strut support and the slenderness of the sheets can often limit the depth of the trench as they are installed by light machinery and could buckle under large vertical loads.

While making deep excavation near an existing structure, it is necessary that the lateral force caused by the existing structure should be taken care of.

Trench supports shall be provided in accordance with the good practice [7(20)].

8 STORAGE, STACKING AND HANDLING PRACTICES

8.1 General

8.1.1 *Planning and Storage Layout*

8.1.1.1 For any site, there should be proper planning of the layout for stacking and storage of different materials, components and equipment with proper access and proper manoeuvrability of the vehicles carrying the material. While planning the layout, the requirements of various materials, components and equipment at different stages of construction shall be considered.

8.1.1.2 Materials shall be segregated as to kind, size and length and placed in neat, orderly piles that are safe against falling. If piles are high they shall be stepped back at suitable intervals in height. Piles of materials shall be arranged so as to allow a passageway of not less than 1 m width in between the piles or stacks for inspection or removal. All passageways shall be kept clear of dry vegetation.

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8.1.1.3 Materials shall be stored, stacked and handled in such a manner as to prevent deterioration or intrusion of foreign matter and to ensure the preservation of their quality and fitness for the work.

8.1.1.4 Materials shall be stacked on well drained, firm and unyielding surface. Materials shall not be stacked so as to impose any undue stresses on walls or other structures.

8.1.1.5 Materials shall be stacked in such a manner as not to constitute a hazard to passerby. At such places the stacks shall have suitable warning signs in day time and red lights on and around them at night.

8.1.1.6 Stairways, passageways and gangways shall not become obstructed by storage of building materials, tools or accumulated rubbish.

8.1.2 *Protection Against Atmospheric Agencies*

Materials stored at site, depending upon the individual characteristics, shall be protected from atmospheric actions, such as rain, sun, winds and moisture, to avoid deterioration.

8.1.3 *Protection Against Fire and Other Hazards*

8.1.3.1 Materials, like timber, bamboo, coal, paints, etc, shall be stored in such a way that there may not be any possibility of fire hazards. Inflammable materials like kerosene and petrol, shall be stored in accordance with the relevant rules and regulations so as to ensure the desired safety during storage. Stacks shall not be piled so high as to make them unstable under fire fighting conditions and in general they shall not be more than 4.5 m in height. The provisions given in good practice [7(21)] shall be followed. Explosives like detonators shall be stored in accordance with the existing regulations of *The Explosives Act*, 1884.

8.1.3.2 Materials which are likely to be affected by subsidence of soil like precast beams, slabs and timber of sizes shall be stored by adopting suitable measures to ensure unyielding supports.

8.1.3.3 Materials liable to be affected by floods, tides, etc, shall be suitably stored to prevent their being washed away or damaged due to floods, tides, etc.

8.1.4 *Manual Handling*

When heavy materials have to be handled manually each workman shall be instructed by his foreman or supervisor for the proper method of handling such materials. Each workman shall be provided with suitable equipment for his personal safety as necessary. All workers shall wear adequate clothing to protect themselves from direct sun-rays and other irritants. Supervisors shall also take care to assign enough men to each such job depending on the weight and the distance involved.

8.2 Storage, Stacking and Handling of Materials

8.2.1 The storage, stacking and handling of materials generally used in construction shall be as given in **8.2.2** to **8.2.31**, which have been summarized in the form of a check list in Annex A. Exposure to asbestos fibres/ dust is known to be harmful to health of human beings. Prescribed guidelines in accordance with good practice [7(22)] shall be followed for handling and usage of asbestos cement products.

8.2.2 *Cement*

a) *Storage and stacking* — Cement shall be stored at the work site in a building or a shed which is dry, leak-proof and as moisture-proof as possible. The building or shed for storage should have minimum number of windows and close fitting doors and these should be kept closed as far as possible.

Cement received in bags shall be kept in such a way that the bags are kept free from the possibility of any dampness or moisture coming in contact with them. Cement bags shall be stacked off the floor on wooden planks in such a way as to keep them about 150 mm to 200 mm clear above the floor. The floor may comprise lean cement concrete or two layers of dry bricks laid on a well consolidated earth. A space of 600 mm minimum shall be left around between the exterior walls and the stacks (*see* Fig. 3). In the stacks the cement bags shall be kept close together to reduce circulation of air as much as possible. Owing to pressure on bottom layer of bags sometimes 'warehouse pack' is developed in these bags. This can be removed easily by rolling the bags when cement is taken out for use. Lumped bags, if any should be removed and disposed of.

The height of stack shall not be more than 10 bags to prevent the possibility of lumping up under pressure. The width of the stack shall be not more than four bags length or 3 m. In stacks more than 8 bags high, the cement bags shall be arranged alternately length-wise and cross-wise so as to tie the stacks together and minimise the danger of toppling over. Cement bags shall be stacked in a manner to facilitate their removal and use in the order in which they are received; a table showing date of receipt of cement shall be put on each stack to know the age of cement.

For extra safety during monsoon, or when it is expected to store for an unusually long period, the stack shall be completely enclosed by a water proofing membrane such as polyethylene, which shall close on the top of the stack. Care shall be taken to see that the waterproofing membrane is not damaged any time during the use.

Cement in gunny bags, paper bags and polyethylene bags shall be stored separately.

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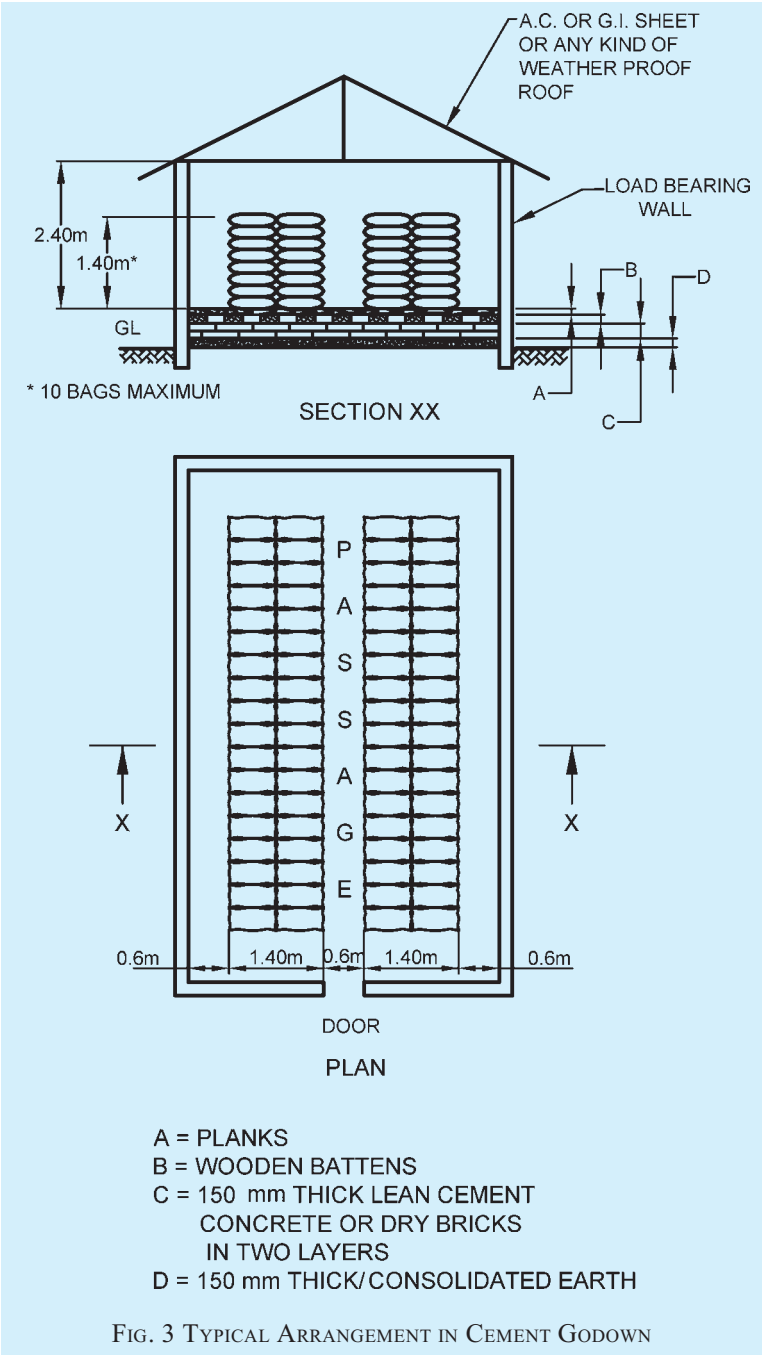


FIG. 3 TYPICAL ARRANGEMENT IN CEMENT GODOWN

In case cement is received in drums, these shall be stored on plane level ground, as far as possible near the concrete mixing place. After taking out the required quantity of cement, the lid of the drum shall be securely tied to prevent ingress of moisture.

In case cement is received in silos, the silos shall be placed near the concrete batching plant. Proper access shall be provided for the replacement of silos.

Different types of cements shall be stacked and stored separately.

b) *Handling* — Hooks shall not be used for handling cement bags unless specifically permitted by the engineer-in-charge. Bags shall be removed uniformly from the top of the piles to avoid tipping of the stack.

For information regarding bulk handling of cement (*see* **8.2.4)**.

8.2.3 *Lime*

8.2.3.1 *Quicklime before slaking*

a) *Storage and stacking* — Quicklime should be slaked as soon as possible. If unavoidable it may be stored in compact heaps having only the minimum of exposed area. The heaps shall

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be stored on a suitable platform and covered to avoid direct contact with rain or being blown away by wind. In case quick lime is stored in a covered shed, a minimum space of 300 mm should be provided all-round the heaps to avoid bulging of walls.

Unslaked lime shall be stored in a place inaccessible to water and because of fire hazards, shall be segregated from the combustible materials.

b) *Handling — See* **8.2.4**.

8.2.3.2 *Hydrated lime*

a) *Storage and stacking* — Hydrated lime is generally supplied in containers, such as jute bags lined with polyethylene or craft paper bags. It should be stored in a building to protect the lime from dampness and to minimise warehouse deterioration.

The building should be with a concrete floor and having least ventilation to eliminate draughts through the walls and roof. In general, the recommendations given in **8.2.2** for storing of cement shall be applicable for hydrated lime. When air movement is reduced to a practical minimum, hydrated lime can be stored for up to three months without appreciable change.

b) *Handling — See* **8.2.4**.

8.2.3.3 *Dry slaked lime*

a) *Storage and stacking* — The lime shall be stored in a dry and closed godown.

b) *Handling — See* **8.2.4**.

8.2.4 *Handling of Cement and Lime*

Workers, handling bulk cement or lime shall wear protective clothing, respirators, and goggles; shall be instructed in the need of cleanliness to prevent dermatitis, and shall be provided with hand cream, petroleum jelly, or similar preparation for protection of exposed skin. Workers handling cement, who are continually exposed to it, shall, in addition to the above be equipped with hand gloves and dust mask.

Bulk cement stored in silos or bins may fail to feed to the ejection system. When necessary to enter a silo or bin for any purpose, the ejection system employed shall be shut down and locked out electrically as well as mechanically. When necessary for a workman to enter such storage area, he shall wear a life-line, with another workman outside the silo or hopper attending the rope.

8.2.5 *Masonry Units*

a) *Stones* — Stones of different sizes, types and classification shall be stored separately. Stones shall be stacked on dry firm ground in a regular heap not more than 1 m in height. Veneering stones shall be stacked against vertical support on a firm dry ground in tiers, upto a height of 1.2 m. A distance of about 0.8 m shall be kept between two adjacent stacks.

b) *Bricks* — Bricks shall be stacked in regular tiers as and when they are unloaded to minimise breakage and defacement. These shall not be dumped at site. In the case of bricks made from clays containing lime *Kankar*, the bricks in stack should be thoroughly soaked in water (docked) to prevent lime bursting.

Bricks shall be stacked on dry firm ground. For proper inspection of quality and ease in counting, the stacks shall be 50 bricks long, 10 bricks high and not more than 4 bricks in width, the bricks being placed on edge, two at a time along the width of the stack. Clear distance between adjacent stacks shall not be less than 0.8 m. Bricks of each truck load shall be put in one stack. Bricks of different types, such as, clay bricks, clay fly ash bricks, fly ash lime bricks, sand lime (calcium silicate) bricks shall be stacked separately. Bricks of different classifications from strength consideration and size consideration (such as, conventional and modular) shall be stacked separately. Also bricks of different types, such as, solid, hollow and perforated shall be stacked separately.

c) *Blocks* — Blocks are available as hollow and solid concrete blocks, hollow and solid light weight concrete blocks, autoclaved aerated concrete blocks, concrete stone masonry blocks and soil based blocks. Blocks shall be unloaded one at a time and stacked in regular tiers to minimise breakage and defacement. These shall not be dumped at site. The height of the stack shall not be more than 1.2 m, the length of the stack shall not be more than 3.0 m, as far as possible and the width shall be of two or three blocks. Normally blocks cured for 28 days only should be received at site. In case blocks cured for less than 28 days are received, these shall be stacked separately. All blocks should be water cured for 10 to 14 days and air cured for another 15 days; thus no blocks with less than 28 days curing shall be used in building construction. Blocks shall be placed close to the site of work so that least effort is required for their transportation. The date of manufacture of the blocks shall be suitably marked on the stacks of blocks

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manufactured at factory or site.

d) *Handling* — Brick stacks shall be placed close to the site of work so that least effort is required to unload and transport the bricks again by loading on pallets or in barrows. Unloading of building bricks or handling in any other way likely to damage the corners or edges or other parts of bricks shall not be permitted.

8.2.6 *Floors, Wall and Roof Tiles*

a) *Storage and stacking* — Floor, wall and clay roof tiles of different types, such as, cement concrete tiles (plain, coloured and terrazzo) and ceramic tiles (glazed and unglazed) shall be stacked on regular platform as far as possible under cover in proper layers and in tiers and they shall not be dumped in heaps. In the stack, the tiles shall be so placed that the mould surface of one faces that of another. Height of the stack shall not be more than one metre.

Tiles of different quality, size and thickness shall be stacked separately to facilitate easy removal for use in work. Tiles when supplied by manufacturers packed in wooden crates shall be stored in crates. The crates shall be opened one at a time as and when required for use.

b) *Handling* — Ceramic tiles and roof tiles are generally supplied in cartons which shall be handled with care to avoid breakage. It is preferable to transport these at the site on platform trolleys.

8.2.7 *Aggregate*

a) *Storage and stacking* — Aggregates shall be stored at site on a hard dry and level patch of ground. If such a surface is not available, a platform of planks or old corrugated iron sheets, or a floor of bricks, or a thin layer of lean concrete shall be made so as to prevent the mixing with clay, dust, vegetable and other foreign matter.

Stacks of fine and coarse aggregate shall be kept in separate stock piles sufficiently removed from each other to prevent the material at the edges of the piles from getting intermixed. On a large job it is desirable to construct dividing walls to give each type of aggregates its own compartment. Fine aggregates shall be stacked in a place where loss due to the effect of wind is minimum.

b) *Handling* — When withdrawals are made from stock piles, no overhang shall be permitted. Employees required to enter hoppers shall be equipped with safety belts and life-lines, attended by another person. Machine driven hoppers, feeders, and loaders shall be locked in the off position prior to entry, electrically as well as mechanically.

8.2.8 *Pulverized Fuel Ash/Fly Ash/Silica*

a) *Storage and stacking* — Fly ash/Silica fume shall be stored in such a manner as to permit easy access for proper inspection and identification of each consignment. Fly ash in bulk quantities shall be stored in stack similar to fine aggregates, avoiding any intrusion of foreign matter. Fly ash in bags shall be stored in stacks not more than 10 bags high. Silica fume, in general, shall be stored similar to cement/fly ash storage depending upon the storage requirements in bags/bulk form.

b) *Handling — See* **8.2.4**.

8.2.9 *Cinder*

Cinder shall be stored in bulk quantities in stacks similar to coarse aggregates avoiding any extrusion of foreign matter.

8.2.10 *Timber*

a) *Storage and stacking* — Timber shall be stored in stacks upon well treated and even surfaced beams, sleepers or brick pillars so as to be above the ground level by at least 150 mm to ensure that the timber will not be affected by accumulation of water under it. Various members shall preferably be stored separately in different lengths, and material of equal lengths shall be piled together in layers with wooden battens, called crossers, separating one layer from another. The crossers shall be of sound wood, straight and uniform in thickness. In case, where separate crossers are not available smaller sections of the available structural timber may be employed in their place. In any layer an air space of about 25 mm shall be provided between adjacent members. The longer pieces shall be placed in the bottom layers and shorter pieces in the top layers but one end of the stack shall be in true vertical alignment. The crossers in different layers shall be in vertical alignment. The most suitable width and height of a stack are recommended to be about 1.5 m and 2.0 m. Distance between adjacent stacks is recommended to be at least 450 mm. In case the stacking with the help of battens is not possible, the timber may be close piled in heaps on raised foundations with the

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precautions specified above.

The stacks shall be protected from hot dry winds or direct sun and rain. Heavy weights, such as metal rails or large sections of wood, are recommended to be placed on the top of the stack to prevent distortion or warping of the timber in the stack. In case timber is to be stored for about a year or more, to prevent end-cracking in the material, the ends of all members shall be coated with coal tar, aluminium leaf paints (hardened gloss oil), microcrystalline wax or any other suitable material.

b) Care must be taken that handler or workers are not injured by rails, straps, etc, attached to the used timber. This applies particularly to planks and formwork for shuttering.

8.2.11 *Bamboo*

8.2.11.1 The site shall be properly inspected and termite colonies or mounds, if detected, shall be destroyed.

All refuse and useless cellulosic materials shall be removed from the site. The ground may then be disinfected by suitable insecticides. The area should have good drainage.

8.2.11.2 Bamboo may preferably be stacked on high skids or raised platform at least 300 mm above ground. Storage under cover reduces the liability to fungal attack. Good ventilation and frequent inspection are important.

8.2.11.3 Bamboo dries by air-seasoning under cover in the storage yards from 6 to 12 weeks' time.

8.2.11.4 Prophylactic treatment of bamboo during storage prevents losses due to fungi and insects even under open storage. Following chemicals have been found suitable at a coverage rate of 24 litre per tonne:

a) Sodium pentachlorophenate : 1 percent solution.
b) Boric acid + borax (1:1) : 2 percent solution.
c) Sodium pentachlorophenate : 2.5 percent solution + boric acid + borax (5:1:1).

A mixture of these compounds yields the best results.

NOTE — For better protection of structural bamboo (if stored outside), repetition of the treatment after four to six months is desirable.

8.2.12 *Partially Prefabricated Wall and Roof Components*

a) *Storage and stacking* — The wall components comprise blocks, sills, lintels, etc. The blocks shall be stacked in accordance with **8.2.5** (c). These shall be stacked on plane level ground having a floor of bricks or a thin layer of lean concrete.

The roof components such as precast RC joists, prefabricated brick panels, RC planks, channel units, cored units, waffle units, L-panel, single tee and double tee sections, ferrocement panels, etc shall be unloaded as individual components. These shall be stacked on plane level ground having a floor of bricks or a thin layer of lean concrete. RC planks, prefabricated brick panels and ferrocement panels shall be stacked against a brick masonry wall in slightly inclined position on both sides of the wall. Channel units, cored units and L-panels shall be stacked one over the other up to five tiers. The waffle units shall be stacked upside down as individual units. The RC joists, single tee and double tee sections shall be stacked as individual units one adjacent to the other. The distance between any two adjacent stacks shall not be less than 450 mm.

b) *Handling* — The components shall be handled by holding the individual components at specified points so that the stresses due to handling are minimised.

8.2.13 *Steel*

a) *Storage and stacking* — For each classification of steel, separate areas shall be earmarked. It is desirable that ends of bars and sections of each class be painted in distinct separate colours. Steel reinforcement shall be stored in a way as to prevent distortion and corrosion. It is desirable to coat reinforcement with cement wash before stacking to prevent scaling and rusting.

Bars of different classification, sizes and lengths shall be stored separately to facilitate issues in such sizes and lengths as to minimise wastage in cut from standard lengths.

In case of long storage or in coastal areas, reinforcement bars shall be stacked above ground level by at least 150 mm and a coat of cement wash shall be given to prevent scaling and rusting.

Structural steel of different sections, sizes and lengths shall be stored separately. It shall be stored above ground level by at least 150 mm upon platforms, skids or any other suitable supports to avoid distortion of sections. In case of coastal areas or in case of long storage, suitable protective coating of cement wash shall be given to prevent scaling and rusting.

b) *Handling* — Tag lines shall be used to control the load in handling reinforcements or structural steel when a crane is employed.

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Heavy steel sections and bundles shall be lifted and carried with the help of slings and tackles and shall not be carried on the shoulders of the workers.

8.2.14 *Aluminium Sections*

a) *Storage and stacking* — Aluminium sections of different classification, sizes and lengths shall be stored separately, on a level platform under cover.

b) *Handling* — The aluminium sections shall not be pulled or pushed from the stack nor shall be slid over each other, to protect the anodizing layer.

8.2.15 *Doors, Windows and Ventilators*

a) *Storage and stacking* — Metal and plastic doors, windows and ventilators shall be stacked upright (on their sills) on level ground preferably on wooden battens and shall not come in contact with dirt or ashes. If received in crates they shall be stacked according to manufacturer's instructions and removed from the crates as and when required for the work.

Metal and plastic frames of doors, windows and ventilators shall be stacked upside down with the kick plates at the top. These shall not be allowed to stand for long in this manner before being fixed so as to avoid the door frames getting out of shape and hinges being strained and shutters drooping.

During the period of storage of aluminium doors, windows and ventilators, these shall be protected from loose cement and mortar by suitable covering, such as tarpaulin. The tarpaulin shall be hung loosely on temporary framing to permit circulation of air to prevent moisture condensation.

All timber and other lignocellulosic material based frames and shutters shall be stored in a dry and clean covered space away from any infestation and dampness. The storage shall preferably be in well-ventilated dry rooms. The storage shall preferably be in well-ventilated dry rooms. The frames shall be stacked one over the other in vertical stacks with cross battens at regular distances to keep the stack vertical and straight. These cross battens should be of uniform thickness and placed vertically one above the other. The door shutters shall be stacked in the form of clean vertical stacks one over the other and at least 80 mm above ground on pallets or suitable beams or rafters. The top of the stack shall be covered by a protecting cover and weighted down by means of scantlings or other suitable weights. The shutter stack shall rest on hard and level surface.

If any timber or other lignocellulosic material based frame or shutter becomes wet during transit, it shall be kept separate from the undamaged material. The wet material may be dried by stacking in shade with battens in between adjacent boards with free access of dry air. Separate stacks shall be built up for each size, each grade and each type of material. When materials of different sizes, grades and types are to be stacked in one stack due to shortage of space, the bigger size shall be stacked in the lower portion of the stacks. Suitable pallets or separating battens shall be kept in between the two types of material.

Precast concrete door and window frames shall be stored in upright position adopting suitable measures against risk of subsidence of soil/support.

b) *Handling* — While unloading, shifting, handling and stacking timber or other lignocellulosic material based, metal and plastic door and window frames and shutters, care shall be taken that the pieces are not dragged one over the other as it may cause damage to their surface particularly in case of the decorative shutters. The pieces should be lifted and carried preferably flat avoiding damage to corners or sides.

8.2.16 *Roofing Materials*

8.2.16.1 Roofing sheets shall be stored and stacked in such a manner as not to damage them in any way.

8.2.16.2 *Asbestos cement sheet*

a) *Storage and stacking* — Asbestos cement sheets shall be stacked horizontally to a height of not more than 1 m on a firm and level ground, with timber or other packing beneath them. If stacked in exposed position, they shall be protected from damage by wind. Asbestos cement sheets of same variety and size shall be stacked together. Damaged sheets shall not be stacked with sound materials. All damaged sheets shall be salvaged as early as possible.

b) *Handling* — Not more than two sheets shall be first pushed forward along the valley line say about one fourth of the sheet length and preferably carried by two workers. Asbestos cement sheets shall be lowered or raised gently and not thrown.

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8.2.16.3 *Corrugated galvanized iron sheets and aluminium sheets*

a) *Storage and stacking* — Corrugated galvanized iron sheets and aluminium sheets shall be stacked horizontally to a height of not more than 0.5 m on a firm and level ground, with timber or other packing beneath them. To protect them from dust and rain water, these shall be covered with tarpaulin or polyethylene sheets.

b) *Handling* — In bulk handling of CGI sheets, workers shall be provided with suitable hand protection.

8.2.16.4 *Plastic sheets and glass reinforced plastic* (*GRP*) *sheets*

a) *Storage and stacking* — Plastic sheets and glass reinforced plastic (GRP) sheets shall be stacked under a shed to a height of not more than 0.5 m on a firm and level ground with timber or other packing beneath them.

b) *Handling* — Handling shall be done to avoid any damage to the sheets.

8.2.17 *Boards*

8.2.17.1 *Gypsum boards*

a) *Storage and stacking* — Gypsum boards shall be stored flat in a covered clean and dry place.

b) *Handling* — *See* **8.2.17.2** (b).

8.2.17.2 *Plywood, fibre board, particle board, block board, etc*

a) *Storage and stacking* — Plywood, fibre board, particle board, block board, etc, shall not be stored in the open and exposed to direct sun and rain. The boards shall be stacked on a flat dunnage, on the top of which a wooden frame shall be constructed with battens of 50 mm × 25 mm (*Min*) in such a way that it supports all four edges and corners of the boards with intermediate battens placed at suitable intervals to avoid warping. If required, the stack shall be adequately raised above ground level to ensure that it will not be affected by accumulation of water under it.

The board shall be stacked in a solid block in a clear vertical alignment. The top sheet of each stack shall be suitably weighed down to prevent warping, wherever necessary.

b) *Handling* — The board shall be unloaded and stacked with utmost care avoiding damage to the corners and surface. In case of decorative plywood and decorative boards, the surfaces of which are likely to get damaged by dragging one sheet over another, it is advisable that these are lifted as far as possible in pairs facing each other.

8.2.18 *Plastic and Rubber Flooring Sheets and Tiles*

a) *Storage and stacking* — Plastic and rubber sheets have tendency to break-down during storage. Plastic and rubber sheets shall be stored according to manufacturer's instructions.

The coolest store room available shall be utilized for the storage of the sheets. The store rooms where the sheets are stored shall be well ventilated and direct light should not be allowed to fall on them.

The sheets shall be stored away from electric generators, electric motors, switchgears and other such electrical equipment as they produce harmful odour/gases.

Contamination of the sheets with vegetable and mineral oils; greases; organic solvents; acids and their fumes; alkalies; dust and grit shall be prevented. Where greasy contamination occurs, this shall be removed immediately with petrol and the sheets and tiles thoroughly wiped dry and dusted with chalk.

Undue stretch and strain, kinks, sharp bends or folds of the sheets and tiles shall be avoided. In case of long storage, the sheets shall be turned over periodically and treated with chalk powder, if necessary.

b) *Handling* — While handling plastic and rubber sheets, workers shall lift the sheets and carry them flat to avoid sharp bends or folds of the sheets.

8.2.19 *Glass Sheets*

a) *Storage and stacking* — The special glasses shall be stored and handled as per manufacturer's instructions. It is important that all glass sheets whether stored in crates or not shall be kept dry. Suitable covered storage space shall be provided for the safe storage of the glass sheets. The glass sheets shall be lifted and stored on their long edges and shall be put into stacks of not more than 25 panes, supported at two points by fillets of wood at about 300 mm from each end. The first pane laid in each stack shall be so placed that its bottom edge is about 25 mm from the base of the wall or other support against which the stack rests. The whole stack shall be as close and as upright as possible. To prevent

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slipping on smooth floor, the floor shall be covered with gunny bags. The glass sheets of different sizes, thickness and type shall be stacked separately. The distance between any two stacks shall be of the order of 400 mm.

b) *Handling* — Workers handling glass panes, waste glass pieces and fibre glass shall be provided with suitable hand protection. In removing glass sheets from crates, due care shall be taken to avoid damages. Glass edges shall be covered or otherwise protected to prevent injuries to workers. Special glasses shall be stored and handled as per manufacturer's instructions.

8.2.20 *Cast Iron, Galvanized Iron and Asbestos Cement Pipes and Fittings*

a) *Storage and stacking* – The pipes shall be unloaded where they are required, when the trenches are ready to receive them.

Storage shall be provided at the bottom layer to keep the stack stable. The stack shall be in pyramid shape or the pipes placed lengthwise and crosswise in alternate layers. The pyramid stack is advisable in smaller diameter pipes for conserving space in storing them. The height of the stack shall not exceed 1.5 m.

Each stack shall contain only pipes of same class and size, with consignment or batch number marked on it with particulars or suppliers wherever possible.

Cast iron detachable joints and fittings shall be stacked under cover and separated from the asbestos cement pipes and fittings.

Rubber rings shall be kept clean, away from grease, oil, heat and light.

b) *Handling* — Pipes in the top layer shall be handled first. At a time only one pipe shall be handled by two labourers while carrying to the actual site and shall be carried on shoulders. Fittings shall be handled individually.

8.2.21 *Polyethylene Pipes*

a) *Storage and stacking* — Black polyethylene pipes may be stored either under cover or in the open. Natural polyethylene pipes, however, should be stored under cover and protected from direct sunlight.

Coils may be stored either on edge or stacked flat one on top of the other, but in either case they should not be allowed to come into contact with hot water or steam pipes and should be kept away from hot surface.

Straight lengths should be stored on horizontal racks giving continuous support to prevent the pipe taking on a permanent set. Storage of pipes in heated areas exceeding 27°C should be avoided.

b) *Handling* — Removal of pipe from a pile shall be accomplished by working from the ends of the pipe.

8.2.22 *Unplasticized PVC Pipes*

a) *Storage and stacking* — Pipes should be stored on a reasonably flat surface free from stones and sharp projections so that the pipe is supported throughout its length. The pipe should be given adequate support at all times. In storage, pipe racks should be avoided. Pipe should not be stacked in large piles especially under warm temperature conditions as the bottom pipes may distort thus giving rise to difficulty in jointing. Socket and spigot pipes should be stacked in layers with sockets placed at alternate ends of the stacks to avoid lopsided stacks.

It is recommended not to store a pipe inside another pipe. On no account should pipes be stored in a stressed or bend condition or near a source of heat. Pipes should not be stacked more than 1.5 m high. Pipes of different sizes and classes should be stacked separately.

In tropical conditions, pipes should be stored in shade. In very cold weather, the impact strength of PVC is reduced making it brittle.

The ends of pipe should be protected from abrasion particularly those specially prepared for jointing either spigot or socket solvent welded joints or soldered for use with couplings.

If due to unsatisfactory storage or handling, a pipe becomes kinked, the damaged portion should be cut out completely. Kinking is likely to occur only on very thin walled pipes.

b) *Handling* — Great care shall be exercised in handling these pipes in wintry conditions as these become brittle in very cold weather.

8.2.23 *Pipes of Conducting Materials*

a) *Storage and stacking* — Pipes shall be stacked on solid level sills and contained in a manner to prevent spreading or rolling of the pipe. Where quantity storage is necessary, suitable packing shall be placed between succeeding layers to reduce the pressure and resulting spreading of the pile.

In stacking and handling of pipes and other conducting materials, the following minimum safety distances shall be ensured from the

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overhead power lines:

1) 11 kV and below : 1.40 m
2) Above 11 and below 33 kV : 3.60 m
3) Above 33 and below 132 kV : 4.70 m
4) Above 132 and below 275 kV : 5.70 m
5) Above 275 and below 400 kV : 6.50 m

b) *Handling* — Removal of pipes from a pile shall be accomplished by working from the ends of the pipe. During transportation, the pipes shall be so secured as to ensure against displacement.

8.2.24 *Piles and Poles*

a) *Storage and stacking* — Piles and poles shall be carefully stacked on solid, level sills so as to prevent rolling or spreading of the pile.

The storage area shall be maintained free of vegetation and flammable materials.

b) *Handling* — When placing piles or poles on the stack, workers shall work from the ends of the piles/poles. Similar precautions shall be observed in removal of piles/poles from the stack. Tag lines shall be used to control piles and poles when handling for any purpose.

In stacking and handling of piles and poles, precautions as laid down in **8.2.18** (a) shall be followed.

8.2.25 *Paints, Varnishes and Thinners*

a) *Storage and stacking* — Paints, varnishes, lacquers, thinners and other flammable materials shall be kept in properly sealed or closed containers. The containers shall be kept in a well ventilated location, free from excessive heat, smoke, sparks or flame. The floor of the paint stores shall be made up of 100 mm thick loose sand.

Paint materials in quantities other than required for daily use shall be kept stocked under regular storage place.

Where the paint is likely to deteriorate with age, the manner of storage shall facilitate removal and use of lots in the same order in which they are received.

Temporary electrical wirings/fittings shall not be installed in the paint store. When electric lights, switches or electrical equipment are necessary, they shall be of explosion proof design.

b) *Handling* — Adequate ventilation to prevent the accumulation of flammable vapours to hazardous levels of concentration shall be provided in all areas where painting is done.

When painting is done in confined spaces where flammable or explosive vapours may develop, any necessary heat shall be provided through duct work remote from the source of flame.

Sources of ignition, such as open flame and exposed heating elements, shall not be permitted in area or rooms where spray painting is done nor shall smoking be allowed there.

Care should be taken not to use any naked flame inside the paint store. Buckets containing sand shall be kept ready for use in case of fire. Fire extinguishers when required shall be of foam type conforming to accepted standards [7(23)] {*see also* good practice [7(24)]}.

Each workman handling lead based paints shall be issued ½ litre milk per day for his personal consumption.

8.2.26 *Bitumen, Road Tar, Asphalt, etc*

a) *Storage and stacking* – Drums or containers containing all types of bitumen, road tar, asphalt, etc, shall be stacked vertically on their bottoms in up to 3 tiers. Leaky drums shall be segregated. Empty drums shall be stored in pyramidal stacks neatly in rows.

b) *Handling* — *See* **9.13.3.1.2** and **9.13.3.4**.

8.2.27 *Bituminous Roofing Felts*

a) *Storage and stacking* — Bituminous roofing felts shall be stored away from other combustible materials and shall be kept under shade.

b) *Handling* — Bituminous roofing felts should be handled in a manner to prevent cracking and other damages.

8.2.28 *Flammable Materials*

a) *Storage and stacking* — In addition to the requirements as laid down in **8.1.3**, the following provisions shall also apply:

1) Outdoor storage of drums requires some care to avoid contamination because moisture and dirt in hydraulic brake and transmission fluid, gasoline, or lubricants may cause malfunction or failure of equipment, with possible danger to personnel. The storage area should be free of accumulations of spilled products, debris and other hazards.
2) Compressed gases and petroleum products shall not be stored in the same building or close to each other. Storage of petroleum products should be as per *Petroleum Rules*, 2002, as amended from time-to-time.

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b) *Handling* — Petroleum products delivered to the job site and stored there in drums shall be protected during handling to prevent loss of identification through damage to drum markings, tags, etc. Unidentifiable petroleum products may result in improper use, with possible fire hazard, damage to equipment or operating failure.

Workers shall be required to guard carefully against any part of their clothing becoming contaminated with flammable fluids. They shall not be allowed to continue work when their clothing becomes so contaminated.

8.2.29 *Water*

Water to be stored for construction purposes shall be stored in proper tanks to prevent any ingress of organic impurities. The aggregate capacity of storage tanks shall be determined after taking into account the requirements of firefighting.

8.2.30 *Sanitary Appliances*

a) *Storage and stacking* — All sanitary appliances shall be carefully stored under cover to prevent damage. When accepting and storing appliances, consideration shall be given to the sequence of removal from the store to the assembly positions. Vitreous fittings shall be stacked separately from the metal ones.

b) *Handling* — Bigger sanitary appliances shall be handled one at a time. Traps, water seals and gullies shall be handled separately. While handling sanitary fittings they shall be free from any oil spilling, etc. The hands of the workers shall also be free from any oily substance. Before lowering the appliances in their position the supporting brackets, pedestals, etc, shall be checked for their soundness and then only the fixtures be attached.

8.2.31 *Other Materials*

Polymeric materials such as coatings, sheeting, reflective surfacing/sheeting, etc, shall be stored as per the manufacturers' instructions. Special precautions shall be taken in case of storage, handling and usage of toxic materials.

Small articles like screws, bolts, nuts, door and window fittings, polishing stones, protective clothing, spare parts of machinery, linings, packings, water supply and sanitary fittings, and electrical fittings, insulation board, etc, shall be kept in suitable and properly protected containers or store rooms. Valuable small materials shall be kept under lock and key.

8.2.32 *Special Considerations*

8.2.32.1 Materials constantly in use shall be relatively nearer to the place of use.

8.2.32.2 Heavy units like precast concrete members shall be stacked near the hoist or the ramp.

8.2.32.3 Materials which normally deteriorate during storage shall be kept constantly moving, by replacing old materials with fresh stocks. Freshly arrived materials shall never be placed over materials which had arrived earlier.

8.2.32.4 Appropriate types of fire extinguishers shall be provided at open sites where combustible materials are stored and for each storage shed/room where flammable/combustible materials are stored. For guidance regarding selection of the appropriate types of fire extinguishers reference may be made to good practice [7(24)]. It is desirable that a minimum of two extinguishers are provided at each such location.

8.2.32.5 Workers handling excavated earth from foundation, particularly if the site happens to be reclaimed area or marshy area or any other infected area, shall be protected against infection affecting their exposed body portions.

8.2.32.6 *House keeping*

Stairways, walkways, scaffolds, and access ways shall be kept free of materials, debris and obstructions. The engineer-in-charge/the foreman shall initiate and carry out a programme requiring routine removal of scrap and debris from scaffolds and walkways.

8.2.32.7 Where stacking of the materials is to be done on road side berms in the street and other public place, the owner shall seek permission from the Authority for such stacking and also for removing the remnants of the same after the construction is over, so as to avoid any hazard to the public.

8.3 Unloading Rail/Road Wagons and Motor Vehicles

8.3.1 *Loading and unloading from rail/road wagons*

8.3.1.1 Appropriate warning signals shall be displayed to indicate that the wagons shall not be coupled or moved.

8.3.1.2 The wheels of wagons shall always be sprigged or chained while the wagons are being unloaded. The brakes alone shall not be depended upon.

8.3.1.3 Special level bars shall preferably be used for moving rail wagons rather than ordinary crow bars.

8.3.1.4 Where gangplanks are used between wagons and platforms of piles (heaps), cleats at lower end of

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gangplank, or pin through end of gangplanks, shall be used to prevent sliding. If gangplank is on a gradient, cleats or abrasive surface shall be provided for the entire length.

8.3.1.5 When rail/road wagons are being loaded or unloaded near passageways or walkways, adequate warning signals shall be placed on each end of the wagon to warn pedestrians.

8.3.2 *Loading and Unloading from Motor Vehicles*

8.3.2.1 The motor vehicles shall be properly blocked while being loaded or unloaded; brakes alone shall not be depended upon to hold them.

8.3.2.2 When motor vehicles are being loaded or unloaded near passageways or walkways, adequate warning signs shall be placed on each end of the vehicle to warn the pedestrians.

8.3.2.3 Adequate lighting shall be provided while loading/unloading.

8.3.3 *Handling Heavy/Long Items*

8.3.3.1 Loading and unloading of heavy items, shall, as far as possible, be done with cranes or gantries. The workman shall stand clear of the material being moved by mechanical equipment. The slings and the ropes used shall be of adequate load carrying capacity, so as not to give way and result in accidents.

8.3.3.2 While heavy and long components are being manually loaded into motor vehicle, wagons, trailer, etc, either wooden sleepers or steel rails of sufficient length and properly secured in position shall be put in a gentle slope against the body of the wagon/vehicle at 3 or 4 places for loading. These long items shall be dragged, one by one, gently and uniformly along these supports by means of ropes, being pulled by men with feet properly anchored against firm surface. As soon as the items come on the floor of the vehicle, the same may be shifted by crowbars and other suitable leverage mechanism, but not by hands to avoid causing accident to the workers.

8.3.3.3 Similar procedure as outlined under **8.3.3.2** shall be followed for manual unloading of long or heavy items.

SECTION 4 SAFETY IN CONSTRUCTION

9 SAFETY IN CONSTRUCTION OF ELEMENTS OF A BUILDING

9.1 General

9.1.1 The provisions of this section shall apply to the erection/alteration of the various parts of a building or similar structure. The construction of the different elements shall conform to **6.4**.

9.1.2 *Other Laws*

Nothing herein stated shall be construed to nullify any rules, regulations, safety standards or statutes of the local state governments or those contained in the various Acts of the Government of India. The specific rules, regulations and acts pertaining to the protection of the public or workers from health and other hazards, wherever specified by the Local/State Authority or in the Acts of the Government take precedence over whatever is herein specified in case of a doubt or dispute.

9.1.3 *Safety Management*

9.1.3.1 The safety of personnel engaged in building construction should be ensured through a well planned and well organized mechanism by employing the guidelines given in good practice [7(12)].

9.1.3.2 Notwithstanding the guidelines given in **9.1.3.1**, all provisions given in relevant Act/Rules/Regulations as amended from time to time shall be followed; in this regard, reference shall also be made to the *Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act*, 1996 and the rules/regulations framed thereunder.

9.2 Temporary Construction, Use of Side Walls and Temporary Encroachments

9.2.1 *Temporary Construction*

The plans and specifications of temporary constructions, which are likely to interfere with facilities or right of way provided by the Authority, shall be submitted to the Authority for approval showing clearly the layout, design and construction.

9.2.1.1 Temporary structure referred to in **9.2.1** shall apply to the following types of structures :

a) Structures with roof or walls made of straw, hay, ulugrass, golpatta, hogle, darma, mat, canvas cloth or other like materials not adopted for permanent or continuous occupancy.

b) Site-work sheds, truck-runways, trestles, foot-bridges, etc.

9.2.2 For detailed information regarding fire safety aspects in respect of construction, location, maintenance and use of temporary structures [mentioned in **9.2.1.1**(a)] including pandals used by public for outdoor assembly, reference may be made to good practice [7(25)].

9.2.3 Special permits shall be obtained for the storage of the materials on side walks and highways. It shall be ensured that the material dump or the storage shed does not create a traffic hazard, nor it shall interfere with the free flow of the pedestrian traffic. Special permits

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shall also be obtained for the use of water and electricity from the public facilities. Whenever such utilities are made use of, adequate safety precautions regarding drainage and elimination of contamination and hazards from electricity shall be taken.

9.2.4 In order to ensure safety for the adjoining property, adequate temporary protective guards are to be provided. In case these protective devices project beyond the property, the consent of the Authority and that of the owner of the adjoining property shall be obtained.

9.3 Testing

9.3.1 *Tests*

No structure, temporary support, scaffolding or any construction equipment during the construction or demolition of any building or structure shall be loaded beyond the allowable loads and working stresses as provided for in Part 6 'Structural Design' of the Code {*see also* good practices [7(26)]}.

9.3.1.1 Whenever any doubt arises about the structural adequacy of a scaffolding, support or any other construction equipment, it shall be tested to two and a half times the superimposed dead and imposed loads to which the material or the equipment is subjected to and the member/material shall sustain the test load without failure if it is to be accepted.

9.3.2 Notwithstanding the test mentioned above, if any distress in any member is visible, the member shall be rejected.

9.4 Inspection and Rectification of Hazardous Defects

9.4.1 *Inspection*

The Authority shall inspect the construction equipment and if during the inspection, it is revealed that unsafe/ illegal conditions exist, the Authority shall intimate the owner and direct him to take immediate remedial measures to remove the hazard/violation.

9.4.2 *Rectification*

The owner shall proceed to rectify the defect, hazardous condition or violation within 24 h of the receipt of the notice from the Authority. The Authority shall have full powers to rectify the unsafe condition and all expenses incurred in this connection is payable by the owner of the property. Illegal encroachments and non-payment of money due, in respect of the rectification of unsafe conditions may vest a lien on the property with the Authority (*see also* Part 2 'Administration' of the Code).

9.4.3 When the strength and adequacy of any scaffold or other construction equipment is in doubt or when any complaint is made, the Authority shall get the same inspected before use.

9.5 Foundations

9.5.1 *General*

The distribution of the supporting foundation shall be such as to avoid any harmful differential settlement of the structure. The type and design of the foundation adopted shall ensure safety to workers during construction and residents of the neighbouring property. Sufficient care shall be taken in areas, where withdrawal of ground water from surrounding areas could result in damages to such foundations. During the construction of the foundation, it shall be ensured that the adjoining properties are not affected by any harmful effects.

9.5.2 *Adjoining Properties*

The person causing excavation shall, before starting the work, give adequate notices in writing to the owner of the adjoining properties, safety of which is likely to be affected due to excavation. After having given such notices, wherein details regarding the type of protective works that are anticipated to be incorporated in the excavation are shown, written permission shall be obtained for such excavation from the adjoining property owners. Where necessary, the person causing excavation shall make adequate provision to protect the safety of adjacent property. If on giving such notices and the precautionary measures having been approved by the Authority, the adjoining property owner still refuses to give necessary facilities to the person causing excavation for protecting/providing both temporary and permanent supports to such property, the responsibility for any damage to the adjoining property shall be that of the adjoining property owner. The person causing excavation shall be absolved of responsibility for any loss of property or life in the adjoining property.

9.5.2.1 *Protection to neighbouring structures and adjoining services*

In driven piles, vibration is set up which may cause damage to adjoining structures or service lines depending on the nature of soil condition and the construction standard of such structures and service lines. Possible extent of all such damages shall be ascertained in advance and operation and mode of driving shall be planned with appropriate measures to ensure safety.

Wherever in the vicinity of a site where bored or driven piling works are to be carried out there are old structures which are likely to be damaged, tell-tales shall be fixed on such structures to watch their behaviour and timely precautions taken against any undesirable effect.

In case of bored piles, measures shall be taken to ensure,

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that there is no appreciable movement of soil mass into the borehole which may cause subsidence to any existing foundation in the close proximity. In wet holes where such possibilities are likely to be there the same shall be minimised by approved technique and the operation should be planned.

9.5.3 During construction, inspection shall be made by the engineer-in-charge to ensure that all protective works carried out to safe-guard the adjoining property are sufficient and in good order to ensure safety (*see* Part 2 'Administration' of the Code).

9.5.4 Before carrying out any excavation work/pile driving, the position, depth and size of underground structures, such as water pipes, mains, cables or other services in the vicinity to the proposed work, may be obtained from the Authority to prevent accidents to workers engaged in excavation work and calamities for the general public.

Prior to commencement of excavation detailed data of the type of soils that are likely to be met with during excavation shall be obtained and the type of protective works by way of shoring timbering, etc, shall be decided upon for the various strata that are likely to be encountered during excavation. For detailed information regarding safety requirements during excavation reference may be made to good practice [7(20)].

9.6 General Requirements and Common Hazards During Excavation

9.6.1 *Location of Machinery and Tools*

Excavating machinery consisting of both heavy and light types shall be kept back from the excavation site at a distance which would be safe for such type of equipment. Heavy equipment, such as excavating machinery and road traffic shall be kept back from the excavated sites at a distance of not less than the depth of trench or at least 6 m for trench deeper than 6 m. Care shall also be taken to keep excavating tools and materials far away from the edge of trench to prevent such items being inadvertently knocked into the trench.

9.6.2 *Excavated Materials*

Excavated materials shall be kept back from the edges of the trench to provide clear berm of safe width. Where this is not feasible, the protective works designed for the trenches shall take into consideration, the additional load due to overburden of materials.

9.6.2.1 *Other surcharges*

Proximity of buildings, piles of lumber, crushed rocks, sand and other construction materials, large trees, etc, may impose surcharges on the side of the trench to cause sliding, etc. Under these conditions additional protective works shall be provided to support the sides of the trench.

9.6.3 *Type of Strata*

Adequate precautions, depending upon the type of strata met with during excavation (like quick sand, loose fills and loose boulder) shall be taken to protect the workers during excavation. Effect of climatic variations and moisture content variations on the materials under excavation shall be constantly watched and precautions taken, where necessary, immediately to prevent accidents at work site.

9.6.4 *Overhang and Slopes*

During any excavation, sufficient slopes to excavated sides by way of provision of steps or gradual slopes shall be provided to ensure the safety of men and machine working in the area.

9.6.5 Blasting for foundation of building is prohibited unless special permission is obtained from the Authority. Where blasting technique has to be resorted to, prior inspection for the stability of slopes shall be carried out. After blasting, overhangs or loose boulders shall be cleared by expert workers carrying out blasting prior to continuation of the excavation by normal working parties.

9.6.5.1 Burrowing or mining or what is known as 'gophering' shall not be allowed. In any trench where such methods have been followed, the cavities felt shall be eliminated by cutting back the bare slope before removing any further material from the section of the trench.

9.6.6 *Health Hazards*

Where gases or fumes are likely to be present in trenches, sufficient mechanical ventilation, to protect the health and safety of persons working there, shall be provided. If necessary, the personnel working there, shall be provided with respiratory protective equipment when work in such unhealthy conditions has to be carried out. The precautionary measures provided shall be inspected by the local health authorities prior to commencement of the work.

9.6.7 *Safety of Materials*

Materials required for excavation, like ropes, planks for gangways and walkways, ladders, etc, shall be inspected by the engineer-in-charge who shall ensure that no accident shall occur due to the failure of such materials (*see* Part 5 'Building Materials' of the Code).

9.6.8 *Fencing and Warning Signals*

Where excavation is going on, for the safety of public and the workers, fencing shall be erected, if there is likelihood of the public including cattle frequenting the area. Sufficient number of notice boards and danger sign lights shall be provided in the area to avoid any

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member of public from inadvertently falling into the excavation. When excavations are being done on roads, diversion of the roads shall be provided with adequate notice board and lights indicating the diversion well ahead. Where necessary, recourse may be had for additional precautionary measures by way of watchmen to prevent accident to the general public, especially during hours of darkness.

9.6.9 *Effect of Freezing and Thawing*

Due to expansion of water when freezing, rock fragments, boulders, etc, are frequently loosened. Therefore, the side walls of the excavation shall be constantly watched for signs of cracks during a thaw. When depending in whole or in part on freezing to support the side walls, great care shall be taken during thaws to provide suitable bracing or remedy the condition by scaling of the loose material from the sides.

9.6.10 *Vibrations from Nearby Sources*

Vibration due to adjacent machinery, vehicles, rail-roads, blasting, piling and other sources require additional precautions to be taken.

9.6.11 *Precautions While Using Petroleum Powered Equipment*

At the site of excavation, where petroleum powered equipment is used, petroleum vapours are likely to accumulate at lower levels and may cause fire explosion under favourable circumstances. Care should, therefore, be taken to avoid all sources of ignition in such places.

9.7 Piling and Other Deep Foundations

9.7.1 *General*

9.7.1.1 *Safety programme*

All operations shall be carried out under the immediate charge of a properly qualified and competent foreman who shall also be responsible for the safety arrangements of the work.

9.7.1.2 For work during night, lighting of at least 100 lux intensity shall be provided at the work site.

9.7.1.3 Barricading/fencing shall be provided, wherever necessary, around the working area or the watchmen provided to prevent onlookers from trespassing into the construction sites. In case of digging a bore hole, precautions shall be taken that it is properly barricaded and is not left open to avoid accidental fall into the bore well.

9.7.1.4 The working area shall be investigated to ascertain the presence of any buried obstruction and actual position of all service lines passing through the work site shall be known before the work commences. Particular attention shall be given in case live electrical cables pass underground, which may interfere within the depth of the foundation.

9.7.1.5 The safety provisions shall be brought to the notice of all concerned and matters needing special attention shall be displayed at a prominent place at the work spot.

9.7.1.6 All necessary personal protective equipment like full body harnesses, safety helmets and safety shoes, as considered suitable, shall be kept available for the use of persons employed on the site and maintained in condition suitable for immediate use.

9.7.1.7 A first-aid kit shall be maintained at the site near the place of work, to comply with the requirements and provisions for the work.

9.7.1.8 Those engaged in mixing and stacking of cement bags or any other material injurious to human body shall be provided with protective wear suitable for the purpose. Welders engaged in the work of welding shall use welding goggles/shields, helmets and gloves.

9.7.1.9 Every crane driver or hoisting appliance operator shall be competent to the satisfaction of the engineer-in-charge and no person under the age of 21 years should be in-charge of any hoisting machine including any scaffolding winch, or give signals to operator. Crane driver and hoisting appliance operator shall posses the knowledge of inherent risks involved in the operation of lifting appliances by undergoing a formal training at any institution of national importance acceptable to the employer and is medically examined periodically including in compliance to the requirement as may be specified in the *Building and other Construction Workers' (Regulation of Employment and Conditions of Service Central) Rules*, 1998.

9.7.1.10 Working in compressed air, in case of deep foundations, requires several precautions to be observed to safeguard the workers against severe hazards to life, compressed air disease and related ailments. For detailed information regarding safety requirements, reference may be made to good practice [7(27)].

9.7.2 *Piling Rig*

9.7.2.1 There are numerous types of piling rigs in piling work, depending on the need for the site conditions. While utilizing specialized rigs the instructions issued by the suppliers shall be kept in view.

9.7.2.1.1 Pile drivers shall not be erected in dangerous proximity to electric conductors.

9.7.2.1.2 If two pile drivers are erected at one place these shall be separated by a distance at least equal to the longest leg in either rig.

9.7.2.2 The frame of any rig shall be structurally safe

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for all anticipated dead, live or wind loads. Whenever there is any doubt about the structural strength, suitable test shall be carried out by the foreman and the results of the test recorded. No pile-driving equipment shall be taken into use until it has been inspected and found to be safe.

9.7.2.3 Pile drivers shall be firmly supported on heavy timber sills, concrete beds or other secure foundation. If necessary, to prevent danger, pile drivers shall be adequately guyed.

When the rig is not in use, extra precautionary measures for stability, such as securing them with minimum four guys, shall be adopted to prevent any accidents due to wind, storm, gales and earthquake.

9.7.2.4 Access to working platforms and the top pulley shall be provided by ladders. Working platforms shall be protected against the weather.

9.7.2.4.1 In tall driven piling rigs or rigs of similar nature where a ladder is necessary for regular use, the ladder shall be securely fastened and extended for the full height of the rig. The ladder shall also be maintained in good condition at all times.

9.7.2.5 Exposed gears, fly wheels, etc, shall be fully enclosed. Boilers, hoisting drums and brakes shall be kept in good condition and sheltered from weather, wherever possible.

9.7.2.6 Pile driving equipment in use shall be inspected by a competent engineer at regular intervals not exceeding three months. Also a register shall be maintained at the site of work for recording the results of such inspections. Pile lines and pulley blocks shall be inspected by the foreman before the beginning of each shift for any excess wear or any other defect.

9.7.2.6.1 Defective parts of pile drivers, such as sheaves, mechanism slings and hose shall be repaired by only competent person and duly inspected by foreman-in-charge of the rig and the results recorded in the register. No steam or air equipment shall be repaired while it is in operation or under pressure. Hoisting ropes on pile drivers shall be made of galvanized steel.

9.7.2.7 All bolts and nuts which are likely to be loosened due to vibration during pile driving shall be checked regularly and tightened.

9.7.2.8 Steam and air lines shall be controlled by easily accessible shut-off valves. These lines shall consist of armoured hose or its equivalent. The hose of steam and air hammers shall be securely lashed to the hammer so as to prevent it from whipping if a connection breaks. Couplings of sections of hose shall be additionally secured by ropes or chains.

9.7.2.9 When not in use, the hammer shall be in dropped position and shall be held in place by a cleat, timber or any other suitable means.

9.7.2.10 For every hoisting machine and for every chain ring hook, shackle, swivel and pulley block, used in hoisting or as means of suspension, the safe working loads shall be ascertained. In case of doubt actual testing shall be carried out and the working load shall be taken as half of the tested load. Every hoisting machine and all gears referred to above shall be plainly marked with the safe working load. In case of a hoisting machine having a variable safe working load, each safe working load together with the conditions under which it is applicable shall be clearly indicated. No part of any machine or any gear shall be loaded beyond the safe working load except for the purpose of testing.

All hoisting appliances should be fitted with automatic safe load indicator, boom angle indicator, swing alarm, back horn, over lift boom alarm. A register shall be maintained containing a system of identification of all tools and tackles, their date of purchase, safe working load and date of examination by competent person. All loads shall have tag-lines attached in order to ensure that the load can be controlled at all times.

9.7.2.11 Motor gearing, transmission, electrical wiring and other dangerous parts of hoisting appliances should be provided with efficient safeguards. Hoisting appliances shall be provided with such means as will reduce, to the minimum, the risk of accidental descent of the load and adequate precautions shall be taken to reduce to the minimum, the risk of any part of suspended load becoming accidentally displaced. When workers are employed on electrical installations which are already energized, insulating mats and wearing apparel, such as gloves, etc, as may be necessary, shall be provided. Sheaves on pile drivers shall be guarded so that workers may not be drawn into them.

When loads have to be inclined, they shall be adequately counter-balanced and the tilting device shall be secured against slipping.

9.7.2.12 Adequate precautions shall be taken to prevent a pile driver from overturning, if a wheel breaks.

9.7.2.13 Adequate precautions shall be taken by providing stirrups or by other effective means, to prevent the rope from coming out of the top pulley or wheel.

9.7.2.14 Adequate precautions shall be taken to prevent the hammer from missing the pile.

9.7.2.15 If necessary to prevent danger, long piles and heavy sheet piling should be secured against falling.

9.7.2.16 Wherever steam boilers are used, the safety regulations of boiler shall be strictly followed and safety

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valves shall be adjusted to 0.07 N/mm^2 in excess of working pressure accurately.

9.7.2.17 Where electricity is used as power for piling rig, only armoured cable conforming to the relevant Indian Standard shall be used and the cable shall be thoroughly waterproofed.

9.7.3 *Operation of Equipment*

9.7.3.1 Workers employed in the vicinity of pile drivers shall wear helmets conforming to accepted standard [7(28)].

9.7.3.2 Piles shall be prepared at a distance at least equal to twice the length of the longest pile from the pile driver.

9.7.3.3 Piles being hoisted in the rig should be so slung that they do not have to be swung round, and may not inadvertently, swing or whip round. A hand rope shall be fastened to a pile that is being hoisted to control its movement. While a pile is being guided into position in the leads, workers shall not put their hands or arms between the pile and the inside guide or on top of the pile, but shall use a rope for guiding.

9.7.3.4 While a pile is being hoisted all workers not actually engaged in the operation shall keep at a distance which ensures safety. Piles shall not be slewed over public areas without stopping the pedestrians and road traffic first.

9.7.3.5 Before a wood pile is hoisted into position it shall be provided with an iron ring or cap over the driving end to prevent brooming.

9.7.3.6 When creosoted wood piles are being driven, adequate precautions shall be taken, such as the provision of personal protective equipment and barrier creams to prevent workers receiving eye or skin injuries from splashes of creosote.

9.7.3.7 When piles are driven at an inclination to the vertical, if necessary to prevent danger, these should rest in a guide.

9.7.3.8 No steam or air line shall be blown down until all workers are at a safe distance.

9.7.4 *Sheet Piling*

9.7.4.1 If necessary to prevent danger from wind or other sources, a hand rope shall be used to control the movement of steel sheet sections that are being transported.

9.7.4.2 Workers who have to sit on a steel sheet section to interlock sheets shall be provided with stirrups or other devices to afford them a safe seat. Workers shall not stand or sit on sheet piling while it is being released from the slings, lowered or moved into position.

9.7.4.3 Workers handling sheets should wear gloves.

9.7.4.4 If necessary to prevent danger from displacement by the current, steel sheet sections shall be braced until they are firmly in position. If necessary to prevent danger from undercutting of the cofferdam by the current a substantial berm shall be installed upstream.

9.7.4.5 Adequate pumping facilities shall be available at cofferdams to keep them clear of water. Also adequate means of escape, such as ladders and boats shall be provided at cofferdams for the protection of workers in case of flooding.

9.7.4.6 Adequate supplies of life-saving equipment shall be provided for workers employed on cofferdams.

9.7.4.7 When sheet sections are being removed, their movements shall be controlled by cables or other effective means.

9.8 Walls

9.8.1 *General*

Depending on the type of wall to be constructed the height of construction per day shall be restricted to ensure that the newly constructed wall does not come down due to lack of strength in the lower layers. Similarly, in long walls adequate expansion/crumple joints shall be provided to ensure safety.

9.8.2 *Scaffold*

Properly designed and constructed scaffolding built by competent workers shall be provided during the construction of the walls to ensure the safety of workers. The scaffolding may be of timber, metal or bamboo sections and the materials in scaffolding shall be inspected for soundness, strength, etc, at site by the engineer-in-charge prior to erection of scaffolds. Steel scaffolds intended for use in normal building construction work shall conform to accepted standard [7(29)]. Bamboo and timber scaffolds shall be properly tied to the junctions with coir ropes of sufficient strength or mechanical joints to ensure that joints do not give way due to the load of workers and material. Joining the members of scaffolds only with nails shall be prohibited as they are likely to get loose under normal weathering conditions. In the erection or maintenance of tall buildings, scaffoldings shall be of non-combustible material especially when the work is being done on any building in occupation. After initial construction of the scaffolding, frequent inspections of scaffolding shall be carried out regularly. The platforms, gangways and runways provided on the scaffoldings shall be of sufficient strength and width to ensure safe passage for the workers working on the scaffolding. The joints provided in these gangways, platforms, etc, shall be such as to ensure a firm foot-hold to the workers. Where necessary, cross bars shall be provided

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to the full width of gangway or runway to facilitate safe walking. For detailed information regarding safety requirements for erection, use and dismantling of scaffolds, reference may be made to good practices [7(30)].

9.8.2.1 The engineer-in-charge shall ensure by frequent inspections that gangways of scaffolding have not become slippery due to spillage of material. Loose materials shall not be allowed to remain on the gangways. Where necessary, because of height or restricted width, hand-rails shall be provided on both sides. Workers shall not be allowed to work on the scaffolding during bad weather and high winds.

9.8.2.2 In the operations involved in the erection or maintenance of outside walls, fittings, etc, of tall buildings, it is desirable to use one or more net(s) for the safety of the workers when the workers are required to work on scaffoldings.

9.8.3 *Ladders*

All ladders shall be constructed of sound materials and shall be capable of carrying their intended loads safely. The ladders shall have not only adequate strength but rigidity as well. If a ladder shows tendency to spring, a brace shall be attached to its middle and supported from some other non-yielding fixed object. No ladder having a missing or defective rung or one which depends for its support solely on nails, shall be used. Ladders shall not be used as guys, braces or skids or for any other purpose for which they are not intended. They shall not be used in horizontal position as runways. They shall not be overcrowded. Wherever possible, ladders shall not be spliced. Where splicing is unavoidable, it shall be done only under the supervision of engineer-in-charge. Ladders leading to landings or walkways shall extend at least 1 m above the landing and shall be secured at the upper end. To prevent slipping, a ladder shall be secured at the bottom end. If this cannot be done, a person shall be stationed at the base whenever it is in use. As a further precaution, the pitch at which a lean-to-ladder is used shall be such that the horizontal distance of its foot from the vertical plane of its top shall be not more than one quarter of its length. If the surface of the floor on which the ladder rests is smooth or sloping, the ladder shall be provided with non-slip bases. If the use of a ladder is essential during strong winds, it shall be securely lashed in position. No ladder shall be placed or leant against window pane, sashes or such other unsafe or yielding objects, nor placed in front of doors opening towards it. If set up in driveways, passageways or public walkways, it shall be protected by suitable barricades. When ascending or descending, the user shall face the ladder, use both his hands and place his feet near the ends of the rungs rather than near the middle. It is dangerous to lean more than 30 cm to side in order to reach a larger area from a single setting of the ladder. Instead, the user shall get down and shift the ladder to the required position.

Metal ladders shall not be used around electrical equipment or circuits of any kind where there is a possibility of coming in contact with the current. Metal ladders shall be marked with signs reading 'CAUTION—DO NOT USE NEAR ELECTRICAL EQUIPMENT'.

Wooden ladders shall be inspected at least once in a month for damage and deterioration. Close visual inspection is recommended in preference to load testing. This condition is particularly applicable to rope and bamboo ladders wherein fraying of ropes and damage to bamboo is likely to occur due to materials falling on them. When a ladder has been accidentally dropped it shall be inspected by the engineer-in-charge prior to re-use. Overhead protection shall be provided for workers under ladder. For detailed information regarding safety requirements for use of ladders, reference may be made to good practice [7(31)].

9.8.4 *Opening in Walls*

Whenever making of an opening in the existing wall is contemplated, adequate supports against the collapse or cracking of the wall portion above or roof or adjoining walls shall be provided.

9.8.4.1 *Guarding of wall openings and holes*

Wall opening barriers and screens shall be of such construction and mounting that they are capable of withstanding the intended loads safely. For detailed information reference may be made to good practice [7(32)]. Every wall opening from which there is a drop of more than 1 200 mm shall be guarded by one of the following:

a) *Rail, roller, picket fence, half door or equivalent barrier* — The guard may be removable but should preferably be hinged or otherwise mounted so as to be conveniently replaceable. Where there is danger to persons working or passing below on account of the falling materials, a removable toe board or the equivalent shall also be provided. When the opening is not in use for handling materials, the guards shall be kept in position regardless of a door on the opening. In addition, a grab handle shall be provided on each side of the opening. The opening should have a sill that projects above the floor level at least 25 mm.

b) Extension platform, into which materials may be hoisted for handling, shall be of full length of the opening and shall have side rails or equivalent guards.

9.8.4.2 Every chute wall opening from which there is a

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drop of more than 1 200 mm shall be guarded by one or more of the barriers specified in **9.8.4.1** or as required by the conditions.

9.8.5 *Projection from Walls*

Whenever projections cantilever out of the walls, temporary formwork shall be provided for such projections and the same shall not be removed till walls over the projecting slabs providing stability load against overturning are completely constructed.

9.9 Common Hazards During Walling

9.9.1 *Lifting of Materials for Construction*

Implements used for carrying materials to the top of scaffoldings shall be of adequate strength and shall not be overloaded during the work. Where workers have to work below scaffoldings or ladder, overhead protection against the falling materials shall be provided. Care shall be taken in carrying large bars, rods, etc, during construction of the walls to prevent any damage to property or injury to workers.

9.9.2 *Haulage of Materials*

9.9.2.1 In case of precast columns, steel beams, etc, proper precautions shall be taken to correctly handle, use and position them with temporary arrangement of guys till grouting of the base.

9.9.2.2 Manila or sisal rope shall not be used in rainy season for hoisting of heavy materials as they lose their strength with alternate wetting and drying.

9.9.3 *Electical Hazards*

No scaffolding, ladder, working platform, gangway runs, etc, shall exist within 3 m from any uninsulated electric wire.

9.9.4 *Fire Hazards*

Gangways and the ground below the scaffolding shall be kept free from readily combustible materials including waste and dry vegetation at all times.

Where extensive use of blow torch or other flame is anticipated scaffoldings, gangways, etc, shall be constructed with fire resistant materials. A portable dry powder extinguisher of 3 kg capacity shall be kept handy.

9.9.5 *Mechanical Hazards*

Care shall be taken to see that no part of scaffolding or walls is struck by truck or heavy moving equipment and no materials shall be dumped against them to prevent any damage. When such scaffoldings are in or near a public thoroughfare, sufficient warning lights and boards shall be provided on the scaffoldings to make them clearly visible to the public.

9.9.6 *Fragile Materials*

During glazing operations, adequate precautions shall be taken to ensure that the fragments of fragile materials do not cause any injury to workers or general public in that area by way of providing covering to such material, side protection at work site, etc.

9.10 Roofing

9.10.1 Prevention of accidental falling of workers during the construction of roofs shall be ensured by providing platforms, catch ropes, etc. If the materials are to be hoisted from the ground level to the roof level, adequate precautions shall be taken by way of correct technique of handling, hoists of sufficient strength to cater for the quantity of stores to be hoisted and prevention of overloading such hoists or buckets, prevention of overturning of hoists or buckets. Where in a multi-storeyed building, the floor of one storey is to be used for storage of materials for the construction of roofs, it shall be ensured that the quantum of stores kept on the floor along with the load due to personnel engaged in the construction work shall not exceed the rated capacity of the floors.

9.10.2 While roofing work is being done with corrugated galvanized iron or asbestos cement sheets, it shall be ensured that joints are kept secured in position and do not slip, thus causing injury to workers. Workers should not be allowed to walk on asbestos cement sheets but should be provided with walking boards. While working with tiles, it shall be ensured that they are not kept loose on the roof site resulting in falling of tiles on workers in lower area. In slopes of more than 30° to the horizontal, the workers shall use ladders or other safety devices to work on the roof.

9.10.3 If any glass work is to be carried out in the roof, it shall be ensured that injury to passerby due to breaking of glass is prevented. During wet conditions, the workers shall be allowed to proceed to work on a sloping roof, only if the engineer-in-charge has satisfied himself that the workers are not likely to slip due to wet conditions.

9.10.4 *Flat Roof*

In any type of flat roof construction, any formwork provided shall be properly designed and executed to ensure that it does not collapse during construction. During actual construction of roof, frequent inspection of the formwork shall be carried out to ensure that no damage has occurred to it.

9.10.5 While using reinforcement in roofs, it shall be ensured that enough walking platforms are provided in the reinforcement area to ensure safe walking to the concreting area. Loose wires and unprotected rod ends shall be avoided.

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9.10.6 *Guarding of Floor Openings and Floor Holes*

9.10.6.1 Every temporary floor opening shall have railings, or shall be constantly attended by someone. Every floor hole into which persons can accidentally fall shall be guarded by either,

a) a railing with toe board on all exposed sides; or

b) a floor hole cover of adequate strength and it should be hinged in place. When the cover is not in place, the floor hole shall be constantly attended by someone or shall be protected by a removable railing.

9.10.6.2 Every stairway floor opening shall be guarded by a railing on all exposed sides, except at entrance to stairway. Every ladder way floor opening or platform shall be guarded by a guard railing with toe board on all exposed sides (except at entrance to opening), with the passage through the railing either provided with a swinging gate or so offset that a person cannot walk directly into the opening.

9.10.6.3 *Guarding of open-side floors and platform*

Every open-sided floor or platform 1 200 mm or more above adjacent floor or ground level shall be guarded by a railing (or the equivalent) on all open sides, except where there is entrance to ramp, stair-way, or fixed ladder. The railing shall be provided with a toe board beneath the open sides wherever,

a) persons may pass;
b) there is moving machinery; or
c) there is equipment with which falling materials could create a hazard.

For detailed information, reference may be made to good practice [7(32)].

9.11 Additional Safety Requirements for Erection of Concrete Framed Structures (High-Rise Buildings)

9.11.1 *Handling of Plant*

9.11.1.1 *Mixers*

All gears, chains and rollers of mixers shall be properly guarded. If the mixer has a charging skip the operator shall ensure that the workers are out of danger before the skip is lowered. Railings shall be provided on the ground to prevent anyone walking under the skip while it is being lowered.

All cables, clamps, hooks, wire ropes, gears and clutches, etc, of the mixer, shall be checked and cleaned, oiled and greased, and serviced once a week. A trial run of the mixer shall be made and defects shall be removed before operating a mixer.

When workers are cleaning the inside of the drums, operating power of the mixer shall be locked in the off position and all fuses shall be removed and a suitable notice hung at the place.

9.11.1.2 *Cranes*

Crane rails where used shall be installed on firm ground and shall be properly secured. In case of tower cranes, it shall be ensured that the level difference between the two rails remains within the limits prescribed by the manufacturer to safeguard against toppling of the crane. Requirements for tower cranes as given in **7.3** shall also be complied with.

Electrical wiring which can possibly touch the crane or any member being lifted shall be removed, or made dead by removing the controlling fuses and in their absence controlling switches.

All practical steps shall be taken to prevent the cranes being operated in dangerous proximity to a live overhead power line. In particular, no member of the crane shall be permitted to approach within the minimum safety distances as laid down in **8.2.23** (a).

If it becomes necessary to operate the cranes with clearances less than those specified above, it shall be ensured that the overhead power lines shall invariably be shut off during the period of operation of cranes. Location of any underground power cables in the area of operation shall also be ascertained and necessary safety precautions shall be taken.

Cranes shall not be used at a speed which causes the boom to swing.

A crane shall be thoroughly examined at least once in a period of 6 months by a competent person who shall record a certificate of the check.

The operator of the crane shall follow the safe reach of the crane as shown by the manufacturer.

No person shall be lifted or transported by the crane on its hook or boom.

Toe boards and limit stops should be provided for wheel barrows on the loading/unloading platforms. Material should be loaded securely with no projections.

Concrete buckets handled by crane or overhead cableway shall be suspended from deep throated hooks, preferably equipped with swivel and safety latch. In the concrete buckets, both bottom drop type and side drop type, closing and locking of the exit door of the bucket shall always be checked by the man-in-charge of loading concrete in the bucket to avoid accidental opening of the exit door and consequent falling of concrete.

Interlocking or other safety devices should be installed

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at all stopping points of the hoists. The hoists shaft way should be fenced properly.

When the bucket or other members being lifted are out of sight of the crane operator, a signalman shall be posted in clear view of the receiving area and the crane operator.

A standard code of hand signals shall be adopted in controlling the movements of the crane, and both the driver and the signaller shall be thoroughly familiar with the signals.

The driver of the crane shall respond to signals only from the appointed signaler but shall obey stop signal at any time no matter who gives it.

If a travelling gantry crane is operating over casting beds, a warning signal which sounds automatically during travel should be provided to avoid accidents to workers crossing or standing in the path of the moving loads.

9.11.1.3 *Trucks*

When trucks are being used on the site, traffic problems shall be taken care of. A reasonably smooth traffic surface shall be provided. If practicable, a loop road shall be provided to permit continuous operation of vehicles and to eliminate their backing. If a continuous loop is not possible, a turnout shall be provided. Backing operations shall be controlled by a signalman positioned so as to have a clear view of the area behind the truck and to be clearly visible to the truck driver. Movement of workers and plant shall be routed to avoid crossing, as much as possible, the truck lanes.

9.11.1.4 *Concrete pumps (Air compressor operated)*

Safety requirements in accordance with good practice [7(33)] shall be followed.

9.11.2 *Formwork*

9.11.2.1 Formwork shall be designed after taking into consideration spans, setting temperature of concrete, dead load and working load to be supported and safety factor for the materials used for formwork {*see also* with good practice [7(26)]}.

9.11.2.2 All timber formwork shall be carefully inspected before use and members having cracks and excessive knots shall be discarded.

9.11.2.3 As timber centering usually takes an initial set when vertical load is applied, the design of this centering shall make allowance for this factor.

9.11.2.4 The vertical supports shall be adequately braced or otherwise secured in position that these do not fall when the load gets released or the supports are accidently hit.

9.11.2.5 Tubular steel centering shall be used in accordance with the manufacturer's instructions. When tubular steel and timber centering is to be used in combination necessary precautions shall be taken to avoid any unequal settlement under load.

9.11.2.6 A thorough inspection of tubular steel centering is necessary before its erection and members showing evidence of excessive resting, kinks, dents or damaged welds shall be discarded. Buckled or broken members shall be replaced. Care shall also be taken that locking devices are in good working order and that coupling pins are effectively aligned to frames.

9.11.2.7 After assembling the basic unit, adjustment screws shall be set to their approximate final adjustment and the unit shall be level and plumb so that when additional frames are installed the tower shall be in level and plumb. The centering frames shall be tied together with sufficient braces to make a rigid and solid unit. It shall be ensured that struts and diagonals braces are in proper position and are secured so that frames develop full load carrying capacity. As erection progresses, all connecting devices shall be in place and shall be fastened for full stability of joints and units.

9.11.2.8 In case of timber posts, vertical joints shall be properly designed. The connections shall normally be with bolts and nuts. Use of rusted or spoiled threaded bolts and nuts shall be avoided.

9.11.2.9 Unless the timber centering is supported by a manufacturer's certificate about the loads it can stand, centering shall be designed by a competent engineer.

9.11.2.10 Centering layout shall be made by a qualified engineer and shall be strictly followed. The bearing capacity of the soil shall be kept in view for every centering job. The effect of weather conditions as dry clay may become very plastic after a rainfall and show marked decrease in its bearing capacity.

9.11.2.11 Sills under the supports shall be set on firm soil or other suitable material in a pattern which assures adequate stability for all props. Care shall be taken not to disturb the soil under the supports. Adequate drainage shall be provided to drain away water coming due to rains, washing of forms or during the curing of the concrete to avoid softening of the supporting soil strata.

9.11.2.12 All centering shall be finally, inspected to ensure that,

a) footings or sills under every post of the centering are sound.
b) all lower adjustment screws or wedges are sung against the legs of the panels.
c) all upper adjustment screws or heads of jacks are in full contact with the formwork.

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d) panels are plumb in both directions.

e) all cross braces are in place and locking devices are in closed and secure position.

f) In case of *Chhajas* and balconies, the props shall be adequate to transfer the load to the supporting point.

9.11.2.13 During pouring of the concrete, the centering shall be constantly inspected and strengthened, if required, wedges below the vertical supports tightened and adjustment screws properly adjusted as necessary. Adequate protection of centering shall be secured from moving vehicles or swinging loads.

While pouring concrete, it should be placed in such a manner that the load should be transmitted to the support of formwork uniformly without causing high eccentric load.

Caution shall be exercised to avoid heap storage of bricks/sand in roof/floor slab as it may lead to failure of slab.

9.11.2.14 Forms shall not be removed earlier than as laid down in the specifications and until it is certain that the concrete has developed sufficient strength to support itself and all loads that will be imposed on it. Only workers actually engaged in removing the formwork shall be allowed in the area during these operations. Those engaged in removing the formwork shall wear helmets, gloves and heavy soled shoes and approved safety belts if adequate footing is not provided above 2 m level. While cutting any tying wires in tension, care shall be taken to prevent backlash which might hit a workman.

9.11.2.14.1 The particular order in which the supports are to be dismantled should be followed according to the instructions of the site engineer.

9.11.3 *Ramps and Gangways*

9.11.3.1 Ramps and gangways shall be of adequate strength and evenly supported. They shall either have a sufficiently flat slope or shall have cleats fixed to the surface to prevent slipping of workers. Ramps and gangways shall be kept free from grease, mud, snow or other slipping hazards or other obstructions leading to tripping and accidental fall of a workman.

9.11.3.1.1 Ramps and gangways meant for transporting materials shall have even surface and be of sufficient width and provided with skirt boards on open sides.

9.11.4 *Materials Hoists*

9.11.4.1 The hoist should be erected on a firm base, adequately supported and secured. All materials supporting the hoist shall be appropriately designed and strong enough for the work intended and free from defects.

9.11.4.2 The size of the drum shall match the size of the rope. Not less than two full turns of rope shall remain on the drum at all times. Ropes shall be securely attached to the drum.

9.11.4.3 All ropes, chains and other lifting gear shall be properly made of sound materials, free from defects and strong enough for the work intended. They shall be examined by a competent person who shall clearly certify the safe working load on each item and the system.

9.11.4.4 Hoistways shall be protected by a substantial enclosure at ground level, at all access points and wherever persons may be struck by any moving part.

9.11.4.5 Gates at access points should be at least 2 m high, wherever possible. Gates shall be kept closed at all times except when required open for immediate movement of materials at that landing place.

9.11.4.6 All gates shall be fitted with electronic or mechanical interlocks to prevent movement of the hoist in the event of a gate being opened.

9.11.4.7 Winches used for hoists shall be so constructed that a brake is applied when the control lever or switch is not held in the operating position (dead-man's handle).

9.11.4.8 The hoist tower shall be tied to a building or structure at every floor level or at least every 3 m. The height of the tower shall not exceed 6 m after the last tie or a lesser height as recommended by the manufacturer. All ties on a hoist tower shall be secured using right angled couples.

9.11.4.9 The hoist shall be capable of being operated only from one position at a time. It shall not be operated from the cage. The operator shall have a clear view of all levels or, if he has not, a clear and distinct system of signaling shall be employed.

9.11.4.10 All hoist platform shall be fitted with guards and gates to a height of at least 1 m, to prevent materials rolling/falling from the platform.

9.11.4.11 Where materials extend over the height of the platform guards, a frame shall be fitted and the materials secured to it during hoisting/lowering. Care should be taken to ensure that neither the frame nor materials interfere or touch any part of the hoisting mechanism.

9.11.4.12 The platform of a goods hoist shall carry a notice stating,

a) the safe working load; and

b) that passengers shall not ride on the hoist.

9.11.4.13 All hoist operators shall be adequately trained

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and competent, and shall be responsible for ensuring that the hoist is not overloaded or otherwise misused.

9.11.4.14 All hoists shall be tested and thoroughly examined by a competent person before use on a site, after substantial alteration, modification or repair of hoists, and at least every 6 months.

9.11.4.15 Every hoist shall be inspected at least once each week by a competent person and a record of these inspections kept.

9.11.5 *Prestressed Concrete*

9.11.5.1 In pre-stressing operations, operating, maintenance and replacement instructions of the supplier of the equipment shall be strictly adhered to.

9.11.5.2 Extreme caution shall be exercised in all operations involving the use of stressing equipment as wires/strands under high tensile stresses become a lethal weapon.

9.11.5.3 During the jacking operation of any tensioning element(s) the anchor shall be kept turned up close to anchor plate, wherever possible, to avoid serious damage, if a hydraulic line fails.

9.11.5.4 Pulling-headers, bolts and hydraulic jacks/ rams shall be inspected for signs of deformation and failure. Threads on bolts and nuts should be frequently inspected for diminishing cross section. Choked units shall be carefully cleaned.

9.11.5.5 Care shall be taken that no one stands in line with the tensioning elements and jacking equipment during the tensioning operations and that no one is directly over the jacking equipment when deflection is being done. Signs and barriers shall be provided to prevent workers from working behind the jacks when the stressing operation is in progress.

9.11.5.6 Necessary shields should be put up immediately behind the prestressing jacks during stressing operations.

9.11.5.7 Wedges and other temporary anchoring devices shall be inspected before use.

9.11.5.8 The prestressing jacks shall be periodically examined for wear and tear.

9.11.5.9 Prestressing shall be done in accordance with Part 6 'Structural Design, Section 5 Plain, Reinforced and Prestressed Concrete, Subsection 5B Prestressed Concrete' of the Code.

9.11.6 *Erection of Prefabricated Members*

9.11.6.1 A spreader beam shall be used wherever possible so that the cable can be as perpendicular to the members being lifted as practical. The angle between the cable and the members to be lifted shall not be less than 60°.

9.11.6.2 The lifting wires shall be tested for double the load to be handled at least once in six months. The guy line shall be of adequate strength to perform its function of controlling the movement of members being lifted.

9.11.6.3 Temporary scaffolding of adequate strength shall be used to support precast members at predetermined supporting points while lifting and placing them in position and connecting them to other members.

9.11.6.4 After erection of the member, it shall be guyed and braced to prevent it from being tipped or dislodged by accidental impact when setting the next member.

9.11.6.5 Precast concrete units shall be handled at specific picking points and with specific devices. Girders and beams shall be braced during transportation and handled in such a way as to keep the members upright. Lifting, handling and installation of prefabricated members shall be in accordance with Part 6 'Structural Design, Section 7 Prefabrication and Systems Building: Subsection 7A Prefabricated Concrete' of the Code.

9.11.6.6 Methods of assembly and erection specified by the designer, shall be strictly adhered to at site. Immediately on erecting any unit in position, temporary connections or supports as specified shall be provided before releasing the lifting equipment. The permanent structural connections shall be established at the earliest opportunity.

9.11.7 *Heated Concrete*

When heaters are being used to heat aggregates and other materials and to maintain proper curing temperatures, the heaters shall be frequently checked for functioning and precautions shall be taken to avoid hazards in using coal, liquid, gas or any other fuel.

9.11.8 *Structural Connections*

9.11.8.1 When reliance is placed on bond between precast and *in-situ* concrete the contact surface of the precast units shall be suitably prepared in accordance with the specifications.

9.11.8.2 The packing of joints shall be carried out in accordance with the assembly instructions.

9.11.8.3 Levelling devices, such as wedges and nuts which have no load bearing function in the completed structure shall be released or removed as necessary prior to integrating the joints.

9.11.8.4 If it becomes necessary to use electric power for *in-situ* work, the same should be stepped down to a safe level as far as possible.

9.11.9 Workers working in any position where there is a falling hazard shall wear safety belts or other adequate

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protection shall be provided.

9.12 Additional Safety Requirements for Erection of Structural Steel Work

9.12.1 *Safety Organization*

The agency responsible for erecting the steel work should analyze the proposed erection scheme for safety; the erection scheme should cover safety aspects right from the planning stage up to the actual execution of the work.

9.12.2 *Safety of Workpersons*

9.12.2.1 *General*

While engaging persons for the job the supervisor should check up and make sure that they are skilled in the particular job they have to perform.

The helmets shall be worn properly and at all times during the work and shall conform to the accepted standard [7(28)].

The safety goggles shall be used while performing duties which are hazardous to eye like drilling, cutting and welding. The goggles used shall conform to the accepted standard [7(34)] and should suit individual workers.

The welders and gas cutters shall be equipped with proper protective equipment like gloves, safety boots, aprons and hand shields [*see* accepted standard 7(35)]. The filter glass of the hand shield shall conform to the accepted standard [7(34)] and should be suitable to the eyes of the particular worker.

When the work is in progress, the area shall be cordoned off by barricades to prevent persons from hitting against structural components, or falling into excavated trenches or getting injured by falling objects.

Warning signs shall be displayed where necessary to indicate hazards, for example (a) '440 V', (b) 'DO NOT SMOKE', (c) 'MEN WORKING AHEAD', etc. Hand lamps shall be of low voltage preferably 24 V to prevent electrical hazards.

All electrically operated hand tools shall be provided with double earthing.

9.12.2.2 Anchors for guys or ties shall be checked for proper placement. The weight of concrete in which the anchors are embedded shall be checked for uplift and sliding. Split-end eye anchors shall only be used in good, solid rock. The first load lifted by a guy derrick shall be kept at a small height for about 10 min and the anchors immediately inspected for any signs or indications of failure.

9.12.2.3 When a number of trusses or deep girders are loaded in one car or on one truck, all but one being lifted shall be tied back unless they have been tied or braced to prevent their falling over and endangering men unloading.

9.12.2.4 The erection gang shall have adequate supply of bolts, washers, rivets, pins, etc, of the correct size. Enough number of bolts shall be used in connecting each piece using a minimum of two bolts in a pattern to ensure that the joint will not fail due to dead load and erection loads. All splice connections in columns, crane girders, etc, shall be completely bolted or riveted or welded as specified in the drawing before erection.

9.12.2.5 Girders and other heavy complicated structural members may require special erection devices like cleats and hooks, which can be shop assembled and bolted or riveted or welded to the piece and may be left permanently in the place after the work.

9.12.2.6 If a piece is laterally unstable when picked at its centre, use of a balance beam is advisable, unless a pair of bridles slings can be placed far enough apart, for them to act as safe lifting points. The top flange of a truss, girder or long beam may be temporarily reinforced with a structural member laid flat on top of the member and secured temporarily.

9.12.2.7 On deep girders, and even on some trusses, a safety 'bar' running their full length will aid the riggers, fitters and others employed on the bottom flange or bottom chord to work with greater safety. This can be a single 16 mm diameter wire rope through vertical stiffeners of such members about 1 m above the bottom flange and clamped at the ends with wire rope clamps. If the holes cannot be provided, short eye bolts can be welded to the webs of the girder at intervals to be removed and the surface chipped or ground to leave it smooth after all work on the piece has been completed.

9.12.2.8 Safety belts shall always be available at work spot to be used, whenever necessary. The rope shall be chemically treated to resist dew and rotting. These shall not be tied on sharp edges of steel structures. They shall be tied generally not more than 2 m to 3 m away from the belt.

9.12.2.9 On a guy derrick or climbing crane job, the tool boxes used by the erection staff shall be moved to the new working floor each time the rig is changed. On a mobile crane job, the boxes shall be moved as soon as the crane starts operating in a new area not too far away for the men to reach the boxes conveniently. While working a tall and heavy guy derrick, it is advisable to control tension in guys by hand winches to avoid jerks, which may cause an accident.

9.12.2.10 The proper size, number and spacing of wire rope clamps shall be used, depending on the diameter of the wire rope. They shall be properly fixed in

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accordance with the procedure given in the accepted standard [7(36)]. They shall be checked as soon as the rope has been stretched, as the rope, especially if new, tends to stretch under the applied load, which in turn may cause it to shrink slightly in diameter. The clamps shall then be promptly tightened to take care of this new condition. In addition, the clamps shall be inspected frequently to be sure that they have not slipped and are tight enough.

9.12.2.11 When the men can work safely from the steel structure itself, this is preferable to hanging platforms or scaffolds, as it eliminates additional operations, which in turn, reduces the hazard of an accident. To aid men working on floats or scaffolds, as well as men in erection gangs, or other gangs using small material, such as bolts and drift pins, adequate bolt baskets or similar containers with handles of sufficient strength and attachment to carry the loaded containers, shall be provided. The men should be trained to use such containers, and to keep small tools gathered up and put away in tool boxes when not in use. Material shall not be dumped overboard when a scaffold is to be moved. Rivet heaters shall have safe containers or buckets for hot rivets left over at the end of the day.

9.12.2.12 During the erection of tall buildings, it is desirable to use nylon nets of sufficient width at a height of 3 m to 4 m from ground to provide safety to people. The safety net should be made from man-made or machine-made fibre ropes which are UV stabilized and conforming to the accepted standard [7(37)].

9.12.2.13 *Safety against fire*

A fire protection procedure is to be set up if there is to be any flame cutting, burning, heating, riveting or any operation that could start a fire. For precautions to be observed during welding and cutting operations, reference may be made to good practice [7(38)]. The workers should be instructed not to throw objects like hot rivets, cigarette stubs, etc, around. Sufficient fire extinguishers shall be placed at strategic points. Extinguishers shall always be placed in cranes, hoists, compressors and similar places. Where electrical equipment are involved, CO_2 or dry powder extinguishers shall be provided {*see also* good practice [7(24)]}.

9.12.2.14 Riding on a load, tackle or runner shall be prohibited.

9.12.2.15 The load shall never be allowed to rest on wire ropes. Ropes in operation should not be touched. Wire rope with broken strand shall not be used for erection work. Wire ropes/manila ropes conforming to acceptable standards [7(39)] shall be used for guying.

9.12.2.16 *Lifting appliances*

Precautions as laid down in **9.11.1.2** shall be followed.

9.12.2.17 *Slinging*

Chains shall not be joined by bolting or wiring links together. They shall not be shortened by tying knots. A chain in which the links are locked, stretched or do not move freely shall not be used. The chain shall be free of kinks and twists. Proper eye splices shall be used to attach the chain hooks.

Pulley blocks of the proper size shall be used to allow the rope free play in the sheave grooves and to protect the wire rope from sharp bends under load. Idle sling should not be carried on the crane hook alongwith a loaded sling. When idle slings are carried they shall be hooked.

While using multilegged slings, each sling or leg shall be loaded evenly and the slings shall be of sufficient length to avoid a wide angle between the legs.

9.12.2.18 *Riveting operations*

9.12.2.18.1 *Handling rivets*

Care shall be taken while handling rivets so that they do not fall, strike or cause injury to men and material below. Rivet catchers shall have false wooden bottoms to prevent rivets from rebounding.

9.12.2.18.2 *Riveting dollies*

Canvas, leather or rope slings shall be used for riveting dollies. Chain shall not be used for the purpose.

9.12.2.18.3 *Riveting hammers*

Snaps and plungers of pneumatic riveting hammers shall be secured to prevent the snap from dropping out of place. The nozzle of the hammer shall be inspected periodically and the wire attachment renewed when born.

9.12.2.18.4 *Fire protection*

The rivet heating equipment should be as near as possible to the place of work. A pail of water shall always be kept ready for quenching the fire during riveting operations and to prevent fires when working near inflammable materials.

9.12.2.19 *Welding and gas cutting*

9.12.2.19.1 For safety and health requirements in electric gas welding and cutting operations, reference may be made to good practice [7(40)]. The recommendations given in **9.12.2.19.2** to **9.12.2.19.4** are also applicable.

9.12.2.19.2 All gas cylinders shall be used and stored in the upright position only and shall be conveyed in trolleys. While handling by cranes they shall be carried in cages. The cylinders shall be marked 'full' or 'empty' as the case may be. Gas cylinders shall be stored away

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from open flames and other sources of heat. Oxygen cylinders shall not be stored near combustible gas, oil, grease and similar combustible materials. When the cylinders are in use, cylinder valve key or wrench shall be placed in position. Before a cylinder is moved, cylinder valve shall be closed. All cylinder valves shall be closed when the torches are being replaced or welding is stopped for some reason. The cylinder valve and connections shall not be lubricated.

9.12.2.19.3 Gas cutting and welding torches shall be lighted by means of special lighters and not with matches. The cables from welding equipment should be placed in such a way that they are not run over by traffic. Double earthing shall be provided. Before undertaking welding operations near combustible materials, suitable blanketing shall be provided and fire extinguishers kept nearby. Welding shall not be undertaken in areas where inflammable liquids and gases are stored.

9.12.2.19.4 Gas lines and compressed air lines shall be identified by suitable colour codes for easy identification, to avoid confusion and to prevent fire and explosion hazards.

9.12.3 *Safety of Structure*

9.12.3.1 *General*

The structure itself should be safeguarded during its erection. The first truss of the roof system shall be guyed on each side before the hoisting rope is detached from it. After the subsequent trusses and roof purlins are erected, protective guides shall be firmly established and the required wind bracings shall be erected to prevent the whole structure being blown over by a sudden gale at night. Bracing and guying precautions shall be taken on every structure until it is complete. Guying shall be specifically done for trusses and structural components which after their erection form an erection device. On structures used for temporary material storage overloading shall be avoided.

9.12.3.1.1 Erection of columns shall be immediately followed by vertical bracing between columns before the roof structure is erected.

9.13 Miscellaneous Items

9.13.1 *Staircase Construction*

While staircase is under construction, depending on the type of construction, namely, concrete or brickwork, etc, suitable precautions shall be taken by way of support, formworks, etc, to prevent any collapse. Workers or any other person shall not be allowed to use such staircases till they are tested and found fit for usage by the Authority/engineer-in-charge. Till the permanent handrails are provided, temporary provisions like ropes, etc, shall be provided on staircases prior to commencement of use of such staircases.

9.13.2 *Lift Wells*

Till the installation of the lift is completed, lift wells shall be protected with check boards or railings together with notice boards, danger lights, etc, to prevent persons accidentally falling into the wells. The handrails provided shall be capable of withstanding pressure exerted due to normal bumping of an individual against the same.

9.13.3 *Construction Involving the Use of Hot Bituminous Tar Materials*

9.13.3.1 *Safety programme*

9.13.3.1.1 *General*

On all major works, an experienced and competent foreman or supervisor shall be placed in-charge of the work, and shall be made responsible for the strict observance of the safety rules. He shall stock the necessary protective equipment, fire extinguishing equipment, first-aid kit, etc. He shall also keep a record of the accidents taking place on any particular job, with reasons thereof, and shall suggest suitable remedial measures to the management for prevention thereof.

9.13.3.1.2 *Protective covering*

Workers engaged on jobs involving handling of hot bitumen, tar, and bituminous mixtures shall use protective wears, such as boots and gloves, preferably of asbestos or otherwise of rubber; goggles and helmet. No workers shall be permitted to handle such materials without wearing the needed protective covering.

9.13.3.1.3 *Fire fighting arrangements*

When heating and handling of hot bituminous materials is to be done in the open, sufficient stocks of clean dry sand or loose earth shall be made available at the work site to cope with any resultant fires. When neither such materials are available, nor are any suitable type of fire extinguishers provided at the work site in the open, and reliance has to be on using water for fighting any fire, the water supply available should be in abundance and the water shall be applied to the fire in the form of spray. When heating of bituminous materials is carried out in enclosed spaces, sufficient number of properly maintained dry powder fire extinguisher or foam extinguisher conforming to accepted standards [7(23)] shall be kept in readiness on the work site.

9.13.3.2 *Sprayer, spreader/paver*

9.13.3.2.1 *Sprayer*

The sprayer shall be provided with a fire resisting screen. The screen shall have an observation window.

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Piping for hot tar and bitumen shall be adequately insulated to protect workers from injury by burns. Flexible piping work under positive pressure shall be of metal which shall be adequately insulated. Workers shall not stand facing the wind directions while spraying hot binder, lest it may fall on them causing burns.

9.13.3.2.2 *Spreader/Paver*

Spreaders in operation shall be protected by signals, signs or other effective means. People should be warned against walking over hot mixture laid. Gravel spreaders shall always keep a safe distance from sprayer. Elevated platforms on spreaders shall be protected by suitable railing and be provided with an access ladder.

9.13.3.3 *Equipment for heating of bitumen and tars*

9.13.3.3.1 Tanks, vats, kettles, pots, drums and other vessels for heating tar, bitumen and other bituminous materials shall be,

a) adequately resistant to damage by heat, transportation, etc;
b) capable of holding a full load without danger of collapse, bursting or distortion;
c) provided with a close fitting cover suitable for smothering a fire in the vessel or protection from rain; and
d) leak proof, and provided with suitable outlets which can be controlled for taking out the hot material.

9.13.3.3.2 Suitable indicator gauges shall be used to ascertain level and temperature of the material in the boiler. On no account shall workers be allowed to peep into the boiler for this purpose. For ascertaining levels, in small plants, dipstick may also be used.

9.13.3.3.3 Gas and oil-fired bitumen and tar kettles or pots shall be equipped with burners, regulators and safety devices of types approved by the Authority. Heating appliances for vessels shall distribute the heat uniformly over the heating surface so as to avoid overheating. In case of bituminous mixtures using mineral aggregates filler together with bitumen, it is preferable to have some means for stirring as well. Only vessels heated by electricity shall be used inside buildings. Tar boilers shall never be used on combustible roof.

9.13.3.3.4 Buckets for hot bitumen, bituminous materials of tar shall have,

a) the bail or handle firmly secured; and
b) a second handle near the bottom for tipping.

9.13.3.3.5 Bitumen or tar boilers mounted on wheels for easy transport or towing shall preferably be provided with hand pumps for spraying purposes.

9.13.3.3.6 Vessels in operation shall be kept at a safe distance from combustible materials. When vessels are used in confined spaces, the gases, fumes and smoke generated shall be removed by exhaust ventilation or by forced ventilations. Vessels that are being heated shall not be left unattended. Pieces of bituminous material shall not be thrown into the hot vessels so as to cause splashing. Covers shall be kept closed when vessels are not in use. Containers shall not be filled with hot bitumen or tar to a level that might cause danger when they are carried or hoisted. Enough space shall be left in vessels for expansion of binder, when heated.

9.13.3.3.7 Bitumen/tar shall be kept dry and to avoid fire due to foaming, boiler shall have a device that prevents foam from reaching the burners or anti-foaming agents shall be used to control the same. Alternatively, to avoid fire due to foaming, the heating shall be at low temperature till the water entrapped, if any, is completely evaporated. Any water present in the boiler shall also be drained before using it for heating binders. No open light shall be used for ascertaining the level of binder in boilers. If a burner goes out, the fuel supply shall be cut off and the heating tube shall be thoroughly blown out by the fan so as to prevent a back fire.

9.13.3.3.8 Cutbacks shall not be heated over an open flame unless a water jacket is used. While they are being heated the vessel shall be kept open.

9.13.3.3.9 Piping shall not be warmed with burning rags and instead blow-lamps or similar devices shall be used.

9.13.3.3.10 Spilled bitumen or tar shall be promptly cleaned up around boilers.

9.13.3.3.11 Inspection openings shall not be opened while there is any pressure in the boiler.

9.13.3.3.12 When tanks are cleaned by steam, adequate precautions shall be taken to prevent any build up of pressure.

9.13.3.4 *Handling bitumen/tar*

Bitumen/tar shall not be heated beyond the temperature recommended by the manufacturer of the product. While discharging heated binder from the boiler, workers shall not stand opposite to the jet so as to avoid the possibility of hot binder falling on them. The container shall be handled only after closing the control valve. While handling hot bitumen/tar, workers shall exercise scrupulous care to prevent accidental spillage thereof. The buckets and cans in which the hot material is carried from boiler shall be checked before use to ensure that they are intact and safe. Mops and other applicators contaminated with bituminous materials shall not be stored inside buildings.

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9.13.3.5 *Bitumen plants*

Safety requirements shall be in accordance with good practice [7(41)].

9.13.4 *Timber Structure*

Preventive measures against hazards in work places involving construction of timber structures shall be taken in accordance with good practice [7(42)].

9.14 Finishes

9.14.1 *Painting, Polishing and Other Finishes*

Only the quantity of paint, thinner and polish required for the day's work should be kept at the work spot.

9.14.1.1 All containers of paint, thinner and polish which are not in actual use should be closed with tight fitting lids and kept at a safe place away from the actual work site.

9.14.1.2 A 5 kg dry powder fire extinguisher conforming to the accepted standard [7(43)] shall be kept handy.

9.14.1.3 Metal receptacles with pedal operated metal lids shall be kept handy at the work site for depositing used cotton rags/waste. The contents of such receptacles shall be disposed off before the end of each day's work at a safe place, preferably by burning under proper supervision.

9.14.1.4 All containers of paint shall be removed from the work site and deposited in the paint store before the close of day's work. Used paint brushes shall be cleaned and deposited in the store along with the containers.

9.14.1.5 Some paints/polishing and finishing materials are injurious to the health of workers. Adequate protective clothing, respiratory equipment, etc, shall be provided for the use of workers during such operations where necessary.

9.15 Fragile Fixtures

It shall be ensured that sufficient number of workers and equipment are provided to carry the fragile fixtures like sanitary fittings, glass panes, etc, to prevent injury to workers due to accidental dropping of such fixtures.

9.16 Safety in Special Operations

Safety in compressed air work, drilling, blasting and welding operations shall be in accordance with good practices [7(44)].

9.17 Electrical Installations and Lifts

9.17.1 *Temporary Electrical Wiring*

9.17.1.1 Frayed and/or bare wires shall not be used for temporary electrical connections during construction. All temporary wiring shall be installed and supervised by a competent electrician. Adequate protection shall be provided for all electrical wiring laid on floor which may have to be crossed over by construction machinery or by the workers. All flexible wiring connecting the electrical appliances shall have adequate mechanical strength and shall preferably be enclosed in a flexible metal sheath. Overhead wires/cables shall be so laid that they leave adequate head room.

9.17.1.2 All electrical circuits, other than those required for illumination of the site at night, shall be switched off at the close of day's work. The main switch board from which connections are taken for lighting, power operated machinery, etc, shall be located in an easily accessible and prominent place. No articles of clothing nor stores shall be kept at the back of or over the board or anywhere near it. One 3 kg/4.5 kg CO_2 extinguisher or one 5 kg dry powder extinguisher conforming to the accepted standard [7(43)] shall be provided near the switch board.

9.7.1.3 Requirements as given in **12** of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code shall also be complied with.

9.17.2 *Permanent Electrical Installations*

Besides the fire safety measures for electrical installations covered under **9.17.1**, safety in electric installations in buildings and installations of lifts shall be in accordance with **12** of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code, and Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks' of the Code, respectively.

9.18 General Safety Requirements for Workplace

9.18.1 *Sanitation*

a) Adequate toilet facilities shall be provided for the workers within easy access of their place of work. The total number to be provided shall be not less than one per 30 employees in any one shift.
b) Toilet facilities shall be provided from the start of building operations, and connection to a sewer shall be made as soon as practicable.
c) Every toilet shall be so constructed that the occupant is sheltered from view and protected from the weather and falling objects.
d) Toilet facilities shall be maintained in a sanitary condition. A sufficient quantity of disinfectant shall be provided. Natural or artificial illumination shall be provided.

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e) An adequate supply of drinking water shall be provided, and unless connected to a municipal water supply, samples of the water shall be tested at frequent intervals by the Authority.

9.18.2 *Fire Protection*

9.18.2.1 In addition to the provision of fire extinguishers, as specified in this part of the Code, other fire extinguishing equipment shall also be provided and conveniently located within the building under construction or on the building site, as required by the Authority.

9.18.2.1.1 All fire extinguishers shall be maintained in a serviceable condition at all times in accordance with good practice [7(24)] and all necessary guidelines regarding fire protection at workplaces followed in accordance with good practice [7(21)].

9.18.2.1.2 It shall be ensured that all workers and supervisory staff are fully conversant with the correct operation and use of fire extinguishers provided at the construction site.

9.18.2.1.3 Telephone number of local fire brigade should be prominently displayed near each telephone provided at construction site.

9.18.2.1.4 Watch and ward services should be provided at construction sites during holidays and nights.

9.18.2.2 Access shall be provided and maintained at all times to all fire fighting equipment, including fire hose, extinguishers, sprinkler valves and hydrants.

9.18.2.2.1 Approach roads for fire fighting should be planned, properly maintained and kept free from blockage. Width of approach road should be not less than 5 m to facilitate fire fighting operations.

9.18.2.2.2 Emergency plan and fire order specifying the individual responsibility in the event of fire should be formulated and mock drills should be practised periodically in case of large and important construction sites to ensure upkeep and efficiency of fire fighting appliances.

9.18.2.2.3 Periodical inspection should be carried out to identify any hazard and proper records maintained and follow up action taken.

9.18.2.2.4 Evacuation facilities and fire exits should be provided at all locations susceptible to fire hazards.

9.18.2.3 Where the building plans require the installation of fixed fire fighting equipment, such as hydrants, stand pipes, sprinklers and underground water mains or other suitable arrangements for provision of water shall be installed, completed and made available for permanent use as soon as possible, but in any case not later than the stage at which the hydrants, etc, are required for use as specified in **9.18.2.3.1** to **9.18.2.3.4**.

9.18.2.3.1 A stand pipe system (landing valves), permanent in nature shall be installed and made available before the building has reached the height of 15 m above the grade, and carried up with each floor.

9.18.2.3.2 The standpipe (landing valve/internal fire hydrant) and its installation shall conform to the accepted standards [7(45)].

9.18.2.3.3 The standpipe shall be carried up with each floor and securely capped at the top. Top hose outlets, should at all times, be not more than one floor below the floor under construction.

9.18.2.3.4 A substantial box, preferably of metal, should be provided and maintained near each hose outlet. The box should contain adequate lengths of hose to reach all parts of the floor as well as a short branch fitted with 12 mm or 20 mm nozzle.

9.18.2.4 Close liaison shall be maintained with the local Fire Brigade, during construction of all buildings above 15 m in height and special occupancies, like educational, assembly, institutional, industrial, storage, hazardous and mixed occupancies with any of the aforesaid occupancies having area more than 500 m^2 on each floor.

9.18.2.5 It is desirable that telephone system or other means of inter-communication system be provided during the construction of all buildings over 15 m in height or buildings having a plinth area in excess of 1 000 m^2.

9.18.2.6 All work waste, such as scrap timber, wood shavings, sawdust, paper, packing materials and oily waste shall be collected and disposed of safely at the end of each day's work. Particular care shall be taken to remove all waste accumulation in or near vertical shaft openings like stairways, lift-shaft, etc.

9.18.2.7 An independent water storage facility shall be provided before the commencement of construction operations for fire-fighting purposes. It shall be maintained and be available for use at all times.

9.18.2.8 *Fire cut-offs*

Fire walls and exit stairways required for a building should be given construction priority. Where fire doors, with or without automatic closing devices, are stipulated in the building plans they should be hung as soon as practicable and before any significant quantity of combustible material is introduced in the building.

9.18.2.8.1 As the work progresses, the provision of permanent stairways, stairway enclosures, fire walls and other features of the completed structure which will prevent the horizontal and vertical spread of fire should be ensured.

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9.18.3 *Clothing*

9.18.3.1 It shall be ensured that the clothes worn by the workers be not of such nature as to increase the chances of their getting involved in accident to themselves or to others. As a rule, wearing of *Chaddars* or loose garments shall be prohibited.

9.18.3.2 Workers engaged in processes which splash liquid or other materials which will injure the skin shall have enough protective clothing to cover the body.

9.18.3.3 Individuals engaged in work involving use of naked flames (such as welding) shall not wear synthetic fibre or similar clothing which increases the risk of fire hazards.

9.18.4 *Safety Measures Against Fall Prevention*

Persons working at heights may use safety belts and harnesses. Provision of cat-walks, wire mesh, railings reduces chances of fall-ladder and scaffoldings, stagings, etc, should be anchored on firm footing and should be secured and railing should be provided as far as possible. All accesses should be barricaded to prevent accidental fall. For details as fall prevention reference may be made to good practice [7(46)].

9.18.5 *Falling Materials Hazard Prevention*

Preventive measures against falling materials hazards in work places shall be taken in accordance with good practice [7(47)].

9.18.6 *Disposal of Debris*

Preventive measures against hazards relating to disposal of debris shall be taken in accordance with [7(48)].

9.19 Construction Machinery

9.19.1 Specification and requirements of construction machinery used in construction or demolition work shall conform to accepted standards [7(49)].

9.19.2 For safety requirements for working with construction machinery, reference may be made to good practice [7(50)].

9.19.3 Petroleum powered air compressors, hoists, derricks, pumps, etc, shall be so located that the exhausts are well away from combustible materials. Where the exhausts are pipes to outside the building under construction, a clearance of at least 150 mm shall be maintained between such piping and combustible material.

9.19.4 Earthing/grounding of electrically powered equipment/tools shall be ensured. Also all electric powered equipment should be switched off from mains, after completion of day's job.

10 SAFETY IN DEMOLITION OF BUILDINGS

10.1 The safety requirements for carrying out demolition/dismantling work shall be as given in **10.2** to **10.15**.

10.2 Planning

Before beginning the actual work of demolition a careful study shall be made of the structure which is to be pulled down and also of all its surroundings. This shall, in particular, include study of the manner in which the various parts of the building to be demolished are supported and how far the stage by stage demolition will affect the safety of the adjoining structure. A definite plan of procedure for the demolition work, depending upon the manner in which the loads of the various structural parts are supported, shall be prepared and approved by the engineer-in-charge and this shall be followed as closely as possible, in actual execution of the demolition work. Before the commencement of each stage of demolition, the foreman shall brief the workers in detail regarding the safety aspects to be kept in view.

It should be ensured that the demolition operations do not, at any stage, and endanger the safety of the adjoining buildings. Moreover, the nuisance effect of the demolishing work on the use of the adjacent buildings should be kept to the minimum.

No structure or part of the structure or any floor or temporary support or scaffold, side wall or any device for equipment shall be loaded in excess of the safe carrying capacity, in its then existing condition.

Electrical installations for demolition sites shall be in accordance with **12** of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

10.3 Precautions Prior to Demolition

10.3.1 On every demolition job, danger signs shall be conspicuously posted all around the structure and all doors and openings giving access to the structure shall be kept barricaded or manned except during the actual passage of workers or equipment. However, provisions shall be made for at least two independent exits for escape of workers during any emergency.

10.3.2 During nights, red lights shall be placed on or about all the barricades.

10.3.3 Where in any work of demolition it is imperative, because of danger existing, to ensure that no unauthorized person shall enter the site of demolition during the outside hours; a watchman should be employed. In addition to watching the site he shall also be responsible for maintaining all notices, lights and barricades.

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10.3.4 All the necessary safety appliances shall be issued to the workers and their use explained. It shall be ensured that the workers are using all the safety appliances while at work.

10.3.5 The power on all electrical service lines shall be shut off and all such lines cut or disconnected at or outside the property line, before the demolition work is started. Prior to cutting of such lines, the necessary approval shall be obtained from the electrical authorities concerned. The only exception will be any power lines required for demolition work itself.

10.3.6 All gas, water steam and other service lines shall be shut off and capped or otherwise controlled at or outside the building line, before demolition work is started.

10.3.7 All the mains and meters of the building shall be removed or protected from damage.

10.3.8 If a structure to be demolished has been partially wrecked by fire, explosion or other catastrophe, the walls and damaged roofs shall be shored or braced suitably.

10.3.9 *Protection of the Public*

10.3.9.1 Safety distances to ensure safety of the public shall be clearly marked and prominently sign posted. Every sidewalk or road adjacent to the work shall be closed or protected. All main roads, which are open to the public, shall be kept open to the public clear and unobstructed at all times. Diversions for pedestrians shall be constructed, where necessary for safety.

10.3.9.2 If the structure to be demolished is more than two storeyed or 7.5 m high, measured from the side walk or street which cannot be closed or safely diverted, and the horizontal distance from the inside of the sidewalk to the structure is 4.5 m or less, a substantial sidewalk shed shall be constructed over the entire length of the sidewalk adjacent to the structure, of sufficient width with a view to accommodating the pedestrian traffic without causing congestion. The side walk shed shall be lighted sufficiently to ensure safety at all times. For detailed information reference may be made to good practice [7(51)].

A toe board of at least 1 m high above the roof of the shed shall be provided on the outside edge and ends of the sidewalk shed. Such boards may be vertical or inclined outward at not more than 45°.

Except where the roof of a sidewalk shed solidly abuts the structure, the face of the sidewalk shed towards the building shall be completely closed by providing sheeting/planking to prevent falling material from penetrating into the shed.

The roof of sidewalk sheds shall be capable of sustaining a load of 73 N/mm^2. Only in exceptional cases, say due to lack of other space, the storing of material on a sidewalk shed may be permitted in which case the shed shall be designed for a load of 146 N/mm^2. Roof of sidewalk shed shall be designed taking into account the impact of the falling debris. By frequent removal of loads it shall be ensured that the maximum load, at any time, on the roof of work shed is not more than 6 000 N/m^2. The height of sidewalk shed shall be such as to give a minimum clearance of 2.4 m.

Sidewalk shed opening, for loading purposes, shall be kept closed at all time except during actual loading operations.

The deck flooring of the sidewalk shed shall consist of plank of not less than 50 mm in thickness closely laid and deck made watertight. All members of the shed shall be adequately braced and connected to resist displacement of members or distortion of framework.

10.3.9.3 When the horizontal distance from the inside of the sidewalk to the structure is more than 4.5 m and less than 7.5 m, a sidewalk shed or fence or a substantial railing shall be constructed on the inside of the sidewalk or roadway along the entire length of the demolition side of the property with movable bars as may be necessary for the proper execution of the work.

NOTE — For guidance on management of pedestrians/cyclists/ vehicles near road construction sites, reference may be made to IRC SP 55 : 2014 ‘Guidelines on traffic management in work zones’.

10.4 Precautions During Demolition

10.4.1 Prior to commencement of work, all material of fragile nature like glass shall be removed.

10.4.2 All openings shall be boarded up.

10.4.3 Dust shall be controlled by suitable means to prevent harm to workers.

10.4.4 Stacking of materials or debris shall be within safe limits of the structural member. Additional supports, where necessary, shall be given.

10.4.5 Adequate natural or artificial lighting and ventilation shall be provided for the workers.

10.5 Sequence of Demolition Operations

10.5.1 The demolition work shall be proceeded with in such a way that,

a) it causes the least damage and nuisance to the adjoining building and the members of the public; and
b) it satisfies all safety requirements to avoid any accidents.

10.5.2 All existing fixtures required during demolition

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operations shall be well protected with substantial covering to the entire satisfaction of the rules and regulations of the undertakings or they shall be temporarily relocated.

10.5.3 Before demolition work is started, glazed sash, glazed doors and windows, etc, shall be removed. All fragile and loose fixtures shall be removed. The lath and all loose plaster shall be stripped off throughout the entire building. This is advantageous because it reduces glass breakage and also eliminates a large amount of dust producing material before more substantial parts of the buildings are removed.

10.5.4 All well openings which extend down to floor level shall be barricaded to a height of not less than one metre above the floor level. This provision shall not apply to the ground level floor.

10.5.5 All floor openings and shafts not used for material chutes shall be floored over and be enclosed with guard rails and toe boards.

10.5.6 The demolition shall always proceed systematically storey by storey in descending order. All work in the upper floor shall be completed and approved by the engineer-in-charge prior to disturbance to any supporting member on the lower floor. Demolition of the structure in sections may be permitted in exceptional cases, if proper precautions are ensured to prevent injuries to persons and damage to property.

10.6 Walls

10.6.1 While walls of sections of masonry are being demolished, it shall be ensured that they are not allowed to fall as single mass upon the floors of the building that are being demolished so as to exceed the safe carrying capacity of the floors. Overloading of floors shall be prevented by removing the accumulating debris through chutes or by other means immediately. The floor shall be inspected by the engineer-in-charge before undertaking demolition work and if the same is found to be incapable to carry the load of the debris, necessary additional precautions shall be taken so as to prevent any possible unexpected collapse of the floor.

10.6.2 Walls shall be removed part by part. Stages shall be provided for the men to work on if the walls are less than one and a half brick thick and dangerous to work by standing over them.

10.6.3 Adequate lateral bracing shall be provided for walls which are unsound. For detailed information reference may be made to good practice [7(51)].

10.7 Flooring

10.7.1 Prior to removal of masonry or concrete floor adequate support centering shall be provided.

10.7.2 When floors are being removed, no worker or person shall be allowed to work in the area, directly underneath and such area shall be barricaded to prevent access to it.

10.7.3 Planks of sufficient strength shall be provided to give workers firm support to guard against any unexpected floor collapse.

10.8 Demolition of Steel Structures

10.8.1 When a derrick is used, care shall be taken to see that the floor on which it is supported is amply strong for the loading so imposed. If necessary heavy planking shall be used to distribute the load to floor beam and girders.

10.8.2 Overloading of equipment shall not be allowed.

10.8.3 Tag lines shall be used on all materials being lowered or hoisted up and a standard signal system shall be used and the workers instructed on the signals.

10.8.4 No person shall be permitted to ride the load line.

10.8.5 No beams shall be cut until precautions have been taken to prevent it from swinging freely and possibly striking any worker or equipment or to any part of the structure being demolished.

10.8.6 All structural steel members shall be lowered from the building and shall not be allowed to drop.

10.9 Catch Platform

10.9.1 In demolition of exterior walls of multistorey structures, catch platform of sufficient strength to prevent injuries to workers below and public shall be provided, when the external walls are more than 20 m in height.

10.9.2 Such catch platform shall be constructed and maintained not more than 3 storeys below the storey from which exterior wall is being demolished. When demolition has progressed to within 3 storeys of ground level, catch platform will not be considered necessary.

10.9.3 Catch platform shall be capable of sustaining a live load of not less than 6 100 N/m^2.

10.9.4 Materials shall not be dumped on the catch platform nor shall they be used for storage of materials.

10.10 Stairs, Passageways and Ladders

10.10.1 Stairs with railings, passageways and ladders shall be left in place as long as possible and maintained in a safe condition.

10.10.2 All ladders shall be secured against, slipping out at the bottom and against movement in any direction at the top.

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10.11 Mechanical Demolition

When demolition is to be performed by mechanical devices, such as weight ball and power shovels, the following additional precautions may be observed:

a) The area shall be barricaded for a minimum distance of 1½ times the height of the wall;
b) While the mechanical device is in operation, no worker shall be allowed to enter the building being demolished;
c) The device shall be so located as to avoid falling debris; and
d) The mechanical device, when being used, shall not cause any damage to adjacent structure, power line, etc.

10.12 Demolition of Certain Special Types and Elements of Structures

10.12.1 *Roof Trusses*

If a building has a pitched roof, the structure should be removed to wall plate level by hand methods. Sufficient purlins and bracing should be retained to ensure stability of the remaining roof trusses while each individual truss is removed progressively.

10.12.1.1 Temporary bracing should be added, where necessary, to maintain stability. The end frame opposite to the end where dismantling is commenced, or a convenient intermediate frame should be independently and securely guyed in both directions before work starts.

10.12.1.2 On no account should the bottom tie of roof trusses be cut until the principal rafters are prevented from making outward movement.

10.12.1.3 Adequate hoisting gears suitable for the loads shall be provided. If during demolition any thing is to be put on the floor below the level of the truss, it shall be ensured that the floor is capable of taking the load.

10.12.2 *Heavy Floor Beams*

Heavy baulks of timber and steel beams should be supported before cutting at the extremities and should then be lowered gently to a safe working place.

10.12.3 *Jack Arches*

Where tie rods are present between main supporting beams, these should not be cut until after the arch or series of arches in the floor have been removed. The floor should be demolished in strips parallel to the span of the arch rings (at right angles to the main floor beams).

10.12.4 *Brick Arches*

Expert advice should be obtained and, at all stages of the demolition, the closest supervision should be given by persons fully experienced and conversant in the type of work to ensure that the structure is stable at all times.

However, the following points may be kept in view:

a) On no account should the restraining influence of the abutments be removed before the dead load of the spandrel fill and the arch rings are removed.
b) A single span arch can be demolished by hand by cutting narrow segments progressively from each springing parallel to the span of the arch, until the width of the arch has been reduced to a minimum which can then be collapsed.
c) Where deliberate collapse is feasible, the crown may be broken by the demolition ball method working progressively from edges to the centre.
d) Collapse of the structure can be affected in one action by the use of explosives. Charges should be inserted into bore holes drilled in both arch and abutments.
e) In multi-span arches, before individual arches are removed, lateral restraint should be provided at the springing level. Demolition may then proceed as for single span; where explosives are used it is preferable to ensure the collapse of the whole structure in one operation to obviate the chance of leaving unstable portion standing.

10.12.5 *Cantilever (Not Part of a Framed Structure)*

Canopies, cornices, staircases and balconies should be demolished or supported before tailing down load is removed.

10.12.6 *In-situ Reinforced Concrete*

Before commencing demolition, the nature and condition of the concrete, the condition and position of reinforcement, and the possibility of lack of continuity of reinforcement should be ascertained.

Demolition should be commenced by removing partitions and external non-load bearing cladding.

10.12.6.1 *Reinforced concrete beams*

A supporting rope should be attached to the beam. Then the concrete should be removed from both ends by pneumatic drill and the reinforcement exposed. The reinforcement should then be cut in such a way as to allow the beam to be lowered under control to the floor.

10.12.6.2 *Reinforced concrete columns*

The reinforcement should be exposed at the base after restraining wire guy ropes have been placed round the member at the top. The reinforcement should then be

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cut in such a way as to allow it to be pulled down to the floor under control.

10.12.6.3 *Reinforced concrete walls*

These should be cut into strips and demolished as for columns.

10.12.6.4 *Suspended floors and roofs*

The slab should be cut into strips parallel to the main reinforcement and demolished strip by strip. Where ribbed construction has been used, the principle of design and method of construction should be determined before demolition is commenced. Care should be taken not to cut the ribs inadvertently.

10.12.7 *Precast Reinforced Concrete*

Due precautions shall be taken to avoid toppling over of prefabricated units or any other part of the structure and whenever necessary temporary supports shall be provided.

10.12.8 *Prestressed Reinforced Concrete*

Before commencing of the demolition work, advice of an engineering expert in such demolition shall be obtained and followed.

10.13 Lowering, Removal and Disposal of Materials

10.13.1 Dismantled materials may be thrown to the ground only after taking adequate precautions. The material shall preferably be dumped inside the building. Normally such materials shall be lowered to the ground or to the top of the sidewalk shed where provided by means of ropes or suitable tackles.

10.13.2 *Through Chutes*

10.13.2.1 Wooden or metal chutes may be provided for removal of materials. The chutes shall preferably be provided at the centre of the building for efficient disposal of debris.

10.13.2.2 Chutes, if provided at an angle of more than 45° from the horizontal, shall be entirely enclosed on all the four sides, except for opening at or about the floor level for receiving the materials.

10.13.2.3 To prevent the descending material attaining a dangerous speed, chute shall not extend in an unbroken line for more than two storeys. A gate or stop shall be provided with suitable means for closing at the bottom of each chute to stop the flow of materials.

10.13.2.4 Any opening into which workers dump debris at the top of chute shall be guarded by a substantial guard rail extending at least one metre above the level of the floor or other surface on which men stand to dump the materials into the chute.

10.13.2.5 A toe board or bumper, not less than 50 mm thick and 150 mm high shall be provided at each chute openings, if the material is dumped from the wheel barrows. Any space between the chute and the edge of the opening in the floor through which it passes shall be solidly planked over.

10.13.3 *Through Holes in the Floors*

10.13.3.1 Debris may also be dropped through holes in the floor without the use of chutes. In such a case the total area of the hole cut in any intermediate floor, one which lies between floor that is being demolished and the storage floor shall not exceed 25 percent of such floor area. It shall be ensured that the storage floor is of adequate strength to withstand the impact of the falling material.

10.13.3.2 All intermediate floor openings for passage of materials shall be completely enclosed with barricades or guard rails not less than one metre high and at a distance of not less than 1 m from the edge of general opening. No barricades or guard rails shall be removed until the storey immediately above has been demolished down to the floor line and all debris cleared from the floor.

10.13.3.3 When the cutting of a hole in an intermediate floor between the storage floor and the floor which is being demolished makes the intermediate floor or any portion of it unsafe, then such intermediate floor shall be properly shored. It shall also be ensured that the supporting walls are not kept without adequate lateral restraints.

10.13.4 *Removal of Materials*

10.13.4.1 As demolition work proceeds, the released serviceable materials of different types shall be separated from the unserviceable lot (hereinafter called '*Malba*') at suitable time intervals and properly stocked clear of the spots where demolition work is being done.

10.13.4.2 The *Malba* obtained during demolition shall be collected in well-formed heaps at properly selected places, keeping in view safe conditions for workers in the area. The height of each *Malba* heap shall be limited to ensure its toppling over or otherwise endangering the safety of workers or passersby.

10.13.4.3 The *Malba* shall be removed from the demolition site to a location as required by the local civil authority. Depending on the space available at the demolition site, this operation of conveying *Malba* to its final disposal location may have to be carried out a number of times during the demolition work. In any case, the demolition work shall not be considered as completed and the area declared fit for further occupation till all the *Malba* has been carried to its final disposal location and the demolition areas tidied up.

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10.13.4.4 Materials which are likely to cause dust nuisance or undue environmental pollution in any other way, shall be removed from the site at the earliest and till then they shall be suitably covered. Such materials shall be covered during transportation also.

10.13.4.5 Following other requirements should also be met:

a) Glass and steel should be dumped or buried separately to prevent injury.
b) Workman should be provided with suitable protective gears for personal safety during works, like safety helmets, boots, hand gloves, goggles, special attire, etc.
c) Work of removal of debris should be carried out during day. In case of poor visibility artificial light may be provided.
d) Debris should first be removed from top. Early removal from bottom or sides of dump may cause collapse of debris, causing injuries.

10.14 Miscellaneous

10.14.1 No demolition work should be carried out during night as far as possible, especially when the structure to be demolished is in an inhabited area. If such night work has to be done, additional precautions by way of additional red warning signals, working lights and watchmen, shall be provided to avoid any injury to workers and public. Demolition work shall not be carried out during storm and heavy rain.

10.14.2 Warning devices shall be installed in the area to warn the workers in case of any danger.

10.14.3 Safety devices like industrial safety helmets conforming to the accepted standards [7(28)] and goggles made of celluloid lens, shall be issued to the workers. Foreman-in-charge of the work areas shall ensure that all the workers are wearing the safety devices before commencing any work.

10.14.4 Construction sheds and tool boxes shall be so located as to protect workers from injuries from the falling debris.

10.14.5 Where there is a likelihood of injuries to hands of workers when demolishing RCC, steel structures, etc, gloves of suitable materials shall be worn by workers.

10.14.6 Sufficient protection by way of both overhead cover and screens shall be provided to prevent injuries to the workers and the public.

10.14.7 Safety belts or ropes shall be used by workers when working at higher levels.

10.14.8 *Grading of Plot*

When a building has been demolished and no building operation has been projected or approved, the vacant plot shall be filled, graded and maintained in conformity to the established street grades at kerb level. The plot shall be maintained free from the accumulation of rubbish and all other unsafe and hazardous conditions which endangers the life or health of the public; and provisions shall be made to prevent the accumulation of water or damage to any foundations on the premises or the adjoining property.

10.15 First-Aid

10.15.1 A copy of all pertinent regulations and notices concerning accidents, injury and first-aid shall be prominently exhibited at the work site.

10.15.2 Depending on the scope and nature of the work, a person, qualified in first-aid shall be available at work site to render and direct first-aid to casualties. He shall maintain a list of individuals qualified to serve in first-aid work. Enough first-aid kit, including a stretcher and a cot with accessories shall be provided at site. A telephone may be provided to first-aid assistant with telephone numbers of the hospitals prominently displayed.

Complete reports of all accidents and action taken thereon shall be forwarded to the competent authorities.

SECTION 5 REPAIRS, RETROFITTING AND STRENGTHENING OF BUILDINGS

11 MAINTENANCE MANAGEMENT

Maintenance management of building is the art of preserving over a long period what has been constructed. Whereas construction stage lasts for a short period, maintenance continues for comparatively very large period during the useful life of building. Inadequate or improper maintenance adversely affects the environment in which people work, thus affecting the overall output. In the post construction stage the day to day maintenance or upkeep of the building shall certainly delay the decay of the building structure. Though the building may be designed to be very durable it needs maintenance to keep it in good condition. The maintenance management of buildings shall be done in accordance with Part 12 'Asset and Facility Management' of the Code.

12 PREVENTION OF CRACKS

12.1 Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces, such as dead, imposed, wind or seismic loads, or foundation settlement or it could be induced internally due to thermal movements, moisture changes, chemical action, etc.

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12.2 Cracks could be broadly classified as structural or non-structural. Structural cracks are those which are due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. Extensive cracking of an RCC beam is an instance of structural cracking. Non-structural cracks are mostly due to internally induced stresses in building materials and these generally do not directly result in structural weakening. In course of time, however, sometime non-structural cracks may, because of penetration of moisture through cracks or weathering action, result in corrosion of reinforcement and thus may render the structure unsafe. Vertical cracks in a long compound wall due to shrinkage or thermal movement is an instance of non-structural cracking. Non-structural cracks, normally do not endanger the safety of a building, but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations, cracks may, because of penetration of moisture through them, spoil the internal finish, thus adding to cost of maintenance. It is, therefore, necessary to adopt measures of prevention or minimization of these cracks.

12.3 For complete details on causes and prevention of non-structural cracks, reference shall be made to good practice SP 25:1984 'Handbook on causes and prevention of cracks in buildings'.

13 REPAIRS AND SEISMIC STRENGTHENING OF BUILDINGS

13.1 General Principles and Concepts

13.1.1 *Non-structural/Architectural Repairs*

13.1.1.1 The buildings affected by earthquake may suffer both non-structural and structural damages. Non-structural repairs may cover the damages to civil and electrical items, including the services in the building. Repairs to non-structural components need to be taken up after the structural repairs and retrofitting work are carried out. Care should be taken about the connection details of architectural components to the main structural components to ensure their stability.

13.1.1.2 Non-structural and architectural components get easily affected/ dislocated during the earthquake. These repairs involve one or more of the following:

a) Patching up of defects such as cracks and fall of plaster;
b) Repairing doors, windows, replacement of glass panes;
c) Checking and repairing electric conduits/ wiring;
d) Checking and repairing gas pipes, water pipes and plumbing services;
e) Rebuilding non-structural walls, smoke chimneys, parapet walls, etc;
f) Replastering of walls, as required;
g) Rearranging disturbed roofing tiles;
h) Relaying cracked flooring at ground level; and
j) Redecoration – white washing, painting, etc.

The architectural repairs as stated above do not restore the original structural strength of structural components in the building and any attempt to carry out only repairs to architectural/non-structural elements, neglecting the required structural repairs, may have serious implications on the safety of the building. The damage would be more severe in the event of the building being shaken by a similar shock because original energy absorption capacity of the building would have been reduced.

13.1.2 *Structural Repairs/Restoration*

13.1.2.1 Prior to taking up of the structural repairs for restoration of original strength and any strengthening measures, it is necessary to conduct detailed damage assessment to determine,

a) the structural condition of the building to decide whether a structure is amenable for repair; whether continued occupation is permitted; to decide the structure as a whole or a part require demolition, if considered dangerous;
b) if the structure is considered amenable for repair then detailed damage assessment of the individual structural components (mapping of the crack pattern, distress location; crushed concrete, reinforcement bending/yielding, etc). Non-destructive testing techniques could be employed to determine the residual strength of the members; and
c) to work out the details of temporary supporting arrangement of the distressed members so that they do not undergo further distress due to gravity loads.

13.1.2.2 After the assessment of the damage of individual structural elements, appropriate repair methods are to be carried out component-wise depending on the extent of damage. The restoration work may consist of the following:

a) Removal of portions of cracked masonry walls and piers and rebuilding them in richer mortar. Use of non-shrinking mortar will be preferable.
b) Addition of reinforcing mesh on both faces of the cracked wall, holding it to the wall through spikes or bolts and then covering it, suitably, with cement mortar or micro-concrete (maximum size of aggregate limited

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to 6 mm or less as suitable), and may be with use of micro-reinforcement as fibre or ferro-cement.

c) Injecting cement, polymer-cement mixture or epoxy materials, which are strong in tension, into the cracks in walls.

d) The cracked reinforced concrete elements may be repaired by epoxy grouting and could be strengthened by epoxy or polymer mortar application like shotcreting, jacketing, etc.

NOTE — In mortar for masonry or plaster, fibres can be used.

13.1.3 *Seismic Strengthening*

The main purpose of the seismic strengthening is to upgrade the seismic resistance of a damaged building while repairing so that it becomes safer under future earthquake occurrences. This work may involve some of the following actions:

a) Increasing the lateral strength in one or both directions by increasing column and wall areas or the number of walls and columns.

b) Giving unity to the structure, by providing a proper connection between its resisting elements, in such a way that inertia forces generated by the vibration of the building can be transmitted to the members that have the ability to resist them. Typical important aspects are the connections between roofs or floors and walls, between intersecting walls and between walls and foundations.

c) Eliminating features that are sources of weakness or that produce concentration of stresses in some members. Asymmetrical plan distribution of resisting members, abrupt changes of stiffness from one floor to the other, concentration of large masses and large openings in walls without a proper peripheral reinforcement are examples of defects of this kind.

d) Avoiding the possibility of brittle modes of failure by proper reinforcement and connection of resisting members.

13.1.4 *Seismic Retrofitting*

Many existing buildings do not meet the seismic strength requirements of present earthquake codes due to original structural inadequacies and material degradation due to time or alterations carried out during use over the years. Their earthquake resistance can be upgraded to the level of the present day codes by appropriate seismic retrofitting techniques, such as mentioned in **13.1.3**.

13.1.5 *Strengthening or Retrofititng Versus Reconstruction*

13.1.5.1 Replacement of damaged buildings or existing unsafe buildings by reconstruction is, generally, avoided due to a number of reasons, the main ones among them being,

a) higher cost than that of strengthening or retrofitting;

b) preservation of historical architecture; and

c) maintaining functional social and cultural environment.

In most instances, however, the relative cost of retrofitting to reconstruction cost determines the decision. As a thumb rule, if the cost of repair and seismic strengthening is less than about 50 percent of the reconstruction cost, the retrofitting is adopted. This may also require less working time and much less dislocation in the living style of the population. On the other hand reconstruction may offer the possibility of modernization of the habitat and may be preferred by well-to-do communities.

13.1.5.2 Cost wise the building construction including the seismic code provisions in the first instance, works out to be the cheaper in terms of its own safety and that of the occupants. Retrofitting an existing inadequate building may involve as much as 4 to 5 times the initial extra expenditure required on seismic resisting features. Repair and seismic strengthening of a damaged building may even be 5 to 10 times as expensive. It is, therefore, very much safe as well as cost-effective to construct earthquake resistant buildings at the initial stage itself according to the relevant seismic IS codes.

13.2 For detailed guidelines for repairs and seismic strengthening of masonry buildings, reference shall be made to good practice [7(52)].

13.3 For detailed guidelines for improving earthquake resistance of low strength masonry buildings, reference shall be made to good practice [7(53)].

13.4 For detailed guidelines for improving earthquake resistance of earthen buildings, reference shall be made to good practice [7(54)].

13.5 For detailed guidelines for seismic evaluation and strengthening of existing reinforced concrete buildings, reference shall be made to good practice [7(55)].

SECTION 6 HABITAT AND WELFARE REQUIREMENTS FOR WORKERS

14 HABITAT AND OTHER WELFARE REQUIREMENTS FOR CONSTRUCTION WORKERS

14.1 The following aspects relating to habitat and other welfare requirements for construction workers at site

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shall be met with, in accordance with **14.2 to 14.16**:

a) Habitat site selection criteria;
b) Area requirements for the various facilities of the habitat;
c) Design of the habitat including the construction materials;
d) Specifications of living area, height of the rooms, windows and doors, ventilation;
e) Specification and requirements for kitchen and other sanitary facilities, such as toilets, bathrooms, etc;
f) Fire and safety requirements;
g) First aid and medical requirements;
h) Crèches;
j) Habitat operation and maintenance;
k) Security;
m) Recreational facilities;
n) Waste management;
p) Habitat inspection and monitoring; and
q) Other facilities.

The project authorities should, depending on size of the project, number of workers employed, location of the project, etc, provide these facilities for the workers. They should also decide the nature of facilities that should be provided at the workplace within working hours.

14.2 Habitat Site Selection Criteria

14.2.1 The criteria given in **14.2.1.1** to **14.2.1.5** shall be met while selecting habitat site for construction workers.

14.2.1.1 Workers habitat shall be located away from overhead electrical lines. If due to non-availability of space, the habitat need to be located in the proximity of electrical line, minimum clearances as given in Part 3 'Development Control Rules and General Building Requirements' of the Code shall be provided.

14.2.1.2 Workers' habitat shall be located sufficiently away from areas like sewage channels, effluent treatment plants, garbage dumping yards, etc.

14.2.1.3 The site selected shall be such that it does not get flooded during monsoon and drainage system available around the site for run-off water.

14.2.1.4 The site shall be separated from the construction site/public area by physical barrier such as fences.

14.2.1.5 Appropriate provisions shall be made for access to the site; and depending upon the location thereof, transportation of workers from their habitat to work locations.

14.3 Minimum Area Requirements

The area requirements as given in Table 1 shall be adopted in a construction workers' habitat.

For female workers and if workers' accommodation is provided for families of workers, separate sanitation facility for women with adequate privacy shall be provided as per Table 1.

Table 1 Area Requirements in Construction Workers' Habitat

(*Clause* 14.3)

Sl No.	Description	Quantity
(1)	(2)	(3)
i)	Minimum floor area per person	3.6 m^2
ii)	Maximum number of persons per room	10
iii)	Minimum height of the room	2.7 m, if two tier beds are provided 3 m
iv)	Minimum area of kitchen per person	0.60 m^2
v)	Number of lavatories, *Min*	1 per 10 person
vi)	Number of bathrooms, *Min*	1 unit per 15 person
vii)	Number of urinals, *Min*	1 per 25 person

14.4 Minimum Facilities to be Provided in Rooms

Following minimum facilities shall be provided in rooms of construction workers:

a) Adequate natural light during the day time and adequate artificial light;
b) Adequate ventilation to ensure sufficient movement of air in all conditions of weather and climate;
c) Lockable doors and windows, provided with mosquito screens where conditions warrant;
d) A separate bed for each worker;
e) Adequate furniture for each worker to secure his or her personal belongings, such as, a ventilated clothes locker which can be locked by the occupant to ensure privacy;
f) Separate storage for work boots and other personal protection equipment to be provided depending on conditions;
g) As far as practicable, sleeping rooms be so arranged that shifts are separated and that no workers working during the day share a room with workers on night shifts;
h) Beds not to be arranged in tiers of more than two.

14.5 Design and Construction of the Habitat

Design and construction of the workers' habitat meeting

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the requirements given in **14.2** to **14.4** shall be structurally sound and may be constructed at site or erected as prefabricated single/two storied accommodation.

14.6 Sanitary Facilities

Following sanitary facilities shall be provided at habitat for construction workers at site:

a) Every lavatory shall be under cover and so partitioned off as to secure privacy, and shall have a proper door and fastenings.

b) Where both male and female building workers are employed, separate sanitary facilities shall be provided for female workers. There shall be displayed outside each block of lavatories or urinals a notice containing therein 'For Men Only' or 'For Women Only', as the case may be, written in the language understood by the majority of such workers. Such notice shall also bear the figure of a man or of a woman, as the case may be.

c) Every lavatory or urinal shall be conveniently situated and accessible to building workers at all times.

d) Every lavatory or urinal and washing facilities shall be adequately lighted and shall be maintained in a clean and sanitary condition at all times.

e) Every lavatory or urinal other than those connected with a flush sewage system shall comply with the requirements of the public health authorities.

f) Water seal lavatories may be provided on the basis of community toilets or shared toilets as per the recommendation given in good practice [7(56)].

g) Water shall be provided by means of a tap or otherwise so as to be conveniently accessible in or near every lavatory or urinal.

h) The walls, ceilings and partitions of every lavatory or urinal shall be white-washed or colour-washed once in every period of six months.

j) Waste water from wash areas, bathrooms and toilets shall be drained in septic tanks/soak pits and suitably disposed in municipal sewerage systems. For very large habitat, sewage treatment plant may be installed. No waste water shall be discharged to ground or other sources without proper treatment.

k) Septic tanks/soak pits shall be located at a minimum distance of 18 m from the wells. Location of septic tank shall meet the requirements of good practice [7(57)].

14.7 Drinking Water Requirements

14.7.1 Sufficient quantity of potable water shall be made available for drinking. Drinking water shall meet the requirements of the accepted standard [7(58)] and water quality shall be monitored regularly.

14.7.2 Drinking water outlet shall be so located such that the distance to travel to nearest outlet shall not be more than 30 m. Drinking water tanks should be legibly marked 'Drinking Water' in a language understood by a majority of the workers and shall be located at least 6 m away from washing place, urinal or lavatory.

14.7.3 Sampling and testing of drinking water for checking its conformity to meet the requirements of **14.7.1** should be carried out quarterly through accredited laboratory.

14.7.4 Storage tanks shall be cleaned as part of regular maintenance procedure to prevent growth of slime and collection of sediments.

14.8 First Aid and Medical Facilities

14.8.1 First aid centre shall be established in the habitat with the required medical facilities. Trained first aiders/ male nurse/doctor shall be employed in the First Aid Centre depending on the number of workers accommodated. Sufficient number of first-aid boxes shall be provided and maintained and the box shall be distinctly marked 'First-aid' and shall be equipped with specified articles.

14.8.2 An emergency vehicle shall be provided or an arrangement shall be made with an identified nearby hospital for providing ambulance for transportation of serious cases of accident or sickness of workers to the hospital promptly. Such vehicle should be maintained in good repair and should be equipped with standard facilities. The contact details, including phone numbers of such nearby hospitals shall be readily available to different managers/supervisors/first-aid facility in-charge. These phone numbers shall also be suitably displayed at site.

14.8.3 Details of all the first-aid/medical treatments shall be logged in the first aid register.

14.8.4 Lighting of 300 lux shall be maintained in the first aid centre.

14.8.5 Health check-up of all the workers shall be done at least once in six months by a registered medical practitioner.

14.8.6 The medical facilities shall meet the provisions of *Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act,* 1996 and rules framed thereunder.

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14.9 Cooking Area

Cooking shall not be permitted in the living area. Separate designated kitchen shall be provided meeting the minimum area requirements given in **14.3**. Canteen and cooking facilities should provide sufficient space for preparing food and eating, as well as conform to hygiene and safety requirements. When workers can individually cook their meals, they should be provided with a space separate from the sleeping areas. Facilities must be kept in a clean and sanitary condition.

14.10 Crèches

In every place wherein more than fifty female building workers are ordinarily employed, there shall be provided and maintained, a suitable room or rooms for the use of children under the age of six years of such female workers. Such rooms shall,

a) provide adequate accommodation;
b) be adequately lighted and ventilated;
c) be maintained in a clean and sanitary condition; and
d) be under the charge of women trained in the care of children and infants.

14.11 Habitat Operation and Maintenance

14.11.1 A detailed plan shall be prepared for the operation and maintenance of the habitat facilities. The plan shall cover all aspects of the operation, preventive and routine maintenance.

14.11.2 Qualified and experienced in-house electrical/ maintenance personnel shall be present and available. A supervisor shall be appointed to supervise hygiene in the habitat facilities. Sufficient cleaners shall be employed to ensure that the buildings and sanitary facilities are always clean and hygienic.

14.11.3 Regular pest and insect control measures shall be taken up to avoid mosquito/pest breeding. This may be done through an approved agency.

14.11.4 Worker's transportation may be done with standard passenger vehicle/bus, where required.

14.12 Fire Prevention

14.12.1 Fire extinguishers shall be provided such that one should not have to travel more than 15 m distance to access a fire extinguisher.

14.12.2 Diesel generator shed and inflammable liquid storage areas shall be provided with foam type fire extinguishers and fire buckets.

14.12.3 Electrical fittings in the inflammable storage areas shall be flame proof.

14.12.4 'No Smoking' boards shall be displayed in gas cylinder and flammable liquid storage areas.

14.12.5 All the security and habitat maintenance personnel, habitat residents and site workers shall be trained on use of fire extinguishers.

14.13 Recreation

Internal and external recreational facilities may be made available depending on the number of workers to be accommodated. Reasonable access to telephone or other modes of communications, with any charges for the use of these services being reasonable in amount, shall be provided.

14.14 Security

14.14.1 Adequate number of security personnel shall be deployed. Specific security personnel shall be deployed at the main entry gate for restricting unauthorized entry and checking vehicle/material exit and entry.

14.14.2 Security staff shall receive adequate training on first aid, firefighting and emergency preparedness. Security staff shall have a good understanding about the importance of respecting workers' rights and the rights of the communities. Security staff shall have the emergency lights, torches and other accessories required to facilitate during emergency situations.

14.14.3 A minimum of 50 lux lighting shall be maintained in the roads, parking area, boundary wall and other general areas of the habitat.

14.15 Other Facilities

Other facilities like provisional stores with separate counters for vegetables, etc, may also be provided in a construction workers habitat.

Facilities like induction/initiation room may be planned as the part of habitat for awareness, education and other related work site requirements.

14.16 Habitat Inspection

Periodical inspection of the habitat shall be carried out by an identified team preferably once in a month. The team shall record their findings on the Inspection Report form and team shall also review and follow-up implementation of the suggested measures. The above periodic inspection report of the habitat should be submitted to Project-in-Charge.

14.17 Notwithstanding the requirements given in **14.1** to **14.16**, all provisions given in relevant Act/Rules/ Regulations as amended from time to time shall be followed; in this regard, reference shall also be made to the *Building and other Construction Workers (Regulation of Employment and Conditions of Service) Act,* 1996 and the rules/regulations framed thereunder.

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ANNEX A

(*Clause* 8.2.1)

CHECK LIST FOR STACKING AND STORAGE OF MATERIALS

Sl No.	*Material/ Component*	*Base*			*Stack*				*Type of Cover*		
		Firm Level Ground	Hard Floor	Off-Floor	Heaps	Tiers	Flat	Vertical	Open	Open but Covered	Under Shed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1.	Cement			✓		✓					✓
2.	Lime:										
	a) Quick lime		✓		✓					✓	
	b) Hydrated lime			✓		✓					✓
3.	Stones and aggregates:										
	a) Stones, aggregates, fly ash and cinder	✓			✓				✓		
	b) Veneering stones	✓				✓		✓	✓		
4.	Bricks and blocks	✓				✓			✓		
5.	Tiles:										
	a) Clay and concrete floor, wall and roof tiles	✓				✓	✓		✓		
	b) Ceramic tiles		✓			✓	✓				✓
6.	Partially pre-fabricated wall and roof components:										
	a) RC planks, prefabricated brick panels and ferro-cement panels	✓						✓	✓		
	b) Channel units, cored units and L-Panels	✓				✓			✓		
	c) Waffle units, RC joists, single tee and double tee	✓					✓		✓		
7.	Timber			✓		✓					✓
8.	Steel	✓					✓		✓		
9.	Aluminium sections		✓				✓				✓
10.	Doors, windows and ventilators		✓					✓			✓
11.	Roofing sheets:										
	a) AC	✓				✓	✓		✓		
	b) GI and aluminium sheets	✓				✓	✓			✓	
	c) Plastic sheets			✓		✓	✓				✓
12.	Boards like plywood, particle boards, fibre boards, blockboards and gypsum board			✓		✓	✓				✓

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ANNEX A — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
13.	Plastic and rubber flooring:										
	a) Sheets in rolls	✓						✓			✓
	b) Tiles	✓				✓	✓				✓
14.	Glass sheets		✓					✓			✓
15.	Glass bricks/blocks		✓			✓					✓
16.	CI, GI and AC pipes and fittings:										
	a) Pipes	✓				✓	✓		✓		
	b) CI and GI fittings		✓				✓				✓
	c) AC fittings		✓				✓		✓		
17.	Polyethylene pipes			✓		✓	✓				✓
18.	Unplasticized PVC pipes	✓				✓	✓		✓		
19.	Bitumen, road tar, asphalt, etc, in drums	✓				✓			✓		
20.	Oil paints		✓			✓					✓
21.	Sanitary appliances			✓			✓				✓

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Part.

	IS No.	*Title*
(1)	7337 : 2010	Glossary of terms in project management (*second revision*)
	10400 : 2013	Glossary of terms in inventory management (*second revision*)
	15198 : 2014	Glossary of terms in human resource development
(2)	16416 : 2016	Construction project management: Project formulation and appraisal — Guidelines
(3)	14580	Use of network analysis for project management
	(Part 1) : 1998	Management, planning, review, reporting and termination procedures
	(Part 2) : 2006	Use of graphic techniques
(4)	15883 (Part 6) : 2015	Guidelines for construction project management: Part 6 Scope management
(5)	15883 (Part 7)	Guidelines for construction project management: Part 7 Procurement management (*under preparation)*
(6)	15883 (Part 2) : 2013	Guidelines for construction project management: Part 2 Time management
(7)	15883 (Part 3) : 2015	Guidelines for construction project management: Part 3 Cost management
(8)	15883 (Part 4) : 2015	Guidelines for construction project management: Part 4 Quality management
(9)	15883 (Part 8) : 2015	Guidelines for construction project management: Part 8 Risk management
(10)	15883 (Part 9)	Guidelines for construction

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IS No.	*Title*
	project management: Part 8 Communication management (*under preparation*)
(11) 15883 (Part 10)	Guidelines for construction project management: Part 10 Human resource management (*under preparation*)
(12) 15883 (Part 5) : 2013	Guidelines for construction project management: Part 5 Health and safety management
(13) 15883 (Part 11)	Guidelines for construction project management: Part 11 Sustainability management (*under preparation*)
(14) 15883 (Part 12) : 2016	Guidelines for construction project management: Part 12 Integration management
(15) a) *Foundations*	
1080 : 1985	Code of practice for design and construction of shallow foundations on soils (other than raft, ring and shell) (*second revision*)
1904 : 1986	Code of practice for design and construction of foundations in soils: General requirements (*third revision*)
2911	Code of practice for design and construction of pile foundations
(Part 1/Sec 1) : 2010	Concrete piles, Section 1 Driven cast *in-situ* concrete piles (*second revision*)
(Part 1/Sec 2) : 2010	Concrete piles, Section 2 Board cast *in-situ* concrete piles (*second revision*)
(Part 1/Sec 3) : 2010	Concrete piles, Section 3 Precast driven concrete piles (*second revision*)
(Part 1/Sec 4) : 2010	Concrete piles, Section 4 Precast concrete piles in prebored holes (*first revision*)
(Part 2) : 1980	Timber piles (*first revision*)
(Part 3) : 1980	Under-reamed piles (*first revision*)
(Part 4) : 2013	Load test on piles (*second revision*)
2974	Code of practice for design and construction of machine foundations
(Part 1) : 1982	Foundations for reciprocating type machines (*second revision*)
(Part 2) : 1980	Foundations for impact type machines (hammer foundations) (*first revision*)
(Part 3) : 1992	Foundations for rotary type machines (medium and high frequency) (*second revision*)
(Part 4) :1979	Foundations for rotary type machines of low frequency (*first revision*)
(Part 5) :1987	Foundations for impact machines other than hammers forging and stamping press pig breakers (drop crusher and jolter) (*first revision*)
9456 : 1980	Code of practice for design and construction of conical and hyperbolic paraboidal types of shell foundations
9556 : 1980	Code of practice for design and construction of diaphragm walls
12070 : 1987	Code of practice for design and construction of shallow foundations on rock
13094 : 1992	Guidelines for selection of ground improvement techniques for foundation in weak soils
14593 : 1998	Design and construction of bored cast-in-situ piles founded on rocks — Guidelines
15284	Design and construction for ground improvement:
(Part 1) : 2003	Stone columns
(Part 2) : 2004	Preconsolidation using vertical drains

b) *Masonry*

IS No.	*Title*
1597	Code of practice for construction of stone masonry
(Part 1) : 1992	Rubble stone masonry (*first revision*)

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IS No.	*Title*
(Part 2) : 1992	Ashlar masonry (*first revision*)
2110 : 1980	Code of practice for *in-situ* construction of walls in buildings with soil-cement (*first revision*)
2212 : 1991	Code of practice for brickwork (*first revision*)
2250 : 1981	Code of practice for preparation and use of masonry mortars (*first revision*)
2572 : 2005	Code of practice for construction of hollow and solid concrete block masonry (*first revision*)
3630 : 1992	Code of practice for construction of non-load bearing gypsum block partitions (*first revision*)
4407 : 1967	Code of practice for reed walling
4441 : 1980	Code of practice for use of silicate type chemical resistant mortars (*first revision*)
4442 : 1980	Code of practice for use of sulphur type chemical resistant mortars (*first revision*)
4443 : 1980	Code of practice for use of resin type chemical resistant mortars (*first revision*)
6041 : 1985	Code of practice for construction of autoclaved cellular concrete block masonry (*first revision*)
6042 : 1969	Code of practice for construction of light weight concrete block masonry (*first revision*)

c) *Timber and Bamboo*

IS No.	*Title*
1634 : 1992	Code of practice for design and constructions of wood stair for houses (*second revision*)
2366 : 1983	Code of practice for nail-jointed timber construction (*first revision*)
3670 : 1989	Code of practice for construction of timber floors (*first revision*)
4913 : 1968	Code of practice for selection, installation and maintenance of timber doors and windows
4983 : 1968	Code of practice for design and construction of nail laminated timber beams
5390 : 1984	Code of practice for construction of timber ceilings (*first revision*)
11096 : 1984	Code of practice for design and construction of bolt-jointed timber construction
12506 : 1988	Code of practice for improved thatching of roof with wrought and fire retardant treatment

d) *Concrete*

IS No.	*Title*
456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
457 : 1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
1343 : 2012	Code of practice for pre-stressed concrete (*second revision*)
2502 : 1963	Code of practice for bending and fixing of bars for concrete reinforcement
2541 : 1991	Code of practice for preparation and use of lime concrete (*second revision*)
3370	Code of practice for concrete structures for the storage of liquids:
(Part 1) : 2009	General requirements (*first revision*)
(Part 2) : 2009	Reinforced concrete structures (*first revision*)
(Part 3) :1967	Prestressed concrete structures
3558 : 1983	Code of practice for use of immersion vibrators for consolidating concrete (*first revision*)

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IS No.	*Title*
4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
5817 : 1992	Code of practice for preparation and use of lime pozzolana mixture concrete in buildings and roads (*first revision*)
7246 : 1974	Recommendations for use of table vibrators for consolidating concrete
7861	Code of practice for extreme whether concreting:
(Part 1) : 1975	Recommended practice for hot weather concreting
(Part 2) : 1981	Recommended practice for cold weather concreting
10262 : 2009	Guidelines for concrete mix design proportioning (*first revision*)
10359 : 1982	Code of practice for manufacture and use of lime pozzolana concrete blocks for paving
14687 : 1999	Guidelines for falsework for concrete structures

e) *Steel*

IS No.	*Title*
800 : 2007	Code of practice for general construction in steel (*third revision*)
801 : 1975	Code of practice for use of cold formed light gauge steel structural members in general building construction (*first revision*)
805 : 1968	Code of practice for use of steel in gravity water tanks
806 : 1968	Code of practice for use of steel tubes in general building construction (*first revision*)
4000 : 1992	Code of practice for high strength bolts in steel structures (*first revision*)
4180 : 1967	Code of practice for corrosion protection of light gauge steel sections used in building
6533	Code of practice for design and construction of steel chimneys:
(Part 1) : 1989	Mechanical aspects (*first revision*)
(Part 2) : 1989	Structural aspects (*first revision*)
8629 (Parts 1 to 3) : 1977	Code of practice for protection of iron and steel structures from atmospheric corrosion
9077 : 1979	Code of practice of corrosion protection of steel reinforcement in RB and RCC construction
9172 : 1979	Recommended design practice for corrosion prevention of steel structures

f) *Flooring and Roofing*

658 : 1982	Code of practice for magnesium oxychloride composition floors (*second revision*)
1196 : 1978	Code of practice for laying bitumen mastic flooring (*second revision*)
1197 : 1970	Code of practice for laying of rubber floors (*first revision*)
1198 : 1982	Code of practice for laying, fixing and maintenance of linoleum floor (*first revision*)
1443 : 1972	Code of practice for laying and finishing of cement concrete flooring tiles (*first revision*)
2118 : 1980	Code of practice for construction of jack-arch type of building floor or roof (*first revision*)
2119 : 1980	Code of practice for construction of brick-cum-concrete composite (Madras terrace) floor or roof (*first revision*)
2204 : 1962	Code of practice for construction of reinforced concrete shell roof
2571 : 1970	Code of practice for laying in-situ cement concrete flooring (*first revision*)

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IS No.	*Title*
2700 : 1987	Code of practice for roofing with wooden shingles (*first revision*)
2792 : 1964	Code of practice for design and construction of stone slab over joist floor
2858 : 1984	Code of practice for roofing with Mangalore tiles (*first revision*)
3007	Code of practice for laying of asbestos cement sheets
(Part 1) : 1999	Corrugated sheets (*first revision*)
(Part 2) : 1999	Semi-corrugated sheets (*first revision*)
3670 : 1989	Code of practice for construction of timber floors (*first revision*)
5119	Code of practice for laying and fixing of sloped roof coverings
(Part 1) : 1968	Slating
5318 : 1969	Code of practice for laying of flexible PVC sheet and tile flooring
5389 : 1969	Code of practice for laying of hard wood parquet and wood block floors
5390 : 1984	Code of practice for construction of timber ceilings (*first revision*)
5766 : 1970	Code of practice for laying burnt clay brick flooring
6061	Code of practice for construction of floor and roof with joists and filler blocks
(Part 1) : 1971	With hollow concrete filler blocks
(Part 2) : 1981	With hollow clay filler blocks (*first revision*)
(Part 3) : 1981	Precast hollow clay blocks joists and hollow clay filler blocks
(Part 4) : 1981	With precast hollow clay block slab panels
6332 : 1984	Code of practice for construction of floors and roofs using precast doubly-curved shell units (*first revision*)
9472 : 1980	Code of practice for laying mosaic parquet flooring
10297 : 1982	Code of practice for design and construction of floors and roofs using precast reinforced/prestressed concrete ribbed or cored slab units
10440 : 1983	Code of practice for construction of reinforced brick and RBC floors and roofs
10505 : 1983	Code of practice for construction of floors and roofs using precast concrete waffle units

g) *Finishes*

IS No.	*Title*
1346 : 1991	Code of practice for waterproofing of roofs with bitumen felts (*third revision*)
1414 : 1989	Code of practice for fixing wall coverings
1477	Code of practice for painting of ferrous metals in buildings
(Part 1) : 1971	Pretreatment (*first revision*)
(Part 2) : 1971	Painting (*first revision*)
1609 : 1991	Code of practice for laying damp-proofing treatment using bitumen felts (*second revision*)
1661 : 1972	Code of practice for application of cement and cement lime plaster finishes (*first revision*)
2114 : 1984	Code of practice for laying *in-situ* terrazzo floor finish (*first revision*)
2115 : 1980	Code of practice for flat-roof finish : Mud *Phuska* (*second revision*)
2338	Code of practice for finishing of wood and wood based materials
(Part 1) : 1967	Operations and work-manship
(Part 2) : 1967	Schedules

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IS No.	*Title*
2394 : 1984	Code of practice for application of lime plaster finish (*first revision*)
2395	Code of practice for painting concrete, masonry and plaster surfaces
(Part 1) : 1994	Operations and workmanship (*first revision*)
(Part 2) : 1994	Schedule (*first revision*)
2402 : 1963	Code of practice for external rendered finishes
2441 : 1984	Code of practice for fixing ceiling covering (*first revision*)
2524	Code of practice for painting of non-ferrous metals in buildings
(Part 1) : 1968	Pre-treatment
(Part 2) : 1968	Painting
3036 : 1992	Code of practice for laying lime concrete for a water-proofed roof finish (*second revision*)
3067 : 1988	Code of practice for general design details and preparatory work for damp-proofing and waterproofing of buildings (*first revision*)
3140 : 1965	Code of practice for painting asbestos cement building products
4101	Code of practice for external facing and veneers
(Part 1) : 1967	Stone facing
(Part 2) : 1967	Cement concrete facing
(Part 3) : 1985	Wall tiling and mosaics (*first revision*)
4365 : 1967	Code of practice for application of bitumen mastic for waterproofing of roofs
4597 : 1968	Code of practice for finishing of wood and wood based products with nitrocellulose and cold catalysed materials
4631 : 1986	Code of practice for laying of epoxy resin floor toppings (*first revision*)
5491 : 1969	Code of practice for laying *in-situ* granolithic concrete floor topping
6278 : 1971	Code of practice for white-washing and colour washing
6494 : 1988	Code of practice for waterproofing of underground water reservoirs and swimming pools (*first revision*)
7198 : 1974	Code of practice for damp-proofing using bitumen mastic
7290 : 1979	Recommendations for use of polyethylene film for waterproofing of roofs (*first revision*)
9918 : 1981	Code of practice for in-situ waterproofing and damp-proofing treatments with glass fibre tissue reinforced bitumen
10439 : 1983	Code of practice for patent glazing
16135 : 2014	Code of practice for dry lining and partitioning using gypsum plasterboards
16231	Code of practice of use of glass in buildings
(Part 1) : 2016	General methodology and selection
(Part 2) : 2016	Energy and light
(Part 3) : 2016	Fire and loading
(Part 4) : 2014	Safety related to human impact

h) *Piping*

IS No.	*Title*
783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
3114 : 1994	Code of practice for laying of cast iron pipes (*second* revision)
4127 : 1983	Code of practice for laying of glazed stoneware pipes (*first revision*)
5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)

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IS No.	*Title*
5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
7634	Code of practice for plastics pipe work for portable water supplies
(Part 1) : 1975	Choice of materials and general recommen-dations
(Part 2) : 2012	Laying and jointing polyethylene (PE) pipes (*first revision*)
(Part 3) : 2003	Laying and jointing of unplasticized PVC pipes
13916 : 1994	Code of practice for installation of glass fibre reinforced plastic piping system

j) *Measurements*

IS No.	*Title*
1200	Method of measurement of building and civil engineering works
(Part 1) : 1992	Earthwork (*fourth revision*)
(Part 2) : 1974	Concrete work (*third revision*)
(Part 3) : 1976	Brickwork (*third revision*)
(Part 4)1976	Stone masonry (*third revision*)
(Part 5) : 2013	Formwork (*fourth revision*)
(Part 6) : 1974	Refactory work (*second revision*)
(Part 7) : 2013	Hardware (*third revision*)
(Part 8) : 1993	Steel work and iron work (*fourth revision*)
(Part 9) : 1973	Roof covering (including cladding) (*second revision*)
(Part 10) : 2013	Ceiling and linings (*third revision*)
(Part 11) : 2013	Paving, floor finishes dado and skirting (*fourth revision*)
(Part 12) : 1976	Plastering and pointing (*third revision*)
(Part 13) : 1994	White washing, colour washing, distempering and painting of building surfaces (*fifth revision*)
(Part 14) : 1984	Glazing (*third revision*)
(Part 15) : 1987	Paining, polishing, varnishing, etc (*fourth revision*)
(Part 16) : 1979	Laying of water and sewer lines including appurtenant items (*third revision*)
(Part 17) : 1985	Roadwork including air field pavements (*third revision*)
(Part 18) : 1974	Demolition and dis-mantling (*third revision*)
(Part 19) : 1981	Water supply, plumbing and drains (*third revision*)
(Part 20) : 1981	Laying of gas and oil pipe lines (*third revision*)
(Part 21) : 1973	Woodwork and joinery (*second revision*)
(Part 23) : 1988	Piling (*fourth revision*)
(Part 24) : 1983	Well foundations (*third revision*)
(Part 27) : 2013	Earth work done by mechanical appliances
3861 : 2002	Method of measurement of plinth, carpet and rentable areas of buildings (*second revision*)

k) *Others*

IS No.	*Title*
1081 : 1960	Code of practice for fixing and glazing of metal (steel and aluminium) doors, windows and ventilators
1649 : 1962	Code of practice for design and construction of flues and chimneys for domestic heating appliances
1946 : 1961	Code of practice for use of fixing devices in walls, ceilings and floors of solid construction
2470	Code of practice for installation of septic tanks
(Part 1) : 1985	Design criteria and construction (*second revision*)
(Part 2) : 1985	Secondary treatment and disposal of septic tank effluent (*second revision*)
2527 : 1984	Code of practice for fixing rain-water gutters and down

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IS No.	*Title*
	pipes for roof drainage (*first revision*)
3414 : 1968	Code of practice for design and installation of joints in buildings
3548 : 1988	Code of practice for glazing in buildings (*first revision*)
3558 : 1983	Code of practice for use of immersion vibrators for consolidating concrete (*first revision*)
3935 : 1966	Code of practice for composite construction
4326 : 2013	Code of practice for earthquake resistant design and construction of buildings (*third revision*)
4913 : 1968	Code of practice for selection, installation and maintenance of timber doors and windows
6313	Code of practice for anti-termite measures in buildings
(Part 1) : 1981	Constructional measures (*first revision*)
(Part 2) : 2013	Pre-constructional chemical treatment measures (*third revision*)
(Part 3) : 2013	Treatment for existing buildings (*third revision*)
6924 : 1973	Code of practice for the construction of refuse chutes in multistoreyed buildings
7246 : 1974	Recommendation for use of table vibrators for consolidating concrete
8147 : 1976	Code of practice for use of aluminium alloys in structures
15345 : 2003	Code of practice for installation of frameless door and window shutters
15916 : 2010	Code of practice for building design and erection using prefabricated concrete
15917 : 2010	Code of practice for building design and erection using mixed/ composite construction
(16) 2750 : 1964	Specification for steel scaffoldings
14687 : 1999	Guidelines for falsework for concrete structures
3696 (Part 1) : 1987	Safety code for scaffolds and ladders: Part 1 Scaffolds
4014	Code of practice for steel tubular scaffolding
(Part 1) : 1967	Definitions and materials
(Part 2) : 2013	Safety regulations for scaffolding (*first revision*)
(17) 6521 (Part 1) : 1972	Code of practice for design of tower cranes: Part 1 Static and rail mounted
(18) 13558 (Part 3) : 1995	Cranes — control — layout and characteristics: Part 3 Tower cranes
(19) 14687 : 1999	Guidelines for falsework for concrete structures
(20) 3764 : 1992	Safety code for excavation work (*first revision*)
(21) 13416 (Part 5) : 1994	Recommendations for preventive measure against hazards at workplaces : Part 5 Fire protection
(22) 11769 (Part 1) : 1987	Guidelines for safe use of products containing asbestos : Part 1 Asbestos cement products
(23) 15683 : 2006	Specification for portable fire extinguishers — Performance and construction
16018 : 2012	Specification for wheeled fire extinguishers — Performance and construction
(24) 2190 : 2010	Code of practice for selection, installation and maintenance of first-aid fire extinguishers (*fourth* revision)
(25) 8758 : 2013	Code of practice for fire precautionary measures in construction of temporary structures and pandals (*second* revision)
(26) 10439 : 1983	Code of practice patent glazing
14687 : 1999	Guidelines for falsework for concrete structures

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IS No.	*Title*
(27) 4138 : 1977	Safety code for working in compressed air (*first revision*)
(28) 2925 : 1984	Specification for industrial safety helmets (*second revision*)
(29) 2750 : 1964	Specification for steel scaffoldings
(30) 3696 (Part 1) : 1987	Safety code for scaffolds and ladders: Part 1 Scaffolds
4014 (Part 2) : 2013	Code of practice for steel tubular scaffolding: Part 2 Safety provisions for scaffolding (*first revision*)
(31) 3696 (Part 2) : 1991	Safety code for scaffolds and ladders: Part 2 Ladders
(32) 4912 : 1978	Safety requirements for floors and wall openings, railing and toe boards (*first revision*)
(33) 11461 : 1985	Code of practice for compressor safety
(34) 5983 : 1980	Specification for eye-protectors (*first revision*)
(35) 1179 : 1967	Specification for equipment for eye and face protection during welding (*first revision*)
(36) 2361 : 2002	Specification for bull-dog grips (*third revision*)
(37) 11057 : 1984	Specification for industrial safety nets
(38) 3016 : 1982	Code of practice for fire precautions in welding and cutting operations (*first revision*)
(39) 1084 : 2005	Specification for manila ropes (*fifth revision*)
2266 : 2002	Specification for steel wire ropes for general engineering purposes (*forth revision*)
(40) 818 : 1968	Code of practice for safety and health requirements in electric and gas welding and cutting operations (*first revision*)
(41) 5916 : 2013	Constructions involving use of hot bituminous materials — Code of safety
(42) 13416 (Part 4) : 1994	Recommendations for preventive measure against hazards at workplaces : Part 4 Timber structure
(43) 15683 : 2006	Portable fire extinguishers — Performance and construction — Specification
(44) 819 : 1957	Code of practice for resistance spot welding for light assemblies in mild steel
1261 : 1959	Code of practice for seam welding in mild steel
3016 : 1982	Code of practice for fire precautions in welding and cutting operations (*first revision*)
4081 : 2013	Blasting and related drilling operations — Code of Safety (*second revision*)
4138 : 1977	Safety code for working in compressed gas (*first revision*)
9595 : 1996	Recommendations for metal arc welding of carbon and carbon manganese steels (*first revision*)
10178 : 1995	Recommended procedure for CO_2 gas shielded metal-arc welding of structural steels (*first* revision)
(45) 3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision*)
5290 : 1993	Specification for landing valves (*third revision*)
(46) 13416 (Part 2) : 1992	Recommendation for preventive measures against hazards at work places: Part 2 Fall prevention
(47) 13416 (Part 1) : 1992	Recommendation for preventive measures against hazards at work places: Part 1 Falling material hazard prevention
(48) 13416 (Part 3) : 1994	Recommendation for preventive measures against hazards at work

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IS No.	*Title*
	places: Part 3 Disposal of debris
(49) 274	Specification for shovels
(Part 1) : 1981	General purpose shovels (*third revision*)
(Part 2) : 1981	Heat-treated shovels (*third revision*)
663 : 1980	Specification for adzes (*second revision*)
704 : 1984	Specification for crow bars and claw bars (*second revision*)
841 : 1983	Specification for steel hammers (*second revision*)
844	Specification for screw drivers
(Part 2) : 1979	Dimensions (*second* revision)
(Part 3) : 1979	Dimensions for screw drivers for recessed head screws (*second revision*)
1630 : 1984	Specification for Mason's tools for plaster work and pointing work (*first revision*)
1759 : 1986	Specification for *Powrahs* (*second revision*)
1791 : 1985	Specification for batch type concrete mixers (*second revision*)
1930 : 2003	Woodworking tools — Chisels and gouges (*third revision*)
1931 : 2000	Specification for engineer's files (*third revision*)
2028 : 2004	Specification for open jaw wrenches (spanners) (*fourth revision*)
2029 : 1998	Specification for ring wrenches (spanners) (*fourth revision*)
2030 : 1989	Specification for box spanners (*second revision*)
2094	Specification for heater for bitumen (tar) and emulsion (*second revision*)
(Part 1) : 1996	Specification (*second revision*)
(Part 2) : 1999	Bitumen sprayer (*third revision*)
(Part 3) : 1999	Emulsion (*third revision*)
2431 : 1963	Specification for steel wheel barrows (single wheel-type)
2438 : 1963	Specification for roller pan mixer
2505 : 1992	Specification for concrete vibrators, immersion type (General requirements) (*third revision*)
2506 : 1985	General requirements for screed board concrete vibrators (*first revision*)
2514 : 1963	Specification for concrete vibrating tables
2587 : 1975	Specification for pipes vices (open side type and fixed sides type) (*first revision*)
2588 : 1975	Specification for black-smith's vices (*first revision*)
2722 : 1964	Specification for portable swing weigh batchers for concrete (single and double bucket type)
2852 : 1998	Specification for carpenters augers (*first revision*)
3066 : 1965	Specification for hot asphalt mixing plants
3251 : 1965	Specification for asphalt paver finisher
3365 : 1965	Specification for floor polishing machines
3559 : 1966	Specification for pneumatic concrete breakers
3587 : 1986	Specification for rasps (*second revision*)
3650 : 1981	Specification for combination side cutting pliers (*second revision*)
3938 : 1983	Specification for electric wire rope hoists (*second revision*)
4003	Specification for pipe wrenches
(Part 1) : 1978	General purposes (*first revision*)
(Part 2) : 1986	Heavy duty (*first revision*)

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IS No.	*Title*
4017 : 1992	Specification for carpenters squares (*first revision*)
4095 : 1991	Specification for pincers (*second revision*)
4183 : 1967	Specification for metal hand rammers
4184 : 1967	Specification for steel wheel barrows (with two wheels)
4508 : 1992	Specification for open ended slugging wrenches (spanners) (*first revision*)
4915 : 1968	Specification for welders chipping hammer
5066 : 1969	Specification for glass pliers
5067 : 1969	Specification for fencing pliers
5087 : 1969	Specification for wire stripping pliers
5098 : 1969	Specification for cross cut and rip saws
5123 : 1969	Specification for tenon and dovetail saws
5169 : 1986	Specification for hack-saw frames (*first revision*)
5200 : 1998	Specification for bolt clippers (*first revision*)
5658 : 1990	Specification for snipenose pliers (*first revision*)
5663 : 1970	Specification for brick and mason's chisels
5684 : 1970	Specification for pipe vices (chain type)
5697 : 1970	Specification for ripping chisels
5889 : 1994	Specification for vibratory plate compactor (*first revision*)
5890 : 2004	Mobile hot mix asphalt plants, light duty — Requirements (*first revision*)
5891 : 1970	Specification for hand-operated concrete mixer
5995 : 1971	Specification for pipe grip pliers
6007 : 1971	Specification for pipe vices (hinged type)
6078 : 1986	Specification for Lineman's pliers (*second revision*)
6087 : 1971	Specification for metal cutting shears
6118 : 1991	Specification for multiple slip joint pliers (*first revision*)
6149 : 1984	Specification for single ended open jaw adjustable wrenches (*(first revision*)
6375 : 1991	Specification for wood splitting wedges (*first revision*)
6389 : 1998	Specification for combination wrenches with equal openings (*second revision*)
6428 : 1972	Specification for pile frame
6430 : 1985	Specification for mobile air compressor for construct-ion purposes (*first revision*)
6433 : 1972	Specification for guniting equipment
6546 : 1989	Specification for claw hammers (*first revision*)
6836 : 1973	Specification for hand snaps and set-ups for solid rivets
6837 : 1973	Specification for three wheel type pipe cutter
6841 : 1973	Specification for wrecking bars
6861 : 1973	Specification for engineers' scrapers
6881 : 1973	Specification for link type pipe cutters
6891 : 1973	Specification for carpenter's auger bits
6892 : 1973	Specification for black-smith's brick-iron
7041 : 1973	Specification for carpenter's plain brace
7042 : 1973	Specification for carpenter's ratchet brace
7077 : 1973	Specification for bending bars
7958 : 1976	Specification for hand vices
8202 : 1999	Specification for car-penter's wooden bodied planes (*first revision*)

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IS No.	*Title*
8671 : 1977	Specification for nail puller
(50) 7293 : 1974	Safety code for working with construction machinery
(51) 4130 : 1991	Safety code for demolition of buildings (*second revision*)
(52) 13935 : 2009	Guidelines for repair and seismic strengthening of masonry buildings (*first revision*)
(53) 13828 : 1993	Improving earthquake resistance of low strength masonry buildings — Guidelines
(54) 13827 : 1993	Improving earthquake resistance of earthen buildings — Guidelines
(55) 15988 : 2013	Seismic evaluation and strengthening of existing reinforced concrete buildings — Guidelines
(56) 13727 : 1993	Guidelines for requirements of cluster planning for housing
(57) 2470 (Part 1) : 1985	Code of practice for installation of septic tanks: Part 1 design, criteria and construction (*second revision*)
(58) 10500 : 2012	Specification for drinking water (*second revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 1 Lighting and Natural Ventilation

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 8/Section 1) covers requirements and methods for lighting and natural ventilation of buildings.

Illumination levels for different tasks are recommended to be achieved either by daylighting or artificial lighting or a combination of both. This Section, read together with Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code, adequately covers the illumination levels required and methods of achieving the same.

Ventilation requirements to maintain air quality and control body odours in terms of air changes per hour and to ensure thermal comfort and heat balance of body are laid for different occupancies and the methods of achieving the same by natural means are covered in this Section. The provisions on mechanical ventilation are covered in Part 8 'Building Services, Section 3 Air conditioning, Heating and Mechanical Ventilation' of the Code.

Climatic factors which normally help in deciding the orientation of the buildings to get desirable benefits of lighting and natural ventilation inside the buildings are also covered in this Section.

This Section was first published in 1970. The first revision of the Section was brought out in 1983. In the second revision, some provisions were updated based on the information given in the SP 41:1987 'Handbook on functional requirements of buildings (other than industrial buildings)'; other major changes in the last revision included rationalization of definitions and inclusion of definitions for some more terms; inclusion of climatic classification map of India based on a new criteria; updating of data on total solar radiations incident on various surfaces of buildings for summer and winter seasons; inclusion of design guidelines for natural ventilation; reference to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code for guidelines on mechanical ventilation, was made, where these provisions were covered exhaustively; inclusion of rationalized method for estimation of desired capacity of ceiling fans and their optimum height above the floor for rooms of different sizes; incorporation of design sky illuminance values for different climatic zones of India, etc. Energy efficiency was another important aspect which was taken care of in the last revision of the Code. Accordingly, the relevant requirements for energy efficient system for lighting and natural ventilation were duly included in the concerned provisions under the Section.

As a result of experience gained on implementation of 2005 version of the Code and feedback data received, a need was felt to revise this Section. This draft revision has, therefore, been formulated to take care of these. The significant changes incorporated in this revision are:

a) Calculation for solar load has been elaborated, and a detailed 'Method of Calculating Solar Load on Vertical Surfaces in Different Orientation' has been added in Annex A, supporting the relevant provisions.
b) Detailed provisions on sky component calculation procedure have been included along with examples in Annex B supporting the relevant clauses.
c) Reference to SP 41 : 1987 for obtaining coefficient utilization for determination of luminous flux has been included.
d) Provisions relating to efficient artificial light source and luminaires have been updated.
e) Modern lighting techniques such as LED and induction light have been included *vis-à-vis* their energy consumption.
f) Provisions relating to photocontrols for artificial lights have been updated.
g) Definitions and enabling provision for lighting shelves and light pipes have been included.
h) Provisions related to thermal comfort clause have been elaborated including therein indices such as effective temperature, adaptive thermal comfort along with elaborations on tropical summer index.
j) Design guidelines for natural ventilation have been elaborated with illustrations.
k) Provisions related to determination of rate of ventilation, particularly on combined effect of wind and thermal actions, have been elaborated.

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m) Provision on colour rendering has been included in line with that in SP 72 : 2010 'National Lighting Code 2010'.

n) Various other existing provisions have been updated based on the latest technical developments in the field.

The provisions of this Section are without prejudice to the various acts, rules and regulations including the *Factories Act*, 1948 and rules and regulations framed thereunder.

The information contained in this Section is largely based on the following Indian Standards/Special Publications:

IS 2440 : 1975	Guide for daylighting of buildings (*second revision*)
IS 3103 : 1975	Code of practice for industrial ventilation (*first revision*)
IS 3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)
IS 3646 (Part 1) : 1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for working interiors (*first revision*)
IS 7662 (Part 1) : 1974	Recommendations for orientation of buildings : Part 1 Non-industrial buildings
IS 11907 : 1986	Recommendations for calculation of solar radiation on buildings
SP 32 : 1986	Handbook on functional requirements of industrial buildings (lighting and ventilation)
SP 41 : 1987	Handbook on functional requirements of buildings other than industrial buildings

Provisions given in National Lighting Code, 'SP 72 : 2010' may also be referred.

The following publication has also been referred to in the formulation of this Section:

Report on energy conservation in buildings, submitted to Department of Power, Ministry of Energy by CSIR-Central Building Research Institute, Roorkee.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 1 Lighting and Natural Ventilation

1 SCOPE

1.1 This Code (Part 8/Section 1) covers requirements and methods for lighting and natural ventilation of buildings.

1.2 The provisions in respect of lighting and ventilation in sustainable buildings are covered in Part 11 'Approach to Sustainability' of the Code which shall be used in conjunction with this Section.

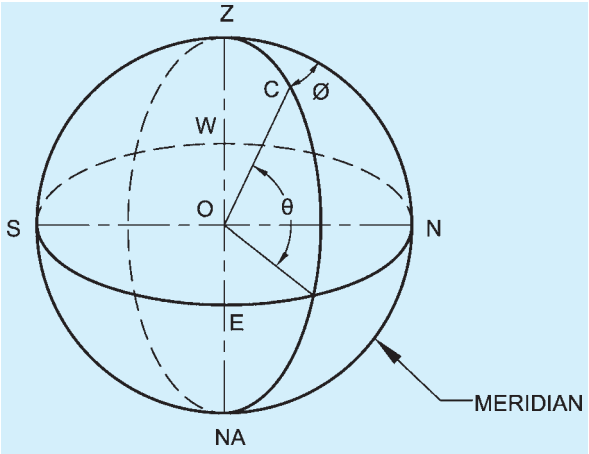
1.3 For all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, adequate lighting and ventilation for barrier free access and movement within and around buildings by elderly and persons with disabilities shall be ensured in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

2 TERMINOLOGY

For the purpose of this Section, the definitions given below shall apply.

2.1 Lighting

2.1.1 *Altitude* (θ) — The angular distance of any point of celestial sphere, measured from the horizon, on the great circle passing through the body and the zenith (*see* Fig. 1).



REFERENCES

O	– Observer's station	*S*	– Geographical south
C	– Celestial body	*E*	– Geographical east
Z	– Zenith	*W*	– Geographical west
NA	– Nadir	*N*	– Geographical north

FIG. 1 ALTITUDE AND AZIMUTH OF A CELESTIAL BODY

2.1.2 *Azimuth* (Φ) — The angle measured between meridians passing through the north point and the point in question (point C in Fig. 1).

2.1.3 *Brightness Ratio or Contrast* — The variations or contrast in brightness of the details of a visual task, such as white print on blackboard.

2.1.4 *Candela* (cd) — The SI unit of luminous intensity.

Candela = 1 lumen per steradian

2.1.5 *Central Field* — The area of circle around the point of fixation and its diameter, subtending an angle of about 2° at the eye. Objects within this area are most critically seen in both their details and colour.

2.1.6 *Clear Design Sky* — The distribution of luminance of such a sky is non-uniform; the horizon is brighter than the zenith, and when L_z is the brightness at zenith, the brightness at an altitude (θ) in the region away from the sun, is given by the expression:

$$L_\theta = L_z \operatorname{cosec} \theta \text{ (for } 15° < \theta \leq 90°)$$

$$L_\theta = L_z \operatorname{cosec} 15° \text{ (for } 0° \leq \theta \leq 15°) = 3.863\ 7\ L_z$$

2.1.7 *Colour Rendering Index (CRI)* — Measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation.

2.1.8 *Correlated Colour Temperature (CCT)* (K) — The temperature of the Planckian radiator whose perceived colour most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions.

2.1.9 *Daylight Area* — The superficial area on the working plane illuminated to not less than a specified daylight factor, that is, the area within the relevant contour.

2.1.10 *Daylight Factor* — The measure of total daylight illuminance at a point on a given plane expressed as the ratio (or percentage) which the illuminance at the point on the given plane bears to the simultaneous illuminance on a horizontal plane due to clear design sky at an exterior point open to the whole sky vault, direct sunlight being excluded.

2.1.11 *Daylight Penetration* — The maximum distance to which a given daylight factor contour penetrates into a room.

2.1.12 *Direct Solar Illuminance* — The illuminance from the sun without taking into account the light from the sky.

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2.1.13 *External Reflected Component (ERC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received by direct reflection from external surfaces as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

2.1.14 *Glare* — A condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution or range of luminance or due to extreme contrasts in space and time.

2.1.15 *Illuminance* — At a point on a surface, the ratio of the luminous flux incident on an infinitesimal element of the surface containing the point under consideration to the area of the element.

NOTE — The unit of illuminance (the measurement of illumination) is lux which is 1 lumen per m^2.

2.1.16 *Internal Reflected Component (IRC)* — The ratio (or percentage) of that part of the daylight illuminance at a point in a given plane which is received by direct reflection or inter-reflection from the internal surfaces as compared to the simultaneous exterior illuminance on a horizontal plane due to the entire hemisphere of an unobstructed clear design sky.

2.1.17 *Light Output Ratio (LOR) or Efficiency* (η) — The ratio of the luminous flux emitted from the luminaire to that emitted from the lamp(s) (nominal luminous flux). It is expressed in percent.

2.1.18 *Light Pipe* — A conduit made of a highly reflective material, which is capable of channeling light from one end to the other through successive internal reflections. Such a pipe may be flexible or rigid.

2.1.19 *Light Shelf* — A daylighting system based on sun path geometry used to bounce the light off a ceiling, project it deeper into a space, distribute it from above, and diffuse it to produce a uniform light level below.

2.1.20 *Lumen* (lm) — SI unit of luminous flux. The luminous flux emitted within unit solid angle (one steradian) by a point source having a uniform intensity of one candela.

2.1.21 *Luminance* (*At a point of a Surface in a Given Direction*) (*Brightness*) — The quotient of the luminous intensity in the given direction of an infinitesimal element of the surface containing the point under consideration by the orthogonally projected area of the element on a plane perpendicular to the given direction. The unit is candela per square metre (cd/m^2).

2.1.22 *Luminous Flux* (ϕ) — The quantity characteristic of radiant flux which expresses its capacity to produce visual sensation evaluated according to the values of relative luminous efficiency for the light adapted eye:

a) *Effective Luminous Flux* (ϕ_n) — Total luminous flux which reaches the working plane.

b) *Nominal Luminous Flux* (ϕ_o) — Total luminous flux of the light sources in the interior.

2.1.23 *Maintenance Factor* (*d*) — The ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the average illuminance obtained under the same conditions for a new installation.

2.1.24 *Meridian* — It is the great circle passing through the zenith and nadir for a given point of observation.

2.1.25 *North and South Points* — The point in the respective directions where the meridian cuts the horizon.

2.1.26 *Orientation of Buildings* — In the case of non-square buildings, orientation refers to the direction of the normal to the long axis. For example, if the length of the building is east-west, its orientation is north-south.

2.1.27 *Peripheral Field* — It is the rest of the visual field which enables the observer to be aware of the spatial framework surrounding the object seen.

NOTE — A central part of the peripheral field, subtending an angle of about 30° on either side of the point of fixation, is chiefly involved in the perception of glare.

2.1.28 *Reflected Glare* — The variety of ill effects on visual efficiency and comfort produced by unwanted reflections in and around the task area.

2.1.29 *Reflection Factor (Reflectance)* — The ratio of the luminous flux reflected by a body (with or without diffusion) to the flux it receives. Some symbols used for reflection factor are:

r_c = reflection factor of ceiling.

r_w = reflection factor of parts of the wall between the working surface and the luminaires.

r_f = reflection factor of floor.

2.1.30 *Reveal* — The side of an opening for a window.

2.1.31 *Room Index* (k_r) — An index relating to the shape of a rectangular interior, according to the formula:

$$k_r = \frac{LW}{(L+W)H_m}$$

where *L* and *W* are the length and width respectively of the interior, and H_m is the mounting height, that is, height of the fittings above the working plane.

NOTES

1 For rooms where the length exceeds 5 times the width, *L* shall be taken as $L = 5W$.

2 If the reflection factor of the upper stretch of the walls is less than half the reflection factor of the ceiling, for indirect or for the greater part of indirect lighting, the value H_m is measured between the ceiling and the working plane.

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2.1.32 *Sky Component (SC)* — The ratio (or percentage) of that part of the daylight illuminance at a point on a given plane which is received directly from the sky as compared to the simultaneous exterior illuminance on a horizontal plane from the entire hemisphere of an unobstructed clear design sky.

2.1.33 *Solar Load* — The amount of heat received into a building due to solar radiation which is affected by orientation, materials of construction and reflection of external finishes and colour.

2.1.34 *Utilization Factor (Coefficient of Utilization) (μ)* — The ratio of the total luminous flux which reaches the working plane (effective luminous flux, ϕ_n) to the total luminous flux of the light sources in the interior (nominal luminous flux, ϕ_o).

2.1.35 *Visual Field* — The visual field in the binocular which includes an area approximately 120° vertically and 160° horizontally centering on the point to which the eyes are directed. The line joining the point of fixation and the centre of the pupil of each eye is called its primary line of sight.

2.1.36 *Working Plane* — A horizontal plane at a level at which work will normally be done (*see* **4.1.4.3** and **4.1.4.4**).

2.2 Ventilation

2.2.1 *Air Change per Hour* — The amount of air leakage into or out of a building or room in terms of the number of times the building volume or room volume exchanged.

2.2.2 *Axial Flow Fan* — A fan having a casing in which the air enters and leaves the impeller in a direction substantially parallel to its axis.

2.2.3 *Centrifugal Fan* — A fan in which the air leaves the impeller in a direction substantially at right angles to its axis.

2.2.4 *Contaminants* — Dusts, fumes, gases, mists, vapours and such other substances present in air that are likely to be injurious or offensive to the occupants.

2.2.5 *Dilution Ventilation* — Supply of outside air to reduce the airborne concentration of contaminants in the building.

2.2.6 *Dry Bulb Temperature* — The temperature of the air, read on a thermometer, taken in such a way so as to avoid errors due to radiation.

2.2.7 *Effective Temperature (ET)* — An arbitrary index which combines into a single value the effect of temperature, humidity and air movement on the sensation of warmth or cold felt by the human body and its numerical value is that of the temperature of still saturated air which would induce an identical sensation.

2.2.8 *Exhaust of Air* — Removal of air from a building or a room and its disposal outside by means of a mechanical device, such as a fan.

2.2.9 *Fresh Air or Outside Air* — Air of that quality, which meets the criteria of Table 1 and in addition shall be such that the concentration of any contaminant in the air is limited to within one-tenth the threshold limit value (TLV) of that contaminant.

NOTES

1 Where it is reasonably believed that the air of quality is not expected as indicated above, sampling and analysis shall be carried out by a competent authority having jurisdiction and if the outside air of the specified quality is not available, filtration and other treatment devices shall be used to bring its quality to or above the levels mentioned in Table 1.

Odour is to be essentially unobjectionable.

2 The above list of contaminants is not exhaustive and available special literature may be referred for data on other contaminants.

Table 1 Maximum Allowable Contaminant Concentrations for Ventilation Air

(*Clause* 2.2.9)

Sl No.	Contaminants	Annual Average (Arithmetic Mean)	Short Term Level (Not to Exceed More than Once a Year)	Averaging Period
		$\mu g/m^3$	$\mu g/m^3$	h
(1)	(2)	(3)	(4)	(2)
i)	Suspended particulates	60	150	24
ii)	Sulphur oxides	80	400	24
iii)	Carbon monoxide	20 000	30 000	8
iv)	Photochemical oxidant	100	500	1
v)	Hydrocarbons (not including methanes)	1 800	4 000	3
vi)	Nitrogen oxide	200	500	24

2.2.10 *General Ventilation* — Ventilation, either natural or mechanical or both, so as to improve the general environment of the building, as opposed to local exhaust ventilation for contamination control.

2.2.11 *Globe Temperature* — The temperature measured by a thermometer whose bulb is enclosed in a matt black painted thin copper globe of 150 mm diameter. It combines the influence of air temperature and thermal radiations received or emitted by the bounding surfaces.

2.2.12 *Humidification* — The process whereby the absolute humidity of the air in a building is maintained at a higher level than that of outside air or at a level higher than that which would prevail naturally.

2.2.13 *Humidity, Absolute* — The mass of water vapour per unit volume.

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2.2.14 *Humidity, Relative* — The ratio of the partial pressure or density of the water vapour in the air to the saturated pressure or density, respectively of water vapour at the same temperature.

2.2.15 *Local Exhaust Ventilation* — Ventilation effected by exhaust of air through an exhaust appliance, such as a hood with or without fan located as closely as possible to the point at which contaminants are released, so as to capture effectively the contaminants and convey them through ducts to a safe point of discharge.

2.2.16 *Make-Up Air* — Outside air supplied into a building to replace the indoor air.

2.2.17 *Mechanical Ventilation* — Supply of outside air either by positive ventilation or by infiltration by reduction of pressure inside due to exhaust of air, or by a combination of positive ventilation and exhaust of air.

2.2.18 *Natural Ventilation* — Supply of outside air into a building through window or other openings due to wind outside and convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building.

2.2.19 *Positive Ventilation* — The supply of outside air by means of a mechanical device, such as a fan.

2.2.20 *Propeller Fan* — A fan in which the air leaves the impeller in a direction substantially parallel to its axis designed to operate normally under free inlet and outlet conditions.

2.2.21 *Spray-Head System* — A system of atomizing water so as to introduce free moisture directly into a building.

2.2.22 *Stack Effect* — Convection effect arising from temperature or vapour pressure difference (or both) between outside and inside of the room and the difference of height between the outlet and inlet openings.

2.2.23 *Tropical Summer Index (TSI)* — The temperature of calm air at 50 percent relative humidity which imparts the same thermal sensation as the given environment.

2.2.24 *Threshold Limit Value (TLV)* — Refers to airborne concentration of contaminants currently accepted by the American Conference of Governmental Industrial Hygienists and represents conditions under which it is believed that nearly all occupants may be repeatedly exposed, day after day, without adverse effect.

2.2.25 *Velocity, Capture* — Air velocity at any point in front of the exhaust hood necessary to overcome opposing air currents and to capture the contaminants in air at that point by causing the air to flow into the exhaust hood.

2.2.26 *Ventilation* — Supply of outside air into, or the removal of inside air from an enclosed space.

2.2.27 *Wet Bulb Temperature* — The steady temperature finally given by a thermometer having its bulb covered with gauze or muslin moistened with distilled water and placed in an air stream of not less than 4.5 m/s.

3 ORIENTATION OF BUILDING

3.1 The chief aim of orientation of buildings is to provide physically and psychologically comfortable living inside the building by creating conditions which suitably and successfully ward off the undesirable effects of severe weather to a considerable extent by judicious use of the recommendations and knowledge of climatic factors.

3.2 Basic Zones

3.2.1 For the purpose of design of buildings, the country may be divided into the major climatic zones as given in Table 2, which also gives the basis of this classification.

Table 2 Classification of Climate

(*Clause* 3.2.1)

Sl No.	Climatic Zone	Mean Monthly Maximum Temperature °C	Mean Monthly Relative Humidity Percent
(1)	(2)	(3)	(4)
i)	Hot-dry	Above 30	Below 55
ii)	Warm-humid	Above 30	Above 55
		Above 25	Above 75
iii)	Temperate	25-30	Below 75
iv)	Cold	Below 25	All values
v)	Composite	*see* **3.2.2**	

The climatic classification map of India is shown in Fig. 2.

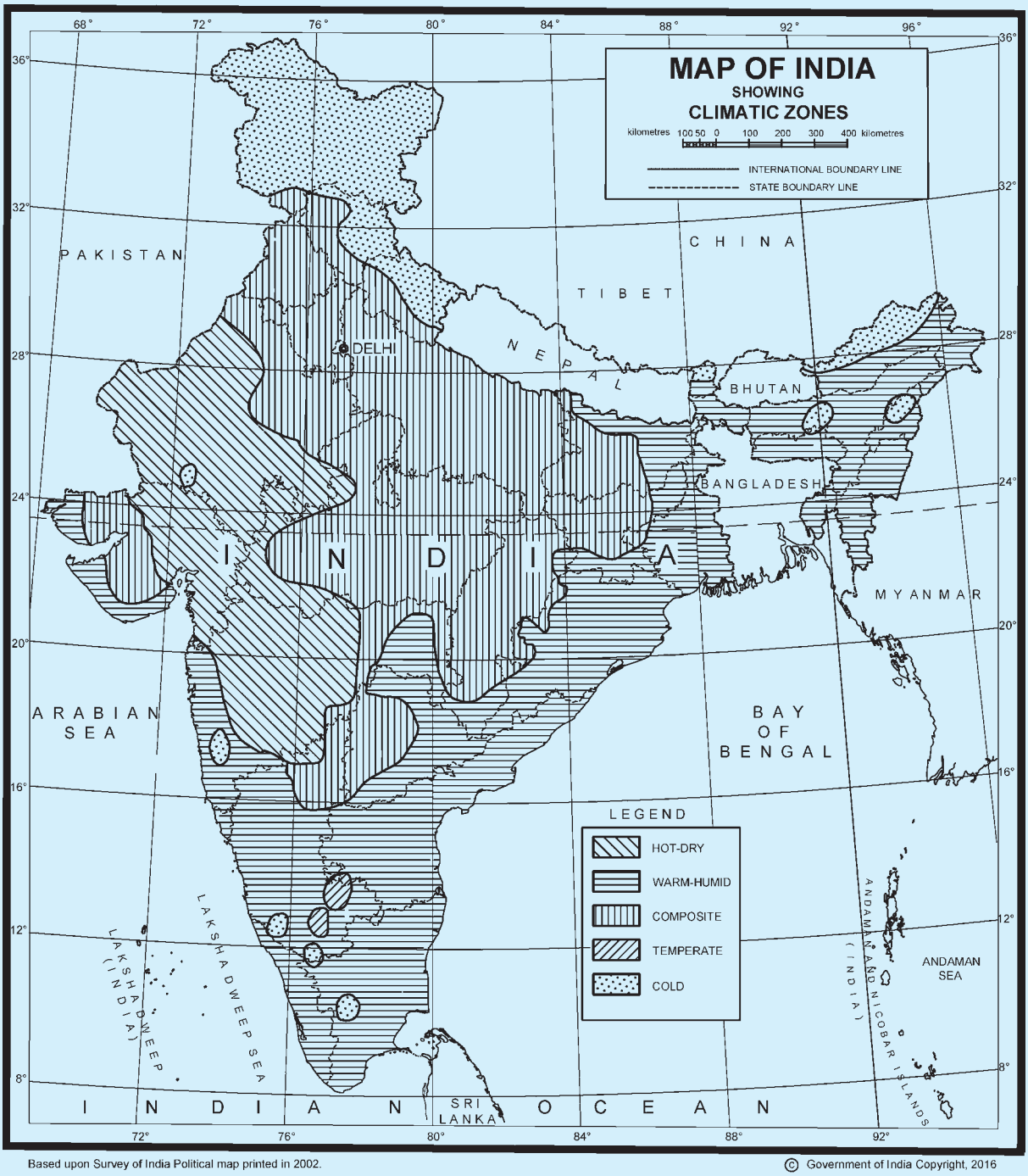
3.2.2 Each climatic zone does not have same climate for the whole year; it has a particular season for more than six months and may experience other seasons for the remaining period. A climatic zone that does not have any season for more than six months may be called as composite zone.

3.3 Climatic Factors

From the point of view of lighting and natural ventilation, the following climatic factors influence the optimum orientation of the building:

a) Solar radiation and temperature,
b) Relative humidity, and
c) Prevailing winds.

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Based upon Survey of India Political map printed in 2002.

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

The responsibility for the correctness of internal details rest with the publisher.

FIG. 2 CLIMATIC ZONES OF INDIA

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3.4 Solar Radiation

3.4.1 The best orientation from solar point of view requires that the building as a whole should receive the maximum solar radiation in winter and the minimum in summer. For practical evaluation, it is necessary to know the duration of sunshine, and hourly solar intensity on the various external surfaces on representative days of the seasons. The total direct plus diffused diurnal solar loads per unit area on vertical surface facing different directions are given in Table 3 for two days in the year, that is, 22 June and 22 December, representative of summer and winter, for latitudes corresponding to some important cities all over India. From Table 3, the total heat intake can be calculated for all possible orientations of the building for these extreme days of summer and winter. Solar load on vertical surfaces of different orientation can be calculated as per the method given in Annex A.

3.4.1.1 Except in cold climatic zone, suitable sun-breakers have to be provided to cut off the incursion of direct sunlight to prevent heat radiation and to avoid glare.

3.5 Relative Humidity and Prevailing Winds

3.5.1 The discomfort due to high relative humidity in air when temperatures are also high can be counteracted, to a great extent, by circulation of air with electric fans or by ventilation. In the past, simultaneously with heavy construction and surrounding *Verandahs* to counter the effect of sun's radiation, there was also an over emphasis on prevailing winds to minimise the adverse effects of high humidity with high temperatures. With the introduction of electric fan to effectively circulate air and owing to taking into account the rise in cost of construction of buildings, emphasis should be placed on protection from solar radiation where temperatures are very high. When, however, there is less diurnal variation between morning and mean maximum temperatures along with high humidity, as in coastal areas, the emphasis should be on prevailing winds.

3.5.1.1 For the purpose of orientation, it is necessary to study the velocity and direction of the wind at each hour and in each month instead of relying on generalizations of a month or a period or for the year as a whole. This helps to spot the right winds for a particular period of day or night.

3.5.1.2 It is generally found that variation up to 30° with respect to the prevalent wind direction does not materially affect indoor ventilation (average indoor air speed) inside the building.

3.5.2 In hot-dry climate, advantage can be taken of evaporative cooling in summer to cool the air before introducing it into the building. But in warm humid climate, it is desirable either to regulate the rate of air movement with the aid of electric fans or to take advantage of prevailing winds.

3.6 Aspects of Daylighting

Since the clear design sky concept for daylighting takes care of the worst possible situation, orientation is not a major problem for daylighting in buildings, except that

Table 3 Total Solar Radiation (Direct Plus Diffused) Incident on Various Surfaces of Buildings, in W/m^2/day, for Summer and for Winter Seasons

(*Clause* 3.4.1)

Sl No.	Orientation		Latitude					
			9°N	13°N	17°N	21°N	25°N	29°N
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	North	Summer	1 494	1 251	2 102	1 775	2 173	1 927
		Winter	873	859	840	825	802	765
ii)	North-East	Summer	2 836	2 717	3 144	3 092	3 294	3 189
		Winter	1 240	1 158	1 068	1 001	912	835
iii)	East	Summer	3 344	3 361	3 475	3 598	3 703	3 794
		Winter	2 800	2 673	2 525	2 409	2 211	2 055
iv)	South-East	Summer	2 492	2 660	2 393	2 629	2 586	2 735
		Winter	3 936	3 980	3 980	3 995	3 892	3 818
v)	South	Summer	1 009	1 185	1 035	1 117	1 112	1 350
		Winter	4 674	4 847	4 958	5 059	4 942	4 981
vi)	South-West	Summer	2 492	2 660	2 393	2 629	2 586	2 735
		Winter	3 936	3 980	3 980	3 995	3 892	3 818
vii)	West	Summer	3 341	3 361	3 475	3 598	3 703	3 794
		Winter	2 800	2 673	2 525	2 409	2 211	2 055
viii)	North-West	Summer	2 836	2 717	3 144	3 092	3 294	3 189
		Winter	1 240	1 158	1 068	1 001	912	835
ix)	Horizontal	Summer	8 107	8 139	8 379	8 553	8 817	8 863
		Winter	6 409	6 040	5 615	5 231	4 748	4 281

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direct sunshine and glare should be avoided. However, due allowance should be given to the mutual shading effects of opposite facades.

3.7 Planting of Trees

Planting of trees in streets and in open spaces should be done carefully to take advantage of both shades and sunshine without handicapping the flow of natural winds. Their advantage in abating glare and in providing cool and/or warm pockets in developed areas should also be taken. Some trees shed leaves in winter while retaining thick foliage in summer. Such trees will be very advantageous, particularly where southern and western exposures are concerned, by allowing maximum sun during winter and effectively blocking it in summer.

3.8 For detailed information regarding orientation of buildings and recommendations for various climatic zones of country, reference may be made to good practice [8-1(1)].

4 LIGHTING

4.1 Principles of Lighting

4.1.1 *Aims of Good Lighting*

Good lighting is necessary for all buildings and has three primary aims. The first aim is to promote work and other activities carried out within the building; the second aim is to promote the safety of the people using the building; and the third aim is to create, in conjunction with the structure and decoration, a pleasing environment conducive to interest of the occupants and a sense of their well-being.

4.1.1.1 Realization of these aims involves the following:

a) Careful planning of the brightness and colour pattern within both the working areas and the surroundings so that attention is drawn naturally to the important areas, detail is seen quickly and accurately and the room is free from any sense of gloom or monotony (*see* **4.1.4**);

b) Using directional lighting, where appropriate, to assist perception of task detail and to give good modeling;

c) Controlling direct and reflected glare from light sources to eliminate visual discomfort;

d) In artificial lighting installations, minimizing flicker from certain types of lamps and paying attention to the colour rendering properties of the light;

e) Correlating lighting throughout the building to prevent excessive differences between adjacent areas so as to reduce the risk of accidents; and

f) Installing emergency lighting systems, where necessary.

4.1.2 *Planning the Brightness Pattern*

The brightness pattern seen within an interior may be considered as composed of three main parts — the task itself, immediate background of the task and the general surroundings of walls, ceiling, floor, equipment and furnishings.

4.1.2.1 In occupations where the visual demands are small, the levels of illumination derived from a criterion of visual performance alone may be too low to satisfy the other requirements. For such situations, therefore, illuminance recommendations are based on standards of welfare, safety and amenity judged appropriate to the occupations; they are also sufficient to give these tasks brightness which ensured that the visual performance exceeds the specified minimum. Unless there are special circumstances associated with the occupation, it is recommended that the illuminance of all working areas within a building should generally be 150 lux.

4.1.2.2 Where work takes place over the whole utilizable area of room, the illumination over that area should be reasonably uniform and it is recommended that the uniformity ratio (minimum illuminance divided by average illuminance levels) should be not less than 0.7 for the working area.

4.1.2.3 When the task brightness appropriate to an occupation has been determined, the brightness of the other parts of the room should be planned to give a proper emphasis to visual comfort and interest.

A general guide for the brightness relationship within the normal field of vision should be as follows:

a) For high task brightness (above 100 cd/m^2): Maximum

   1) Between the visual task and the adjacent areas like table tops — 3:1
   2) Between the visual task and the remote areas of the room — 10:1

b) For low and medium task brightness (below 100 cd/m^2): The task should be brighter than both the background and the surroundings; the lower the task brightness, the less critical is the relationship.

4.1.2.4 In case of all buildings and facilities open to and used by the public including all forms of public housing by the government/civic bodies and private developers, the requirements for visual contrast as given in **13** and Annex B of Part 3 'Development Control and Rules and General Building Requirements' of the Code shall also be complied with for ensuring visual comfort for elders and persons with disabilities.

4.1.3 *Glare*

Excessive contrast or abrupt and large changes in

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brightness produce the effect of glare. When glare is present, the efficiency of vision is reduced and small details or subtle changes in scene cannot be perceived. It may be,

a) direct glare due to light sources within the field of vision;
b) reflected glare due to reflections from light sources or surfaces of excessive brightness; and
c) veiling glare where the peripheral field is comparatively very bright.

4.1.3.1 An example of glare sources in daylighting is the view of the bright sky through a window or skylight, especially when the surrounding wall or ceiling is comparatively dark or weakly illuminated. Glare can be minimised in this case either by shielding the open sky from direct sight by louvers, external hoods or deep reveals, curtains or other shading devices or by cross lighting the surroundings to a comparable level. A gradual transition of brightness from one portion to the other within the field of vision always avoids or minimises the discomfort from glare.

For electric lamps the minimum shielding angles for lamp luminance shall not be less than the values given in the table below:

Lamp Luminance kcd/m^2	*Minimum Shielding Angle* Degree
1 to 20	10
20 to 50	15
50 to 500	20
≥ 500	30

The above mentioned shielding angle should not be applied to luminaires that do not appear in the field of view of a worker during usual work and/or do not give the worker any noticeable disability glare.

Table 4 also gives recommended value of quality class of direct glare limitation for different tasks. These are numbers assigned to qualitative limits of direct glare: high, medium and low quality as 1, 2 and 3, respectively. For more details reference may be made to good practice [8–1(2)].

4.1.4 *Recommended Values of Illuminance*

Table 4 gives recommended values of illuminance commensurate with the general standards of lighting described in this Section and related to many occupations and buildings. These are valid under most of the conditions whether the illumination is by daylighting, artificial lighting or a combination of the two. The great variety of visual tasks makes it impossible to list them all and those given should be regarded as representing types of task.

4.1.4.1 The different locations and tasks are grouped within the following four sections:

a) Industrial buildings and process;
b) Offices, schools and public buildings;
c) Surgeries and hospitals; and
d) Hotels, restaurants, shops and homes.

4.1.4.2 The illumination levels recommended in Table 4 are those to be maintained at all time on the task. As circumstances may be significantly different for different interiors used for the same application or for different conditions for the same kind of activity, a range of illuminances is recommended for each type of interior or activity instead of a single value of illuminance. Each range consists of three successive steps of the recommended scale of illuminances. They represent good practice and should be regarded as giving order of illumination commonly required rather than as having some absolute significance. For working interiors the middle value of each range represents the recommended service illuminance that would be used unless one or more of the factors mentioned below apply.

4.1.4.2.1 The higher value of the range should be used when,

a) unusually low reflectances or contrasts are present in the task;
b) errors are costly to rectify;
c) visual work is critical;
d) accuracy or higher productivity is of great importance; and
e) visual capacity of the worker makes it necessary.

4.1.4.2.2 The lower value of the range may be used when,

a) reflectances or contrast are unusually high;
b) speed and accuracy is not important; and
c) the task is executed only occasionally.

4.1.4.3 Where a visual task is required to be carried out throughout an interior, general illumination level to the recommended value on the working plane is necessary; where the precise height and location of the task are not known or cannot be easily specified, the recommended value is that on horizontal plane 850 mm above floor level.

NOTE — For an industrial task, working plane for the purpose of general illumination levels is that on a work place which is generally 750 mm above the floor level. For certain purposes, such as viewing the objects of arts, the illumination levels recommended are for the vertical plane at which the art pieces are placed.

4.1.4.4 Where the task is localized, the recommended value is that for the task only; it need not, and sometimes should not, be the general level of illumination used

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throughout the interior. Some processes, such as industrial inspection process, call for lighting of specialized design, in which case the level of illumination is only one of the several factors to be taken into account.

4.1.4.5 In case of all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, the minimum luminance level as given in **13** and Annex B of Part 3 'Development Control Rules and General Building Requirements' of the Code shall also be complied with for ensuring sufficient lighting for accessibility by elders and persons with disabilities.

4.1.5 *Lighting for Movement About a Building*

Most buildings are complexes of working areas and other areas, such as passages, corridors, stairways, lobbies and entrances. The lighting of all these areas shall be properly correlated to give safe movement within the building at all times.

In case of all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, the illuminance in these areas shall comply with requirements given in **13** and Annex B of Part 3 'Development Control Rules and General Building Requirements' of the Code.

4.1.5.1 *Corridors, passages and stairways*

Accidents may result if people leave a well-lighted working area and pass immediately into corridors or on to stairways where the lighting is inadequate, as the time needed for adaptation to the lower level may be too long to permit obstacles or the treads of stairs to be seen sufficiently quickly. For the same reason, it is desirable that the illumination level of rooms which open off a working area should be fairly high even though the rooms may be used only occasionally.

It is important, when lighting stairways, to prevent disability from glare caused by direct sight of bright sources to emphasize the edges of the treads and to avoid confusing shadows. The same precautions should be taken in the lighting of catwalks and stairways on outdoor industrial plants.

4.1.5.2 *Entrances*

The problems of correctly grading the lighting within a building to allow adequate time for adaptation when passing from one area to another area are particularly acute at building entrances. These are given below:

a) By day, people entering a building will be adapted to the very high levels of brightness usually present outdoors and there is risk of accident if entrance areas, particularly any steps, are poorly lighted. This problem may often be overcome by arranging windows to give adequate natural lighting at the immediate entrance, grading to lower levels further inside the entrance area. Where this cannot be done, supplementary artificial lighting should be installed to raise the level of illumination to an appropriate value.

b) At night it is desirable to light entrance halls and lobbies so that the illumination level reduces towards the exit and so that no bright fittings are in the line of sight of people leaving the building. Any entrance steps to the building should be well-lighted by correctly screened fittings.

4.1.6 *Colour Rendering*

The colour appearance of light and its colour rendering capability are different aspects of the light sources. A faithful reproduction of an object colour depends on the colour rendering capability of the light source. In 1965 International Commission on Illumination (CIE) developed a quantitative method of assignment of colour rendering property, and is denoted as Colour Rendering Index (CRI).

CRI is arrived at by a test by which a number of specified samples are tested under a standard or reference light source and the chromaticity coordinate are plotted on the IE triangle as given in Fig. 7 of Part 2 'Physics of Light, Section 3 Colour' of National Lighting Code 2010. The same test is repeated under the source under test and corresponding chromaticity coordinate are plotted on the same plot. The difference between the position of each sample for test and standard source is measured to scale. The general colour rendering index (Ra) is obtained by the average value for eight samples (*see* Fig. 8 of Part 2 'Physics of Light, Section 3 Colour' of National Lighting Code 2010). For perfect agreement of colour, the R1 value should be 100. In general:

$$Ra = 1/ (R1 + R2 + R3 + R4 + ...+ R8)$$

The specific colour rendering index for an individual sample is given by:

$$Ri = 100 – 4.6\Delta Ei$$

where

ΔEi = chromaticity shift on the CIE chromaticity diagram for each sample.

From the obtained value of Ra, as calculated above, the colour rendering shall be evaluated as mentioned in the following table:

Colour Rendering Evaluated	*Ra (General Colour Rendering Index)*
True	90 - 100
Good	70 - 90
Moderate	50 - 70

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Table 4 Recommended Values of Illuminance
(*Clauses* 4.1.3.1, 4.1.4, 4.1.4.2, 4.3.2 *and* 4.3.2.1)

Sl No.	Type of Interior or Activity	Range of Service Illuminance (*See* Note) lux	Quality Class of Direct Glare Limitation (*See* Note)	Remarks
(1)	(2)	(3)	(4)	(5)
1	**AGRICULTURE AND HORTICULTURE**			
1.1	Inspection of Farm Produce where Colour is Important	300-500-750	1	Local lighting may be appropriate
	Other Important Tasks	200-300-500	2	Local lighting may be appropriate
1.2	Farm Workshops			
1.2.1	General	50-100-150	3	
1.2.2	Workbench or machine	200-300-500	2	Local or portable lighting may be appropriate
1.3	Milk Premises	50-100-150	3	
1.4	Sick Animal Pets, Calf Nurseries	30-50-100	3	
1.5	Other Firm and Horticultural Buildings	20-30-50	3	
2	**COAL MINING (SURFACE BUILDINGS)**			
2.1	Coal Preparation Plant			
2.1.1	Walkways, floors under conveyors	30-50-100	3	
2.1.2	Wagon loading, bunkers	30-50-100	3	
2.1.3	Elevators, chute transfer pits, wash box area	50-100-150	3	
2.1.4	Drum filters, screen, rotating shafts	100-150-200	3	
2.1.5	Picking belts	150-200-300	3	Directional and colour properties of lighting may be important for easy recognition of coal and rock
2.2	Lamp Rooms			
2.2.1	Repair section	200-300-500	2	
2.2.2	Other areas	100-150-200	3	
2.3	Weight Cabins, Fan Houses	100-150-200	3	
2.4	Winding Houses	100-150-200	3	
3	**ELECTRICITY GENERATION, TRANSMISSION AND DISTRIBUTION**			
3.1	General Plant			
3.1.1	Turbine houses (operating floor)	150-200-300	2	
3.1.2	Boiler and turbine house basements	50-100-150	3	
3.1.3	Boiler houses, platforms, areas around burners	50-100-150	3	
3.1.4	Switch rooms, meter rooms, oil plant rooms, HV substations (indoor)	100-150-200	2	
3.1.5	Control rooms	200-300-500	1	Localized lighting of control display and the control desks may be appropriate
3.1.6	Relay and telecommunication rooms	200-300-500	2	
3.1.7	Diesel generator rooms, compressor rooms	100-150-200	3	
3.1.8	Pump houses, water treatment plant houses	100-150-200	3	
3.1.9	Battery rooms, chargers, rectifiers	50-100-150	3	
3.1.10	Precipitator chambers, platforms, etc	50-100-150	3	
3.1.11	Cable tunnels and basements, circulating water culverts and screen chambers, storage tanks (indoor), operating areas and filling points at outdoor tanks	30-50-100	3	
3.2	Coal Plant			
3.2.1	Conveyors, gantries, junction towers, unloading hoppers, ash handling plants, settling pits, dust hoppers outlets	50-100-150	3	
3.2.2	Other areas where operators may be in attendance	100-150-200	3	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
3.3	Nuclear Plants			
	Gas Circulation Bays, Reactor Area, Boiler Platform, Reactor Charges and Discharge Face	100-150-200	2	
4	**METAL MANUFACTURE**			
4.1	Iron Making			
4.1.1	Sinter plant:			
	Plant floor	150-200-300	3	
	Mixer drum, fan house, screen houses, coolers, transfer stations	100-150-200	3	
4.1.2	Furnaces, cupola:			
	General	100-150-200	3	
	Control platforms	200-300-500	2	Local lighting may be appropriate
	Conveyor galleries, walkways	30-50-100	3	
4.2	Steel Making			
4.2.1	Electric melting shops	150-200-300	3	
4.2.2	Basic oxygen steel making plants			
4.2.2.1	General	100-150-200	3	
4.2.2.2	Convertor floor, teeming bay	150-200-300	3	
4.2.2.3	Control platforms	200-300-500	2	Local lighting may be appropriate
4.2.2.4	Scrap bays	100-150-200	3	
4.3	Metal Forming and Treatment			
4.3.1	Ingot stripping, soaking pits, annealing and heat treatment bays, acid recovery plant Picking and cleaning bays, roughing mills, cold mills, finishing mills, tinning and galvanizing lines, cut up and rewind lines	150-200-300	3	
4.3.2	General	100-150-200	3	
4.3.3	Control platforms	200-300-500	2	Local lighting may be appropriate
4.3.4	Wire mills, product finishing, steel inspection and treatment	200-300-500	3	
4.3.5	Plate/strip inspection	300-500-700	2	
4.3.6	Inspection of tin plate, stainless steel, etc	–	–	Special lighting to reveal faults in the specular surface of the material will be required
4.4	Foundries			
4.4.1	Automatic plant			
4.4.1.1	Without manual operation	30-50-100	3	
4.4.1.2	With occasional manual operation	100-150-200	3	
4.4.1.3	With continuous manual operation	150-200-300	3	
4.4.1.4	Control room	200-300-500	1	Localized lighting of the control display and the control desks may be appropriate
4.4.1.5	Control platforms	200-300-500	2	
4.4.2	Non-automatic plants			
4.4.2.1	Charging floor, pouring, shaking out, cleaning, grinding fettling	200-300-500	3	
4.4.2.2	Rough moulding, rough core making	200-300-500	3	
4.4.2.3	Fine moulding, fine core making	300-500-750	2	
4.4.2.4	Inspection	300-500-750	2	
4.5	Forges (Severe vibration is likely to occur)			
4.5.1	General	200-300-500	2	
4.5.2	Inspection	300-500-750	2	
5	**CERAMICS**			
5.1	Concrete Products			
	Mixing, Casting, Cleaning	150-200-300	3	
5.2	Potteries			
5.2.1	Grinding, moulding, pressing, cleaning, trimming, glazing, firing	200-300-500	3	
5.2.2	Enamelling, colouring	500-750-1 000	1	
5.3	Glass Works			
5.3.1	Furnace rooms, bending, annealing	100-150-200	3	
5.3.2	Mixing rooms, forming, cutting, grinding, polishing, toughening	200-300-500	3	
5.3.3	Beveling, decorative cutting, etching, silvering	300-500-750	2	
5.3.4	Inspection	300-500-750	2	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
6	**CHEMICALS**			
6.1	Petroleum, Chemical and Petrochemical Works			
6.1.1	Exterior walkways, platforms, stairs and ladders	30-50-100	3	
6.1.2	Exterior pump and valve areas	50-100-150	3	
6.1.3	Pump and compressor houses	100-150-200	3	
6.1.4	Process plant with remote control	30-50-100	3	
6.1.5	Process plant requiring occasional manual intervention	50-100-150	3	
6.1.6	Permanently occupied work stations in process plant	150-200-300	3	
6.1.7	Control rooms for process plant	200-300-500	1	
6.2	Pharmaceutical Manufacturer and Fine Chemicals Manufacturer			
6.2.1	Pharmaceutical manufacturer grinding, granulating, mixing, drying, tableting, sterilizing, washing, preparation of solutions, filling, capping, wrapping, hardening	300-500-750	2	
6.2.2	Fine chemical manufacture			
6.2.2.1	Exterior walkways, platforms, stairs and ladders	30-50-100	3	
6.2.2.2	Process plant	50-100-150	3	
6.2.2.3	Fine chemical finishing	300-500-750	2	
6.2.2.4	Inspection	300-500-750	1	Local lighting may be appropriate
6.3	Soap Manufacture			
6.3.1	General area	200-300-500	2	
6.3.2	Automatic processes	100-200-300	2	
6.3.3	Control panels	200-300-500	1	Local lighting may be appropriate
6.3.4	Machines	200-300-500	2	
6.4	Paint Works			
6.4.1	General	200-300-500	2	
6.4.2	Automatic processes	150-200-300	2	
6.4.3	Control panels	200-300-500	2	
6.4.4	Special batch mixing	500-750-1 000	2	
6.4.5	Colour matching	750-1 000-1 500	1	
7	**MECHANICAL ENGINEERING**			
7.1	Structural Steel Fabrication			
7.1.1	General	200-300-500	3	
7.1.2	Marking off	300-500-750	3	Local lighting may be appropriate
7.2	Sheet Metal Works			
7.2.1	Pressing, punching, shearing, stamping, spinning, folding	300-500-750	2	
7.2.2	Benchwork, scribing, inspection	500-750-1 000	2	
7.3	Machine and Tool Shops			
7.3.1	Rough bench and machine work	200-300-500	3	
7.3.2	Medium bench and machine work	300-500-750	2	
7.3.3	Fine bench and machine work	500-750-1 000	2	
7.3.4	Gauge rooms	750-1000-1 500	1	Optical aids may be required
7.4	Die Sinking Shops			
7.4.1	General	300-500-750	2	
7.4.2	Fine work	1 000-1 500-2 000	1	Flexible local lighting is desirable
7.5	Welding and Soldering Shops			
7.5.1	Gas and arc welding, rough spot welding	200-300-500	3	
7.5.2	Medium soldering, brazing, spot welding	300-500-750	3	
7.5.3	Fine soldering, fine spot welding	750-1 000-1 500	2	Local lighting is desirable
7.6	Assembly Shops			
7.6.1	Rough work for example, frame and heavy machine assembly	200-300-500	3	The lighting of vertical surface may be important
7.6.2	Medium work, for example, engine assembly, vehicle body assembly	300-500-750	2	
7.6.3	Fine work, for example, office machinery assembly	500-750-1 000	1	Localized lighting may be useful
7.6.4	Very fine work, for example, instrument assembly	750-1 000-1 500	1	Local lighting and optical aids are desirable
7.6.5	Minute work, for example, watch making	1 000-1 500-2 000	1	Local lighting and optical aids are desirable

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
7.7	Inspection and Testing Shops			
7.7.1	Coarse work, for example, using go/no go gauges, inspection of large sub-assemblies	300-500-750	2	Local or localized lighting may be appropriate
7.7.2	Medium work, for example, inspection of painted surfaces	500-750-1 000	1	Local or localized lighting may be appropriate
7.7.3	Fine work, for example, using calibrated scales, inspection of precision mechanisms	750-1 000-1 500	1	Local or localized lighting may be appropriate
7.7.4	Very fine work, for example, inspection of small intricate parts	1 000-1 500-2 000	1	Local lighting and optical aids are desirable
7.7.5	Minute work, for example, inspection of very small instruments	2 000	1	Local lighting and optical aids are desirable
7.8	Points Shops and Spray Booths			
7.8.1	Dipping, rough spraying	200-300-500	3	
7.8.2	Preparation, ordinary painting, spraying and finishing	200-500-750	2	
7.8.3	Fine painting, spraying and finishing	500-750-1 000	2	
7.8.4	Inspection, retouching and matching	750-1 000-1 500	2	
7.9	Plating Shops			
7.9.1	Vats and baths	200-300-500	3	
7.9.2	Buffing, polishing burnishing	300-500-750	2	
7.9.3	Final buffing and polishing	500-750-1 000	2	
7.9.4	Inspection	–	–	Special light to reveal fault in the surface of the material will be required
8	**ELECTRICAL AND ELECTRONIC ENGINEERING**			
8.1	Electrical Equipment Manufacture			
8.1.1	Manufacture of cables and insulated wires, winding, varnishing and immersion of coils, assembly of large machines, simple assembly work	200-300-500	3	
8.1.2	Medium assembly, for example, telephones, small motors	300-500-750	3	Local lighting may be appropriate
8.1.3	Assembly of precision components, for example, telecommunication equipment, adjustment, inspection and calibration	750-1 000-1 500	1	Local lighting is desirable. Optical aids may be useful
8.1.4	Assembly of high precision parts	1 000-1 500-2 000	1	Local lighting is desirable. Optical aids may be useful
8.2	Electronic Equipment Manufacture			
8.2.1	Printed circuit board			
8.2.1.1	Silk screening	300-500-750	1	Local lighting may be appropriate
8.2.1.2	Hand insertion of components, soldering	500-750-1 000	1	Local lighting may be appropriate
8.2.1.3	Inspection	750-1 000-1 500	1	A large, low luminance luminaire overhead ensures specular reflection conditions which are helpful for inspection of printed circuits
8.2.1.4	Assembly of wiring harness, cleating harness, testing and calibration	500-750-1 000	1	Local lighting may be appropriated.
8.2.1.5	Chassis assembly	750-1 000-1 500	1	Local lighting may be appropriated.
8.2.2	Inspection and testing			
8.2.2.1	Soak test	150-200-300	2	
8.2.2.2	Safety and functional tests	200-300-500	2	
9	**FOOD, DRINK AND TOBACCO**			
9.1	Slaughter Houses			
9.1.1	General	200-300-500	3	
9.1.2	Inspection	300-500-750	2	
9.2	Canning, Preserving and Freezing			
9.2.1	Grading and sorting of raw materials	500-750-1 000	2	Lamp of colour rendering group 1A or 1B will be required, if colour judgement is required
9.2.2	Preparation	300-500-750	3	
9.2.3	Canned and bottled goods			
9.2.3.1	Retorts	200-300-500	3	
9.2.3.2	Automatic processes	150-200-300	3	
9.2.3.3	Labelling and packaging	200-300-500	3	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
9.2.4	Frozen foods			
9.2.4.1	Process area	200-300-500	3	
9.2.4.2	Packaging and storage	200-300-500	3	
9.3	Bottling, Brewing and Distilling			
9.3.1	Keg washing and handling, bottle washing	150-200-300	3	
9.3.2	Keg inspection	200-300-500	3	
9.3.3	Bottle inspection			Special lighting will be required
9.3.4	Process areas	200-300-500	3	
9.3.5	Bottle filling	500-750-1 000	3	
9.4	Edible Oils and Fats Processing			
9.4.1	Refining and blending	200-300-500	3	
9.4.2	Production	300-500-750	2	
9.5	Mills-Milling, Filtering and Packing	200-300-500	3	
9.6	Bakeries			
9.6.1	General	200-300-500	2	
9.6.2	Hand decorating, icing	300-500-750	2	
9.7	Chocolate and Confectionery Manufacture			
9.7.1	General	200-300-500	3	
9.7.2	Automatic processes	150-200-300	3	
9.7.3	Hand decoration, inspection, wrapping and packing	300-500-750	2	If accurate colour judgements are required, lamps of colour rendering group 1A or 1B are used
9.8	Tobacco Processing			
9.8.1	Material preparation, making and packing	300-500-750	2	
10	**TEXTILES**			
10.1	Fibre Preparation			
10.1.1	Bale breaking, washing	200-300-500	3	
10.1.2	Stock dyeing, tinting	200-300-500	3	
10.2	Yarn Manufacture			
10.2.1	Spinning, roving, winding, etc	300-500-750	2	
10.2.2	Healding (drawing in)	750-1000-750	2	
10.3	Fabric Production			
10.3.1	Knitting	300-500-750	2	
10.3.2	Weaving			
10.3.2.1	Jute and hemp	200-300-500	2	
10.3.2.2	Heavy woolens	300-500-750	1	
10.3.2.3	Medium worsteds, fine woolens, cottons	500-750-1 000	1	
10.3.2.4	Fine worsteds, fine linens, synthetics	750-1 000-1 500	1	
10.3.2.5	Mending	1 000-1 500-2 000	1	
10.3.2.6	Inspection	1 000-1 500-2 000	1	
10.4	Fabric Finishing			
10.4.1	Dyeing	200-300-500	3	
10.4.2	Calendaring, chemical treatment, etc	300-500-750	2	
10.4.3	Inspection			
10.4.3.1	`Grey' cloth	750-1 000-1 500	1	
10.4.3.2	Final	1 000-1 500-2 000	1	
10.5	Carpet Manufacture			
10.5.1	Winding, beaming	200-300-500	3	
10.5.2	Setting pattern, turfing cropping, trimming, fringing, latexing and latex drying	300-500-750	2	
10.5.3	Designing, weaving, mending	500-750-1 000	2	
10.5.4	Inspection			
10.5.4.1	General	750-1 000-1 500	1	Local lighting may be appropriate
10.5.4.2	Piece dyeing	500-750-1 000	1	Local lighting may be appropriate
11	**LEATHER INDUSTRY**			
11.1	Leather Manufacture			
11.1.1	Cleaning, tanning and stretching, vats, cutting, fleshing, stuffing	200-300-500	3	
11.1.2	Finishing, scarfing	300-500-750	2	
11.2	Leather Working			
11.2.1	General	200-300-500	3	
11.2.2	Pressing, glazing	300-500-750	2	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
11.2.3	Cutting, splitting, scarfing, sewing	500-750-1 000	2	Directional lighting may be useful.
11.2.4	Grading, matching		2	Local lighting may be appropriate
12	**CLOTHING AND FOOTWEAR**			
12.1	Clothing Manufacture			
12.1.1	Preparation of cloth	200-300-500	2	
12.1.2	Cutting	500-750-1 000	1	
12.1.3	Matching	500-750-1 000	1	
12.1.4	Sewing	750-1 000-1 500	1	
12.1.5	Pressing	300-500-750	2	
12.1.6	Inspection	1 000-1 500-2 000	1	Local lighting may be appropriate
12.1.7	Hand tailoring	1 000-1 500-2 000	1	Local lighting may be appropriate
12.2	Hosiery and Knitwear Manufacture			
12.2.1	Flat bed knitting machines	300-500-750	2	
12.2.2	Circular knitting machines	500-750-1000	2	
12.2.3	Lockstitch and overlocking machine	750-1 000-1 500	1	
12.2.4	Linking or running on	750-1 000-1 500	1	
12.2.5	Mending, handfinishing	1 000-1 500-3 000	-	Local lighting may be appropriate
12.2.6	Inspection	1 000-1 500-2 000	2	Local lighting may be appropriate
12.3	Glove Manufacture			
12.3.1	Sorting and grading	500-750-1 000	1	
12.3.2	Pressing, knitting, cutting	300-500-750	2	
12.3.3	Sewing	500-750-1 000	2	
12.3.4	Inspection	1 000-1 500-2 000	-	Local lighting may be appropriate
12.4	Hat Manufacture			
12.4.1	Stiffening, braiding, refining, forming, sizing, pounding, ironing	200-300-500	2	
12.4.2	Cleaning, flanging, finishing	300-500-750	2	
12.4.3	Sewing	500-750-1000	2	
12.4.4	Inspection	1 000-1 500-2 000	-	Local lighting may be appropriate
12.5	Boot and Shoe Manufacture			
12.5.1	Leather and synthetics			
12.5.2	Sorting and grading	750-1 000-1 500	1	
12.5.3	Clicking, closing	750-1 000-1 500	2	Local or localized lighting may be appropriate
12.5.4	Preparatory operations	750-1 000-1 500	2	Local or localized lighting may be appropriate
12.5.5	Cutting tables and pressure	1 000-1 500-2 000	1	Local or localized lighting may be appropriate
12.5.6	Bottom stock preparation, lasting, bottoming finishing, shoe rooms	750-1 000-1 500	1	Local or localized lighting may be appropriate
12.5.7	Rubber			
12.5.7.1	Washing, compounding, coating, drying, varnishing, vulcanizing, calendaring, cutting	200-300-500	3	
12.5.7.2	Lining, making and finishing	300-500-750	2	
13	**TIMBER AND FURNITURE**			
13.1	Sawmills			
13.1.1	General	150-200-300	3	
13.1.2	Head saw	300-500-750	2	Localized lighting may be appropriate
13.1.3	Grading	500-750-1 000	2	Directional lighting may be useful
13.2	Woodwork Shops			
13.2.1	Rough sawing, bench work	200-300-500	2	
13.2.2	Sizing, planning, sanding, medium machining and bench work	300-500-750	2	
13.2.3	Fine bench and machine work, fine sanding, finishing	500-750-1 000	2	Localized lighting may be appropriate
13.3	Furniture Manufacture			
13.3.1	Raw material stores	50-100-150	3	
13.3.2	Finished goods stores	100-150-200	3	
13.3.3	Wood matching and assembly, rough sawing, cutting	200-300-500	2	
13.3.4	Machining, sanding and assembly, polishing	300-500-750	2	Localized lighting may be appropriate
13.3.5	Tool room	300-500-750	2	
13.3.6	Spray booths			
13.3.6.1	Colour finishing	300-500-750	2	
13.3.6.2	Clear finishing	200-300-500	2	
13.3.7	Cabinet making			
13.3.7.1	Veneer sorting and grading	750-1 000-1 500	1	
13.3.7.2	Marquetry, pressing, patching and fitting	300-500-750	1	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
13.3.7.3	Final inspection	500-750-1 000	1	Special lighting will be required
13.4	Upholstery Manufacture			
13.4.1	Cloth inspection	1 000-1 500-2 000	1	Special lighting will be required
13.4.2	Filling, covering	300-500-750	2	
13.4.3	Slipping, cutting, sewing	500-750-1 000	2	
13.4.4	Mattress making			
13.4.5	Assembly	300-500-750	2	
13.4.6	Tape edging	750-1 000-1 500	2	Local lighting may be appropriate
14	**PAPER AND PRINTING**			
14.1	Paper Mills			
14.1.1	Pulp mills, preparation plants	200-300-500	3	
14.1.2	Paper and board making			
14.1.2.1	General	200-300-500	3	
14.1.2.2	Automatic process	150-200-300	3	Supplementary lighting may be necessary for maintenance work
14.1.2.3	Inspection, sorting	300-500-750	1	
14.1.3	Paper converting processes			
14.1.3.1	General	200-300-500	3	
14.1.3.2	Associated printing	300-500-750	2	
14.2	Printing Works			
14.2.1	Type foundries			
14.2.1.1	Matrix making, dressing type, hand and machine coating	200-300-500	3	
14.2.1.2	Front assembly, sorting	500-750-1 000	2	
14.2.2	Composing rooms			
14.2.2.1	Hand composing, imposition and distribution	500-750-1 000	1	
14.2.2.2	Hot metal keyboard	500-750-1 000	1	
14.2.2.3	Hot metal casting	200-300-500	2	
14.2.2.4	Photo composing keyboard or setters	300-500-750	1	
14.2.2.5	Paste up	500-750-1 000	1	
14.2.2.6	Illuminated tables – general lighting	200-300-500		Dimming may be required
14.2.2.7	Proof presses	300-500-750	2	
14.2.2.8	Proof reading	500-750-1 000	1	
14.2.3	Graphic Reproduction			
14.2.3.1	General	300-500-750	2	
14.2.3.2	Precision proofing, retouching, etching	750-1 000-1 500	1	Local lighting may be appropriate
14.2.3.3	Colour reproduction and inspection	750-1 000-1 500	1	
14.2.4	Printing machine room			
14.2.4.1	Presses	300-500-750	2	
14.2.4.2	Premake ready	300-500-750	2	
14.2.4.3	Printed sheet inspection	750-1 000-1 500	1	
14.2.5	Binding			
14.2.5.1	Folding, pasting, punching and stitching	300-500-750	2	
14.2.5.2	Cutting, assembling, embossing	500-750-1 000	2	
15	**PLASTIC AND RUBBER**			
15.1	Plastic Products			
15.1.1	Automatic plant			
15.1.1.1	Without manual control	30-50-100	3	
15.1.1.2	With occasional manual control	50-100-150	3	
15.1.1.3	With continuous manual control	200-300-500	3	
15.1.1.4	Control rooms	200-300-500	1	
15.1.1.5	Control platforms	200-300-500	2	Local lighting may be appropriate
15.1.2	Non-automatic plant			
15.1.2.1	Mixing, calendaring, extrusion, injection, compression and blow moulding, sheet fabrication	200-300-500	3	
15.1.2.2	Trimming, cutting, polishing, cementing	300-500-750	2	
15.1.2.3	Printing, inspection	750-1 000-1 500	1	
15.2	Rubber Products			
15.2.1	Stock preparation – plasticizing, milling	150-200-300	3	
15.2.2	Calendaring, fabric preparation, stock-cutting	300-500-750	3	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
15.2.3	Extruding, moulding	300-500-750	2	
15.2.4	Inspection	750-1 000-1 500	-	
16	**DISTRIBUTION AND STORAGE**			
16.1	Work Stores	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.1	Unpacking, sorting	150-200-300	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.2	Large item storage	50-100-150	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.3	Small item rack storage	200-300-500	3	Avoid glare to drivers of vehicles approaching the loading bay
16.1.4	Issue counter, records, storeman's desk	300-500-750	2	Local or localized lighting may be appropriate
16.2	Warehouses and Bulk Stores			
16.2.1	Storage of goods where indentification requires only limited preparation of detail	50-100-150	3	
16.2.2	Storage of goods where identification requires perception of detail	100-150-200	3	
16.2.3	Automatic high bay rack stores			
16.2.3.1	Gangway	20		
16.2.3.2	Control station	150-200-300	3	
16.2.3.3	Packing and dispatch	200-300-500	3	
16.2.3.4	Loading bays	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
16.3	Cold Stores			
16.3.1	General	200-300-500	3	
16.3.2	Breakdown, make-up and dispatch	200-300-500	3	
16.3.3	Loading bays	100-150-200	3	Avoid glare to drivers of vehicles approaching the loading bay
17	**COMMERCE**			
17.1	Offices			
17.1.1	General offices	300-500-750	1	
17.1.2	Deep plan general offices	500-750-1000	1	
17.1.3	Computer work stations	300-500-750	1	
17.1.4	Conference rooms, executive offices	300-500-750	1	
17.1.5	Computer and data preparation rooms	300-500-750	1	
171.6	Filing rooms	200-300-500	1	
17.2	Drawing Offices			
17.2.1	General	300-500-750	1	
17.2.2	Drawing boards	500-750-1 000	1	
17.2.3	Computer aided design and drafting			Special lighting is required
17.2.4	Print rooms	200-300-500	1	
17.3	Banks and Building Societies			
17.3.1	Counter, office area	300-500-750	1	
17.3.2	Public area	200-300-500	1	
18	**SERVICES**			
18.1	Garages			
18.1.1	Interior parking areas	20-30-50	3	
18.1.2	General repairs, servicing, washing, polishing	200-300-500	2	
18.1.3	Workbench	300-500-750	1	Local or localized lighting may be appropriate
18.1.4	Spray booths	300-500-750	1	
18.1.5	External apron			
18.1.5.1	General	30-50-100		Care should be taken to avoid glare to drivers and neighbouring residents
18.1.5.2	Pump area (retail sales)	200-300-500		*See* `Retailing'
18.2	Appliance servicing			
18.2.1	Workshop			
18.2.1.1	General	200-300-500	2	
18.2.1.2	Workbench	300-500-750	2	Localized lighting may be appropriate
18.2.1.3	Counter	200-300-500	2	Localized lighting may be appropriate
18.2.1.4	Stores	200-300-500	3	
18.3	Laundries			
18.3.1	Commercial laundries			
18.3.2	Receiving, sorting, washing, drying, ironing, despatch, dry-cleaning, bulk machine work	200-300-500	3	

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
18.3.3	Head ironing, pressing, mending, spotting, inspection	300-500-750	3	
18.3.4	Launderettes	200-300-500	3	
18.4	Sewage Treatment Works			
18.4.1	Walkways	30-50-100	3	
18.4.2	Process areas	50-100-150	3	
19	**RETAILING**			The service illuminance should be provided on the horizontal plane of the counter. Where wall displays are used, a similar illuminance on the walls is desirable
19.1	Small Shops with Counters	300-500-750	1	
19.2	Small Self-Service Shops with Island Displays	300-500-750	1	
19.3	Super Markets, Hyper-Markets			
19.3.1	General	300-500-750	2	
19.3.2	Checkout	300-500-750	2	
19.3.3	Showroom for large objects, for example, cars, furniture	300-500-750	1	
19.3.4	Shopping precincts and arcades	100-150-200	2	
20	**PLACES OF PUBLIC ASSEMBLY**			
20.1	Public Rooms, Village Halls, Worship Halls	200-300-500	1	
20.2	Concert Halls, Cinemas and Theatres			
20.2.1	Foyer	150-200-300		
20.2.2	Booking office	200-300-500		Local or localized lighting may be appropriate
20.2.3	Auditorium	50-100-150		Dimming facilities will be necessary. Special lighting of the aisles is desirable
20.2.4	Dressing rooms	200-300-500		Special mirror lighting for make-up may be required
20.2.5	Projection room	100-150-200		
20.3	Churches			
20.3.1	Body of church	100-150-200	2	
20.3.2	Pulpit, lectern	200-300-500	2	Use local lighting
20.3.3	Choir stalls	200-300-500	2	Local lighting may be appropriate
20.3.4	Alter, communion table, chancel	100-150-200	2	Additional lighting to provide emphasis is desirable
20.3.5	Vestries	100-150-200	2	
20.3.6	Organ	200-300-500		
20.4	Hospitals			
20.4.1	Anaesthetic rooms			
20.4.1.1	General	200-300-500		
20.4.1.2	Local	750-1 000-1 500		
20.4.2	Consulting areas			
20.4.2.1	General	200-300-500		
20.4.2.2	Examination	750-1 000-1 500		
20.4.3	Corridors			
20.4.3.1	General	100-150-200		
20.4.4	Ward corridors			
20.4.4.1	Day, screened from bays	150-200-300		
20.4.4.2	Day, open to natural light	150-200-300 (total)		
20.4.4.3	Morning/evening	100-150-200		
20.4.4.4	Night	5-10		
20.4.5	Cubicles			
20.4.5.1	General	200-300-500		
20.4.5.2	Treatment	750-1 000-1 500		
20.4.6	Examination			
20.4.6.1	General	200-300-500		
20.4.6.2	Local inspection	750-1 000-1 500		
20.4.7	Intensive therapy			
20.4.7.1	Bad head	30-50		
20.4.7.2	Circulation between bed ends	50-100-150		
20.4.7.3	Observation	200-300-500		
20.4.7.4	Local observation	750-1 000-1 500		
20.4.7.5	Staff base (day)	200-300-500		
20.4.7.6	Staff base (night)	30		
20.4.8	Laboratories			
20.4.8.1	General	200-300-500		
20.4.8.2	Examination	300-500-750		
20.4.9	Nurses' stations			

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
20.4.9.1	Morning/day/evening	200-300-500		
20.4.9.2	Night desks	30		
20.4.9.3	Night, medical trolleys	50-100-150		
20.4.10	Operating theatres			
20.4.10.1	General	300-500-750		
20.4.10.2	Local	10 000 to 50 000		Special operating lights are used.
20.4.11	Pathology departments			
20.4.11.1	General	200-300-500		
20.4.11.2	Examination	300-500-750		
20.4.11.3	Pharmacies	200-300-500		
20.4.11.4	Reception/enquiry	200-300-500		
20.4.11.5	Recovery rooms	200-300-500		
20.4.12	Ward-circulation			
20.4.12.1	Day	50-100-150		
20.4.12.2	Morning/evening	50-100-150		
20.4.12.3	Night	3-5		
20.4.13	Ward-bed head			
20.4.13.1	Morning/evening	30-50		
20.4.13.2	Reading	100-150-200		
20.4.14	Night			
20.4.14.1	Adult	0.1-1		
20.4.14.2	Pediatric	1		
20.4.14.3	Psychiatric	1-5		
20.4.14.4	Watch	5		
20.4.15	X-Ray areas			
20.4.15.1	General	150-200-300		
20.4.15.2	Diagnostic	150-200-300		
20.4.15.3	Operative	200-300-500		
20.4.15.4	Process dark room	50		
20.4.16	Surgeries			
20.4.16.1	General	200-300-500		
20.4.16.2	Waiting rooms	100-150-200		
20.4.17	Dental surgeries			
20.4.17.1	Chair	Special lighting		
20.4.17.2	Laboratories	300-500-750		
20.4.18	Consulting rooms			
20.4.18.1	General	200-300-500		
20.4.18.2	Desk	300-500-750		
20.4.18.3	Examination couch	300-500-750		
20.4.18.4	Ophthalmic wall and near-vision charts	300-500-750		
20.5	Hotels			
20.5.1	Entrance halls	50-100-150		
20.5.2	Reception, cashier's and porters' desks	200-300-500		Localized lighting may be appropriate.
20.5.3	Bars, coffee base, dining rooms, grill rooms, restaurants, lounges	50-200		The lighting should be designed to create an appropriate atmosphere
20.5.4	Cloak rooms, baggage rooms	50-100-150	3	
20.5.5	Bed rooms	30-50-100		Supplementary local lighting at the bed head, writing table should be provided
20.5.6	Bathroom	50-100-150		Supplementary local lighting near the mirror is desirable
20.5.7	Food preparation and stores, cellars, lifts and corridors			*See* `General Building Areas'
20.6	Libraries			
20.6.1	Lending library			
20.6.1.1	General	200-300-500	1	
20.6.1.2	Counters	300-500-750	1	Localized lighting may be appropriate.
20.6.1.3	Bookshelves	100-150-200	2	The service illuminance should be provided on the vertical face at the bottom of the bookstack
20.6.1.4	Reading rooms	200-300-500	1	
20.6.1.5	Reading tables	200-300-500	1	Localized lighting may be appropriate
20.6.2	Catalogues			
20.6.2.1	Card	100-150-200	2	
20.6.2.2	Microfiche/Visual display units	100-150-200	2	
20.6.3	Reference libraries			
20.6.3.1	General	200-300-500	1	
20.6.3.2	Counters	300-500-750	1	Localized lighting may be appropriate.

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Table 4 — (*Continued*)

(1)	(2)	(3)	(4)	(5)
20.6.3.3	Bookshelves	100-150-200	2	The service illuminance should be provided on a vertical surface at the foot of the bookshelves
20.6.3.4	Study tables, carrels	300-500-750	1	
20.6.3.5	Map room	200-300-500	1	
20.6.4	Display and exhibition areas			
20.6.4.1	Exhibits insensitive to light	200-300-500		
20.6.4.2	Exhibit sensitive to light, for example, pictures, prints, rare books in archives	50 to 150		
20.6.5	Library workrooms			
20.6.5.1	Book repair and binding	300-500-750	2	
20.6.5.2	Catalogue and sorting	300-500-750	2	
20.6.5.3	Remote book stores	100-150-200	3	
20.7	Museums and Art Galleries			
20.7.1	Exhibits insensitive to light	200-300-500		
20.7.2	Light sensitive exhibits, for example, oil and temper paints, undyed leather, bone, ivory, wood, etc	150		This is a maximum illuminance to be provided on the principal plane of the exhibit
20.7.3	Extremely light sensitive exhibits, for example, textiles, water colours, prints and drawings, skins, botanical specimens, etc	50		This is the maximum illuminance to be provided on the principal plane of the object
20.7.4	Conservation studies and workshops	300-500-750	1	
20.8	Sports Facilities			
	Multi-purpose sports halls	300-750		This lighting system should be sufficiently flexible to provide lighting suitable for the variety of sports and activities that take place in sports halls. Higher illuminance of 1000-2000 lux would be required for television coverage
21	**EDUCATION**			
21.1	Assembly Halls			
21.1.1	General	200-300-500	3	
21.1.2	Platform and stage			Special lighting to provide emphasis and to facilitate the use of the platform/ stage is desirable
21.2	Teaching Spaces			
	General	200-300-500	1	
21.3	Lecture Theatres			
21.3.1	General	200-300-500	1	
21.3.2	Demonstration benches	300-500-750	1	Localized lighting may be appropriate
21.4	Seminar Rooms	300-500-750	1	
21.5	Art Rooms	300-500-750	1	
21.6	Needlework Rooms	300-500-750	1	
21.7	Laboratories	300-500-750	1	
21.8	Libraries	200-300-500	1	
21.9	Music Rooms	200-300-500	1	
21.10	Sports Halls	200-300-500	1	
21.11	Workshops	200-300-500	1	
22	**TRANSPORT**			
22.1	Airports			
22.1.1	Ticket counters, checking desks, and information desks	300-500-750	2	Localized lighting may be appropriate
22.1.2	Departure lounges, other waiting areas	150-200-300	2	
22.1.3	Baggage reclaim	150-200-300	2	
22.1.4	Baggage handling	50-100-150	2	
22.1.5	Customs and immigration halls	300-500-750	2	
22.1.6	Concourse	150-200-300	2	
22.2	Railway Stations			
22.2.1	Ticket office	300-500-750	2	Localized lighting may be appropriate
22.2.2	Information office	300-500-750	2	Localized lighting over the counter may be appropriate
22.2.3	Parcels office, left			
22.2.4	Luggage office			
22.2.4.1	General	50-100-150	2	
22.2.4.2	Counter	150-200-300	2	
22.2.5	Waiting rooms	150-200-300	2	
22.2.6	Concourse	150-200-300	2	

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Table 4 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)
22.2.7	Time table	150-200-300	2	Localized lighting may be appropriate
22.2.8	Ticket barriers	150-200-300	2	Localized lighting may be appropriate
22.2.9	Platforms (covered)	30-50-100	2	Care should be taken to light and mark the edge of the platform clearly
22.2.10	Platforms (open)	20		Care should be taken to light and mark the edge of the platform clearly
22.3	Coach Stations			
22.3.1	Ticket offices	300-500-750	2	Localized lighting over the counter may be appropriate
22.3.2	Information offices	300-500-750	2	Localized lighting over the counter may be appropriate
22.3.3	Left luggage office			
22.3.3.1	General	50-100-150	3	
22.3.3.2	Counter	150-200-300	3	Localized lighting is appropriate
22.3.4	Waiting rooms	150-200-300	2	
22.3.5	Concourse	150-200-300	2	
22.3.6	Time tables	150-200-300	2	Local lighting is appropriate
22.3.7	Loading areas	100-150-200	3	
23	**GENERAL BUILDING AREAS**			
23.1	Entrance			
23.1.1	Entrance halls, lobbies, waiting rooms	150-200-300	2	
23.1.2	Enquiry desks	300-500-750	2	Localized lighting may be appropriate
23.1.3	Gatehouses	150-200-300	2	
23.2	Circulation Areas			
23.2.1	Lifts	50-100-150		
23.2.2	Corridors, passageways, stairs	50-100-150	2	
23.2.3	Escalators, revelators	100-150-200		
23.3	Medical and First Aid Centres			
23.3.1	Consulting rooms, treatment rooms	300-500-750	1	
23.3.2	Rest rooms	100-150-200	1	
23.3.3	Medical stores	100-150-200	2	
23.4	Staff Rooms			
23.4.1	Changing, locker and cleaners rooms, cloakrooms, lavatories	50-100-150		
23.4.2	Rest rooms	100-150-200	1	
23.5	Staff Restaurants			
23.5.1	Canteens, cafeterias, dining rooms, mess rooms	150-200-300	2	
23.5.2	Servery, vegetable preparation, washing-up area	200-300-500	2	
23.5.3	Food preparation and cooking	300-500-750	2	
23.5.4	Food stores, cellars	100-150-200	2	
23.6	Communications			
23.6.1	Switchboard rooms	200-300-500	2	
23.6.2	Telephone apparatus rooms	100-150-200	2	
23.6.3	Telex room, post room	300-500-750	2	
23.6.4	Reprographic room	200-300-500	2	
23.7	Building Services			
23.7.1	Boiler houses			
23.7.1.1	General	50-100-150	3	
23.7.1.2	Boiler front	100-150-200	3	
23.7.1.3	Boiler control room	200-300-500	2	Localized lighting of the control display and the control desk may be appropriate
23.7.1.4	Control rooms	200-300-500	2	Localized lighting of the control display and the control desk may be appropriate
23.7.1.5	Mechanical plant room	100-150-200	2	
23.7.1.6	Electrical power supply and distribution rooms	100-150-200	2	
23.7.1.7	Store rooms	50-100-150	3	
23.8	Car Parks			
23.8.1	Covered car parks			
23.8.1.1	Floors	5-20		
23.8.1.2	Ramps and corners	30		
23.8.1.3	Entrances and exits	50-100-150		
23.8.1.4	Control booths	150-200-300		
23.8.1.5	Outdoor car parks	5-20		

NOTE — For details on use of the ranges of illumination given in three steps in this table, reference shall be made to **4.1.4.2**, **4.1.4.2.1** and **4.1.4.2.2**. For details on quality class of direct glare limitation, reference shall be made to **4.1.3.1**.

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4.1.7 For detailed information regarding principles of good lighting, reference may be made to good practice [8-1(2)].

4.2 Daylighting

The primary source of lighting for daylighting is the sun. The light received by the earth from the sun consists of two parts, namely, direct solar illuminance and sky illuminance. For the purposes of daylighting design, direct solar illuminance shall not be considered and only sky illuminance shall be taken as contributing to illumination of the building interiors during the day.

4.2.1 The relative amount of sky illuminance depends on the position of the sun defined by its altitude, which in turn, varies with the latitude of the locality, the day of the year and the time of the day, as indicated in Table 5.

4.2.2 The external available horizontal sky illuminance (diffuse illuminance) values which are exceeded for about 90 percent of the daytime working hours may be taken as outdoor design illuminance values for ensuring adequacy of daylighting design. The outdoor design sky illuminance varies for different climatic regions of the country. The recommended design sky illuminance values are 6 800 lux for cold climate, 8 000 lux for composite climate, 9 000 lux for warm humid climate, 9 000 lux for temperate climate and 10 500 lux for hot-dry climate. For integration with the artificial lighting during daytime working hours an increase of 500 lux in the recommended sky design illuminance for daylighting is suggested.

4.2.3 The daylight factor is dependent on the sky luminance distribution, which varies with atmospheric conditions. A clear design sky with its non-uniform distribution of luminance is adopted for the purposes of design in this Section.

4.2.4 *Components of Daylight Factor*

Daylight factor is the sum of all the daylight reaching on an indoor reference point from the following sources:

a) Direct sky visible from the point,
b) External surfaces reflecting light directly to the point (*see* Note 1), and
c) Internal surfaces reflecting and inter-reflecting light to the point.

NOTES

1 External surface reflection may be computed approximately only for points at the centre of the room, and for detailed analysis procedures are complicated and these may be ignored for actual calculations.

2 Each of the three components, when expressed as a ratio or percent of the simultaneous external illuminance on the horizontal plane, defines respectively the sky component (SC), the external reflected component (ERC) and the internal reflected component (IRC) of the daylight factor.

4.2.4.1 The daylight factors on the horizontal plane only are usually taken, as the working plane in a room is generally horizontal; however, the factors in vertical planes should also be considered when specifying daylighting values for special cases, such as daylighting on classrooms, blackboards, pictures and paintings hung on walls.

4.2.5 *Sky Component (SC)*

Sky component for a window of any size is computed by the use of the appropriate table of Annex B.

a) The recommended sky component level should be ensured generally on the working plane at the following positions:
   1) At a distance of 3 m to 3.75 m from the window along the central line perpendicular to the window,
   2) At the centre of the room if more appropriate, and
   3) At fixed locations, such as school desks, blackboards and office tables.
b) The daylight area of the prescribed sky component should not normally be less than half the total area of the room.

4.2.5.1 The values obtainable from the tables are for rectangular, open unglazed windows, with no external obstructions. The values shall be corrected for the presence of window bars, glazing and external obstructions, if any. This assumes the maintenance of a regular cleaning schedule.

4.2.5.2 *Corrections for window bars*

The corrections for window bars shall be made by multiplying the values read from tables in Annex B by a factor equal to the ratio of the clear opening to the overall opening.

4.2.5.3 *Correction for glazing*

Where windows are glazed, the sky components obtained from Annex A shall be reduced by 10 to 20 percent, provided the panes are of clear and clean glass. Where glass is of the frosted (ground) type, the sky components read from Annex A may be reduced by 15 to 30 percent. In case of tinted or reflective glass the reduction is about 50 percent. Higher indicated correction corresponds to larger windows and/or near reference points. In the case of openings and glazings which are not vertical, suitable correction shall be taken into account.

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Table 5 Solar Altitudes (to the Nearest Degree) for Indian Latitudes

(*Clause* 4.2.1)

Period of Year	22 June						21 March and 23 September						22 December					
Hours of Day (Sun or Solar) Latitude	07 00 17 00	08 00 16 00	09 00 15 00	10 00 14 00	11 00 13 00	12 00 —	07 00 17 00	08 00 16 00	09 00 15 00	10 00 14 00	11 00 13 00	12 00 —	07 00 17 00	08 00 16 00	09 00 15 00	10 00 14 00	11 00 13 00	12 00 —
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
10°N	18	31	45	58	70	77	15	30	44	59	72	80	9	23	35	46	53	57
13°N	19	32	46	60	72	80	15	29	44	58	70	77	8	21	33	43	51	54
16°N	20	33	47	61	74	83	14	29	43	56	68	74	7	19	31	41	48	51
19°N	21	34	48	62	75	86	14	28	42	55	66	71	5	18	29	48	45	48
22°N	22	35	49	62	75	89	14	28	41	53	64	68	4	16	27	36	42	45
25°N	23	36	49	63	76	88	13	27	40	52	61	65	3	14	25	34	39	42
28°N	23	36	49	63	76	86	13	26	39	50	59	62	1	13	23	31	37	39
31°N	24	37	50	62	75	82	13	25	37	48	56	56	—	11	21	28	34	36
34°N	25	37	49	62	73	79	12	25	36	46	53	56	—	9	18	26	31	33

4.2.5.4 *Correction for external obstructions*

There is no separate correction, except that the values from tables in Annex B shall be read only for the unobstructed portions of the window.

4.2.6 *External Reflected Component (ERC)*

The value of the sky component corresponding to the portion of the window obstructed by the external obstructions may be found by the use of methods described in Annex C of good practice [8-1(3)].

These values when multiplied by the correction factors, corresponding to the mean elevation of obstruction from the point in question as given in Table 6, can be taken as the external reflected components for that point.

Table 6 Correction Factor for ERC

(*Clause* 4.2.6)

Sl No.	Mean Angle of Elevation	Correction Factor
(1)	(2)	(3)
i)	5°	0.086
ii)	15°	0.086
iii)	25°	0.142
iv)	35°	0.192
v)	45°	0.226
vi)	55°	0.274
vii)	65°	0.304
viii)	75°	0.324
ix)	85°	0.334

4.2.6.1 For method of calculating ERC, reference may be made to accepted standard (*see* Examples 10 and 11 given in Annex B of good practice [8-1(3)].

4.2.7 *Internal Reflected Component (IRC)*

The component of daylight factor contributed by reflection from the inside surfaces varies directly as the window area and inversely as the total area of internal surfaces, and depends on the reflection factor of the floor, wall and roof surfaces inside and of the ground outside. For rooms white-washed on walls and ceiling and windows of normal sizes, the IRC will have sizeable value even at points far away from the window. External obstructions, when present, will proportionately reduce IRC. Where accurate values of IRC are desired, the same may be done in accordance with the good practice [8-1(3)].

4.2.8 *General Principles of Openings to Afford Good Lighting*

4.2.8.1 Generally, while taller openings give greater penetrations, broader openings give better distribution of light. It is preferable that some area of the sky at an altitude of 20° to 25° should light up the working plane.

4.2.8.2 Broader openings may also be equally or more efficient, provided their sills are raised by 300 mm to 600 mm above the working plane.

NOTE — It is to be noted that while placing window with a high sill level might help natural lighting, this is likely to reduce ventilation at work levels. While designing the opening for ventilation also, a compromise may be made by providing the sill level about 150 mm below the head level of workers.

4.2.8.3 For a given penetration, a number of small openings properly positioned along the same, adjacent or opposite walls will give better distribution of illumination than a single large opening. The sky component at any point, due to a number of openings may be easily determined from the corresponding sky

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component contour charts appropriately superposed. The sum of the individual sky component for each opening at the point gives the overall component due to all the openings. The same charts may also facilitate easy drawing of sky component contours due to multiple openings.

4.2.8.4 Unilateral lighting from side openings will, in general, be unsatisfactory if the effective width of the room is more than 2 to 2.5 times the distance from the floor to the top of the opening. In such cases provision of light shelves is always advantageous.

4.2.8.5 Openings on two opposite sides will give greater uniformity of internal daylight illumination, especially when the room is 7 m or more across. They also minimise glare by illuminating the wall surrounding each of the opposing openings. Side openings on one side and clerestory openings on the opposite side may be provided where the situation so requires.

4.2.8.6 Cross-lighting with openings on adjacent walls tends to increase the diffused lighting within a room.

4.2.8.7 Openings in deep reveals tend to minimise glare effects.

4.2.8.8 Openings shall be provided with *Chajjahs*, louvers, baffles or other shading devices to exclude, as far as possible, direct sunlight entering the room. *Chajjahs*, louvers, etc, reduce the effective height of the opening for which due allowance shall be made. Broad and low openings are, in general, much easier to shade against sunlight entry. Direct sunlight, when it enters, increases the inside illuminance very considerably. Glare will result if it falls on walls at low angles, more so than when it falls on floors, especially when the floors are dark coloured or less reflective.

4.2.8.9 Light control media, such as translucent glass panes (opal or matt) surfaced by grinding, etching or sandblasting, configurated or corrugated glass, certain types of prismatic glass, tinted glass and glass blasts are often used. They should be provided, either fixed or movable outside or inside, especially in the upper portions of the openings. The lower portions are usually left clear to afford desirable view. The chief purpose of such fixtures is to reflect part of the light on to the roof and thereby increase the diffuse lighting within, light up the farther areas in the room and thereby produce a more uniform illumination throughout. They will also prevent the opening causing serious glare discomfort to the occupants but will provide some glare when illuminated by direct sunlight.

4.2.9 *Availability of Daylight in Multistoreyed Block*

Proper planning and layout of building can add appreciably to daylighting illumination inside. Certain dispositions of building masses offer much less mutual obstruction to daylight than others and have a significant relevance, especially when intensive site planning is undertaken. As guidance, the relative availability of daylight in multi-storeyed blocks (up to 4 storeys) of different relative orientations may be taken as given in Table 7.

Table 7 Relative Availability of Daylight on the Window Plane at Ground Level in a Four-Storeyed Building Blocks (Clear Design-Sky as Basis, Daylight Availability Taken as Unity on an Unobstructed Facade, Values are for the Centre of the Blocks)

(*Clause* 4.2.9)

Sl No.	Distance of Separation Between Blocks	Infinitely Long Parallel Blocks	Parallel Blocks Facing Each Other (Length = 2 × Height)	Parallel Blocks facing Gaps Between Opposite Blocks (Length = 2 × Height)
(1)	(2)	(3)	(4)	(5)
i)	0.5 Ht	0.15	0.15	0.25
ii)	1.0 Ht	0.30	0.32	0.38
iii)	1.5 Ht	0.40	0.50	0.55
iv)	2.0 Ht	0.50	0.60	0.68

NOTE — Ht = Height of building.

4.2.10 For specified requirements for daylighting of special occupancies and areas, reference may be made to good practice [8-1(4)].

4.3 Artificial Lighting

4.3.1 Artificial lighting may have to be provided,

a) where the recommended illumination levels have to be obtained by artificial lighting only;
b) to supplement daylighting when the level of illumination falls below the recommended value; and
c) where visual task may demand a higher level of illumination.

4.3.2 *Artificial Lighting Design for Interiors*

For general lighting purposes, the recommended practice is to design for a level of illumination on the working plane on the basis of the recommended levels for visual tasks given in Table 4 by a method called 'Lumen method'. In order to make the necessary detailed calculations concerning the type and quantity of lighting equipment necessary, advance information on the surface reflectances of walls, ceilings and floors is required. Similarly, calculations concerning the brightness ratio in the interior call for details of the interior decoration and furnishing. Stepwise guidance regarding designing the interior lighting systems for a

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building using the 'Lumen method' is given in **4.3.2.1** to **4.3.2.4.**

4.3.2.1 *Determination of the illumination level*

Recommended value of illumination shall be taken from Table 4, depending upon the type of work to be carried out in the location in question and the visual tasks involved.

4.3.2.2 *Selection of the light sources and luminaires*

The selection of light sources and luminaires depends on the choice of lighting system, namely, general lighting, directional lighting and localized or local lighting.

4.3.2.3 *Determination of the luminous flux*

a) The luminous flux (F) reaching the working plane depends upon the following:
   1) Lumen output of the lamps,
   2) Type of luminaire,
   3) Proportion of the room (room index) (k_r),
   4) Reflectance of internal surfaces of the room,
   5) Depreciation in the lumen output of the lamps after burning their rated life, and
   6) Depreciation due to dirt collection on luminaires and room surface.

b) *Coefficient of utilization or utilization factor*
   1) The compilation of tables for the utilization factor requires a considerable amount of calculations, especially if these tables have to cover a wide range of lighting practices. For every luminaire, the exact light distribution has to be measured in the laboratory and their efficiencies have to be calculated and measured exactly. These measurements comprise,
      i) the luminous flux radiated by the luminaires directly to the measuring surface;
      ii) the luminous flux reflected and re-reflected by the ceiling and the walls to the measuring surface; and
      iii) the inter-reflections between the ceiling and wall which result in the measuring surface receiving additional luminous flux.

      All these measurements have to be made for different reflection factors of the ceiling and the walls for all necessary room indices. These tables have also to indicate the maintenance factor to be taken for the luminous flux depreciation throughout the life of an installation due to ageing of the lamp and owing to the deposition of dirt on the lamps and luminaires and room surfaces.
   2) The values of the reflection factor of the ceiling and of the wall are as follows:

White and very light colours	:	0.7
Light colours	:	0.5
Middle tints	:	0.3
Dark colours	:	0.1

      For the walls, taking into account the influence of the windows without curtains, shelves, almirahs and doors with different colours, etc, should be estimated.

c) *Calculation for determining the luminous flux* [*see Table 22 of SP : 41 (S&T) — 1987 'Handbook on functional requirements of buildings other than industrial buildings'*]

$$E_{av} = \frac{\mu.\phi}{A}$$

or, $\phi = \frac{E_{av}.A}{\mu}$, for new condition, and

$$\phi = \frac{E_{av}.A}{\mu.d}, \text{ for working condition}$$

where

ϕ = total luminous flux of the light sources installed in the room, in lumens;

E_{av} = average illumination level required on the working plane, in lux;

A = area of the working plane, in m^2;

μ = utilization factor in new conditions; and

d = maintenance factor.

In practice, it is easier to calculate straightaway the number of lamps or luminaires from:

$$N_{lamp} = \frac{E_{av}.A}{\mu.d.\phi_{lamp}}$$

$$N_{luminaires} = \frac{E_{av}.A}{\mu.d.\phi_{luminaires}}$$

where

ϕ_{lamp} = luminous flux of each lamp, in lumens

$\phi_{luminaires}$ = luminous flux of each luminaire, in lumens

N_{lamp} = total number of lamps

$N_{luminaires}$ = total number of luminaires.

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4.3.2.4 *Arrangement of the luminaires*

This is done to achieve better uniformly distributed illumination. The location of the luminaires has an important effect on the utilization factor.

a) In general, luminaires are spaced 'x' metre apart in either direction, while the distance of the end luminaire from the wall is '0.5x' metre. The distance 'x' is more or less equal to the mounting height 'H_m' between the luminaire and the working plane. The utilization factor tables are calculated for this arrangement of luminaires [*see* Table 22 of SP : 41 (S&T) – 1987 'Handbook on functional requirements of buildings other than industrial buildings'].

b) For small rooms where the room index (k_r) is less than 1, the distance 'x' should always be less than H_m, since otherwise luminaires cannot be properly located. In most cases of such rooms, four or two luminaires are placed for good general lighting. If, however, in such rooms only one luminaire is installed in the middle, higher utilization factors are obtained, but the uniformity of distribution is poor. For such cases, references should be made to the additional tables for k_r = 0.6 to 1.25 for luminaires located centrally.

4.3.3 *Artificial Lighting to Supplement Daylighting*

4.3.3.1 The need for general supplementary artificial lighting arises due to diminishing of daylighting beyond design hours, that is, for solar altitude below 15° or when dark cloudy conditions occur.

4.3.3.2 The need may also arise for providing artificial lighting during the day in the innermost parts of the building which cannot be adequately provided with daylighting, or when the outside windows are not of adequate size or when there are unavoidable external obstructions to the incoming daylighting.

4.3.3.3 The need for supplementary lighting during the day arises, particularly when the daylighting on the working plane falls below 100 lux and the surrounding luminance drops below 19 cd/m^2.

4.3.3.4 The requirement of supplementary artificial lighting increases with the decrease in daylighting availability. Therefore, conditions near sunset or sunrise or equivalent conditions due to clouds or obstructions, etc, represent the worst conditions when the supplementary lighting is most needed.

4.3.3.5 The requirement of supplementary artificial lighting when daylighting availability becomes poor may be determined from Fig. 3 for an assumed ceiling height of 3.0 m, depending upon floor area, fenestration percentage and room surface reflectance. Cool daylight fluorescent tubes are recommended with semi-direct luminaires. To ensure a good distribution of illumination, the mounting height should be between 1.5 m and 2.0 m above the work plane for a separation of 2.0 m to 3.0 m between the luminaires. Also the number of lamps should preferably be more in the rear half of the room than in the vicinity of windows. The

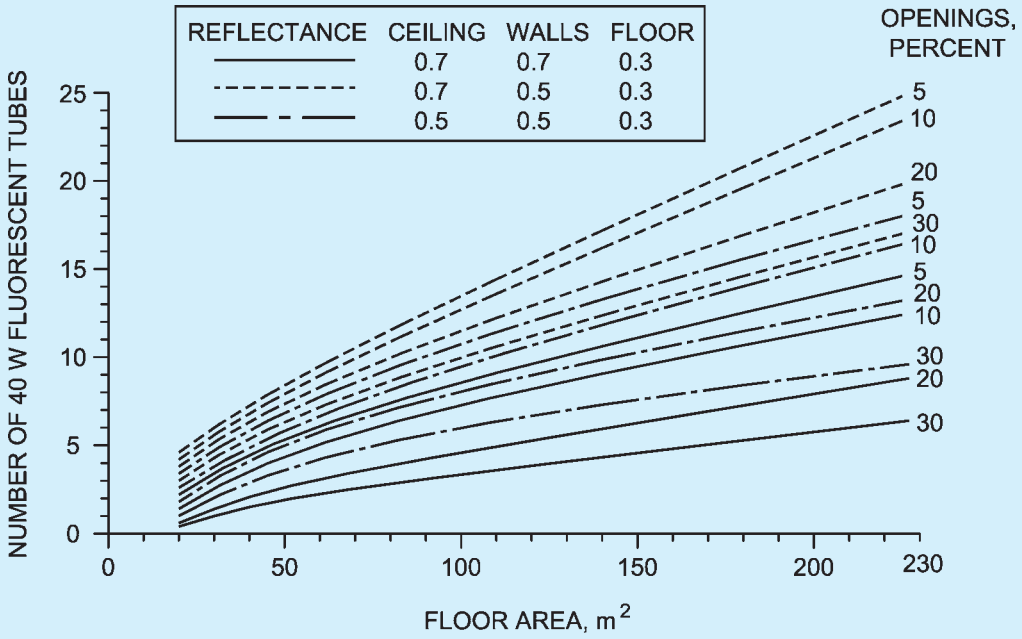


FIG. 3 SUPPLEMENTARY ARTIFICIAL LIGHTING FOR 40 W FLUORESCENT TUBES

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following steps may be followed for using Fig. 3 for determining the number of fluorescent tubes required for supplementary daylighting.

a) Determine fenestration percentage of the floor area, that is,

$$\frac{\text{Window area}}{\text{Floor area}} \times 100$$

b) In Fig. 3, refer to the curve corresponding to the percent fenestration determined above and the set of reflectances of ceiling, walls and floor actually provided.

c) For the referred curve of Fig. 3 read, along the ordinate, the number of 40 W fluorescent tubes required, corresponding to the given floor area on the abscissa.

4.3.4 For detailed information on the design aspects and principles of artificial lighting, reference may be made to good practice [8-1(2)].

4.3.5 For specific requirements for lighting of special occupancies and areas, reference may be made to good practice [8-1(5)].

4.3.6 Electrical installation aspect for artificial lighting shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

4.4 Energy Conservation in Lighting

4.4.1 A substantial portion of the energy consumed on lighting may be saved by utilization of daylight and rational design of supplementary artificial lights.

4.4.2 Daytime use of artificial lights may be minimised by proper design of windows for adequate daylight indoors. Daylighting design should be according to **4.2**.

4.4.3 Fenestration expressed as percentage of floor area required for satisfactory visual performance of a few tasks for different separation to height (S/H) ratio of external obstructions such as opposite buildings may be obtained from the design nomogram (*see* Fig. 4). The obstructions at a distance of three times their height or more (S/H >3) from a window façade are not significant and a window facing such an obstruction may be regarded as a case of unobstructed window.

4.4.3.1 The nomogram consists of horizontal lines indicating fenestration percentage of floor area and vertical lines indicating the separation to height ratio of external obstructions such as opposite buildings. Any vertical line for separation to height ratio other than already shown in the nomogram (1.0, 2.0 and 3.0) may be drawn by designer, if required. For cases where there is no obstruction, the ordinate corresponding to the value 3.0 may be used. The value of percentage fenestration and separation to height ratio are marked on left hand ordinate and abscissa, respectively. The illumination levels are marked on the right hand ordinate. The values given within brackets are the illumination levels on the work plane at center and rear of the room. The wattage of fluorescent tubes required per m^2 of the floor area for different illumination levels is shown on each curve.

4.4.3.2 Following assumptions have been made in the construction of the nomogram:

a) An average interior finish with ceiling white, walls off white and floor grey has been assumed.

b) Ceiling height of 3 m, room depths up to 10 m and floor area between 30 m^2 and 50 m^2 have been assumed. For floor area beyond 50 m^2 and less than 30 m^2, the values of percent fenestration as well as wattage per m^2 should be multiplied by a factor of 0.85 and 1.15, respectively.

c) It is assumed that windows are of metallic sashes with louvers of width up to 600 mm or a *Chhajja* (balcony projection) at ceiling level of width up to 2.0 m. For wooden sashes, the window area should be increased by a factor of about 1.1.

d) Luminaires emanating more light in the downward direction than upward direction (such as reflectors with or without diffusing plastics) and mounted at a height of 1.5 m to 2.0 m above the work plane have been considered.

4.4.3.3 *Method of use*

The following steps shall be followed for the use of nomogram:

a) *Step 1* — Decide the desired illumination level depending upon the task illumination requirement in the proposed room and read the value of watts per m^2 on the curve corresponding to the required illumination level.

b) *Step 2* — Fix the vertical line corresponding to the given separation to height ratio of opposite buildings on the abscissa. From the point of intersection of this vertical line and the above curve move along horizontal, and read the value of fenestration percent on the left hand ordinate.

c) *Step 3* — If the floor area is greater than 50 m^2 or if it is less than 30 m^2, the value of watt per m^2 as well as fenestration percent may be easily determined for adequate daylighting and supplemental artificial lighting for design

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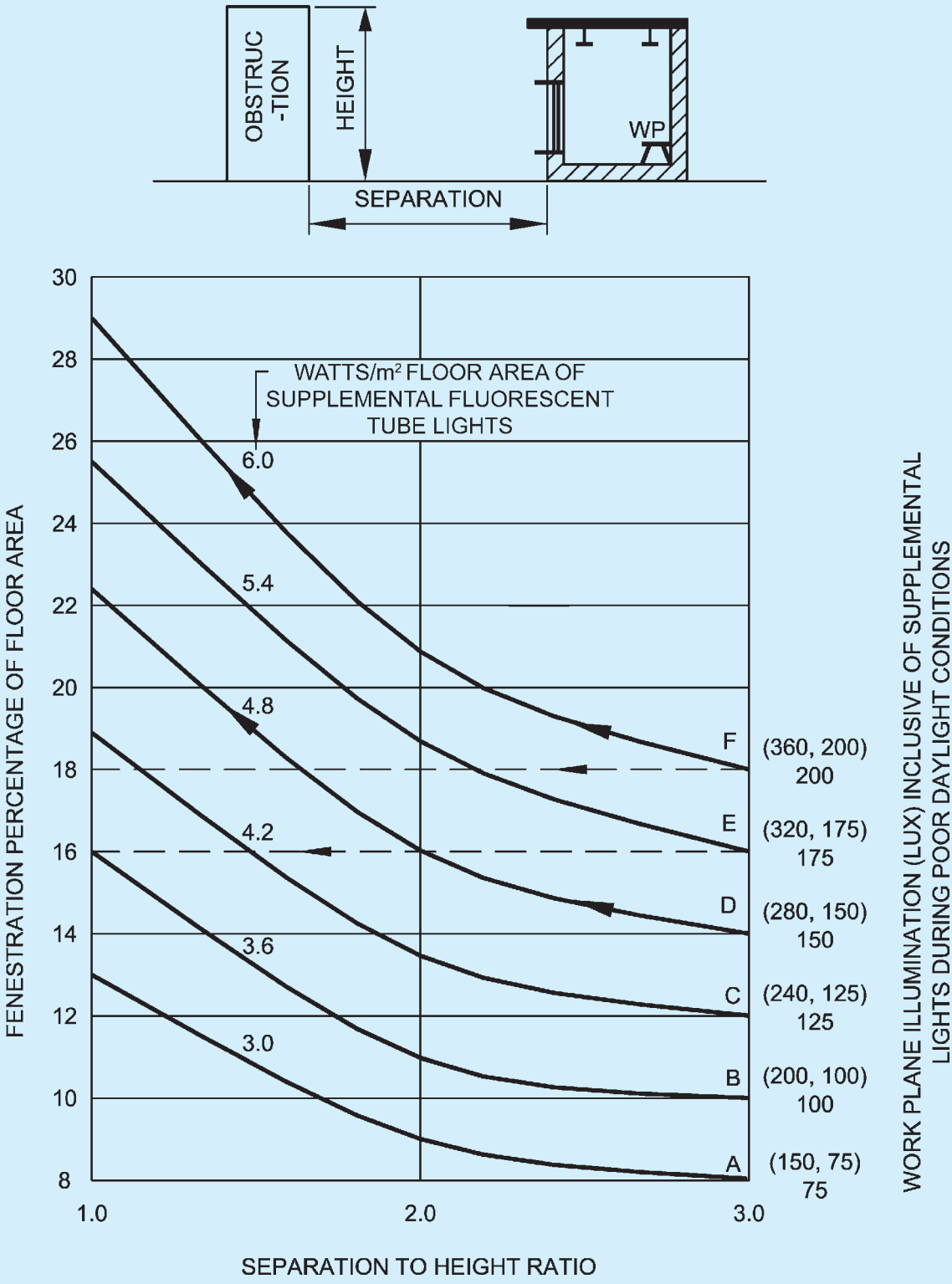


FIG. 4 NOMOGRAPH FOR DAYLIGHTING AND SUPPLEMENTAL LIGHTING DESIGN OF BUILDINGS

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purposes. However, if the fenestration provided is less than the required value, the wattage of supplementary artificial lights should be increased proportionately to make up for the deficiency of natural illumination.

4.4.4 For good distribution of day light on the working plane in a room, window height, window width and height of sill should be chosen in accordance with the following recommendations:

a) In office buildings windows of height 1.2 m or more in the centre of a bay with sill level at 1.0 to 1.2 m above floor and in residential buildings windows of height 1.0 m to 1.1 m with sill height as 0.7 m to 0.9 m above floor are recommended for good distribution of daylight indoors. Window width can accordingly be adjusted depending upon the required fenestration percentage of the floor area.

b) If the room depth is more than 10 m, windows should be provided on opposite sides for bilateral lighting.

c) It is desirable to have a white finish for ceiling and off white (light colour) to white for walls. There is about 7 percent improvement in lighting levels in changing the finish of walls from moderate to white.

4.4.5 For good distribution and integration of daylight with artificial lights the following guidelines are recommended:

a) Employ cool daylight fluorescent tubes for supplementary artificial lighting.

b) Distribute luminaries with a separation of 2 m to 3 m in each bay of 3 m to 4 m width.

c) Provide more supplementary lights such as twin tube luminaries in work areas where daylight is expected to be poor, for example in the rear region of a room having single window and in the central region of a room having windows on opposite walls. In the vicinity of windows only single tube luminaries should be provided.

4.4.6 *Artificial Lighting*

Energy conservation in lighting is affected by reducing wastage and using energy effective lamps and luminaires without sacrificing lighting quality. Measures to be followed comprise utilization of daylight, energy effective artificial lighting design by providing required illumination where needed, turning off artificial lights when not needed, maintaining lighter finishes of ceiling, walls and furnishings, and implementing periodic schedule for cleaning of luminaires and group replacement of lamps at suitable intervals. Choice of light sources with higher luminous efficacy and luminaires with appropriate light distribution is the most effective means of energy saving in lighting. However, choice of light sources also depends on the other lighting quality parameters like colour rendering index and colour temperature or appearance. For example, high pressure sodium vapour lamps, which have very high luminous efficacy, are not suitable for commercial interiors because of poor colour rendering index and colour appearance, but are highly desirable in heavy industries. Also the choice of light sources depends on the mounting height in the interiors. For example, fluorescent lamps are not preferred for mounting beyond 7 m height, when high pressure gas discharge lamps are preferred because of better optical control due to their compact size.

4.4.6.1 *Efficient artificial light sources and luminaires*

Luminous efficacies of some of the lamps used in lighting of buildings are given in Table 8 along with average life in burning hours, colour rendering index and colour temperature.

Following recommendations may be followed in the choice of light sources for different locations:

a) For supplementary artificial lighting of work area in office building care should be taken to use fluorescent lamps, which match with colour temperature of the daylight.

b) For residential buildings fluorescent lamps and/or CFLs of proper CRI and CCT are recommended to match with the colours and interior design of the room.

c) For commercial interiors, depending on the mounting heights and interior design, fluorescent lamps, CFLs and low wattage metal halide lamps are recommended. For highlighting the displays in show windows, hotels, etc, low wattage tubular or dichroic reflector type halogen lamps can be used.

d) For industrial lighting, depending on the mounting height and colour consideration fluorescent lamps, high pressure mercury vapour lamps or high pressure sodium vapour lamps are recommended.

4.4.6.2 For the same lumen output, it is possible to save 50 to 70 percent energy if CFL lamps are replaced with induction lighting, and 40 to 60 percent if replaced with LED lamps. Similar energy effective solutions are to be chosen for every application area.

Similarly with white fluorescent tubes recommended for corridors and staircases, the electrical consumption reduces to 1/4.5 of the energy consumption with incandescent lamps.

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Table 8 Luminous Efficacy, Life, Lumen Maintenance and Colour Rendition of Light Sources

(*Clause* 4.4.6.1)

Sl No.	Light Source	Wattage Range W	Efficacy lm/W	Average Life h	Lumen Maintenance	Colour Rendition
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Incandescent lamps	15 to 200	12 to 20	500 to 1 000	Fair to good	Very good
ii)	Tungsten halogen	300 to 1 500	20 to 27	200 to 2 000	Good to very good	Very good
iii)	Standard fluorescent lamps	20 to 80	55 to 65	5 000	Fair to good	Good
iv)	Compact fluorescent lamps (CFL)	5 to 40	60 to 70	7 500	Good	Good to very good
v)	Slim line fluorescent	18 to 58	57 to 67	5 000	Fair to good	Good
v)	High pressure mercury vapour lamps	60 to 1 000	50 to 65	5 000	Very low to fair	Federate
vi)	Blended - light lamps	160 to 250	20 to 30	5 000	Low to fair	Federate
vii)	High pressure sodium vapour lamps	50 to 1 000	90 to 125	10 000 to 15 000	Fair to good	Low to good
viii)	Metal halide lamps	35 to 2 000	80 to 95	4 000 to 10 000	Very low	Very good
ix)	Low pressure sodium	10 to 180	100 to 200	10 000 to 20 000	Good to very good	Poor
x)	LED	0.5 to 2.0	60 to 100	10 000	Very good	Good for white LED

NOTES

1 The table includes lamps and wattages currently in use in buildings in India.

2 Luminous efficacy varies with the wattage of the lamp.

3 Average life values are from available Indian Standards. Where Indian Standard is not available, values given are only indicative.

4 For exact values, it is advisable to contact manufacturers.

4.4.6.3 Efficient luminaire also plays an important role for energy conservation in lighting. The choice of a luminaire should be such that it is efficient not only initially but also throughout its life. Following luminaries are recommended for different locations:

a) For offices semi-direct type of luminaries are recommended so that both the work plane illumination and surround luminance can be effectively enhanced.

b) For corridors and stair cases direct type of luminaries with wide spread of light distributions are recommended.

c) In residential buildings, bare fluorescent tubes are recommended. Wherever the incandescent lamps are employed, they should be provided with white enameled conical reflectors at an inclination of about 45° from vertical.

4.4.7 *Cleaning Schedule for Window Panes and Luminaires*

Adequate schedule for cleaning of window panes and luminaries will result in significant advantage of enhanced daylight and lumen output from luminaries. This will tend to reduce the duration over which artificial lights will be used and minimise the wastage of energy. Depending upon the location of the building a minimum of three to six months interval for periodic cleaning of luminaries and window panes is recommended for maximum utilization of daylight and artificial lights.

4.4.8 *Photocontrols for Artificial Lights*

There is a considerable wastage of electrical energy in lighting of buildings due to carelessness in switching off lights even when sufficient daylight is available indoors. In offices and commercial buildings, occupants may switch on lights in the morning and keep them on throughout the day. When sufficient daylight is available inside, suitable photo controls can be employed to switch off the artificial lights and thus prevent the wastage of energy.

The photocontrol should have the following features:

a) An integrated photocontrol system continually measures the amount of visible light under the lighting fixture and maintains the lux levels as referred in Table 4.

b) An integrated photocontrol system should maintain six daylighting scenarios that can be adjusted by the user namely; daytime occupied, daytime unoccupied, sunset occupied, sunset unoccupied, night time occupied and night time unoccupied.

c) The photocontrol sensor should have a 60° cone of reference to measure the amount of light on the work surface.

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4.4.9 *Solar Photovoltaic Systems (SPV)*

Solar photovoltaic system enables direct conversion of sunlight into electricity and is a viable option for lighting purpose in remote nongrid areas. The common SPV lighting systems are:

a) Solar lantern,
b) Fixed type solar home lighting system, and
c) Street lighting system.

4.4.9.1 SPV lighting system should preferably be provided with CFL for energy efficiency.

4.4.9.2 Inverters used in buildings for supplying electricity during the power cut period should be charged through SPV system.

4.4.9.3 Regular maintenance of SPV system is necessary for its satisfactory functioning.

4.4.10 Lighting shelves and light pipes may be explored for utilization and integration in the lighting design.

5 VENTILATION

5.1 General

Ventilation of buildings is required to supply fresh air for respiration of occupants, to dilute inside air to prevent vitiation by body odours and to remove any products of combustion or other contaminants in air and to provide such thermal environments as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health of the occupants.

5.2 Design Considerations

5.2.1 *Respiration*

Supply of fresh air to provide oxygen for the human body for elimination of waste products and to maintain carbon dioxide concentration in the air within safe limits rarely calls for special attention as enough outside air for this purpose normally enters the areas of occupancy through crevices and other openings.

5.2.1.1 In normal habitable rooms devoid of smoke generating source, the content of carbon dioxide in air rarely exceeds 0.5 percent to 1 percent and is, therefore, incapable of producing any ill effect. The amount of air required to keep the concentration down to 1 percent is very small. The change in oxygen content is also too small under normal conditions to have any ill effects; the oxygen content may vary quite appreciably without noticeable effect, if the carbon dioxide concentration is unchanged.

5.2.2 *Vitiation by Body Odours*

Where no products of combustion or other contaminants are to be removed from air, the amount of fresh air required for dilution of inside air to prevent vitiation of air by body odours, depends on the air space available per person and the degree of physical activity; the amount of air decreases as the air space available per person increases, and it may vary from 20 m^3 to 30 m^3 per person per hour. In rooms occupied by only a small number of persons such an air change will automatically be attained in cool weather by normal leakage around windows and other openings and this may easily be secured in warm weather by keeping the openings open.

No standards have been laid down under *Factories Act*, 1948 as regards the amount of fresh air required per worker or the number of air changes per hour. Section 16 of the *Factories Act*, 1948 relating to overcrowding requires that at least 14 m^3 to 16 m^3 of space shall be provided for every worker and for the purpose of that section no account shall be taken of any space in a work room which is more than 4.25 m above the floor level.

NOTE — Vitiation of the atmosphere can also occur in factories by odours given off due to contaminants of the product itself, say for example, from tobacco processing in a '*Beedi*' factory. Here the ventilation will have to be augmented to keep odours within unobjectionable levels.

5.2.2.1 *Recommended values for air changes*

The standards of general ventilation are recommended/ based on maintenance of required oxygen, carbon dioxide and other air quality levels and for the control of body odours when no products of combustion or other contaminants are present in the air; the values of air changes should be as follows:

Sl No. (1)	*Application* (2)	*Air Change per Hour* (3)
1.	Assembly rooms	4-8
2.	Bakeries	20-30
3.	Banks/building societies	4-8
4.	Bathrooms	6-10
5.	Bedrooms	2-4
6.	Billiard rooms	6-8
7.	Boiler rooms	*see* Note 2
8.	Cafes and coffee bars	10-12
9.	Canteens	8-12
10.	Cellars	3-10
11.	Changing rooms	6-10
12.	Churches	1-3
13.	Cinemas and theatres	10-15
14.	Club rooms	12, *Min*
15.	Compressor rooms	10-12
16.	Conference rooms	8-12
17.	Corridors	5-10

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Sl No. (1)	*Application* (2)	*Air Change per Hour* (3)
18.	Dairies	8-12
19.	Dance halls	12, *Min*
20.	Dye works	20-30
21.	Electroplating shops	10-12
22.	Engine rooms/DG Rooms/GG Rooms	*see* Note 2
23.	Entrance halls	3-5
24.	Factories and work shops	8-10
25.	Foundries	15-30
26.	Garages	6-8
27.	Glass houses	25-60
28.	Gymnasium	6, *Min*
29.	Hair dressing saloon	10-15
30.	Hospitals sterilising	15-25
31.	Hospital wards	6-8
32.	Hospital domestic	15-20
33.	Laboratories	6-15
34.	Launderettes	10-15
35.	Laundries	10-30
36.	Lavatories	6-15
37.	Lecture theatres	5-8
38.	Libraries	3-5
39.	Lift cars	20, *Min*
40.	Living rooms	3-6
41.	Mushroom houses	6-10
42.	Offices	6-10
43.	Paint shops (not cellulose)	10-20
44.	Photo and X-ray dark room	10-15
45.	Public house bars	12, *Min*
46.	Recording control rooms	15-25
47.	Recording studios	10-12
48.	Restaurants	8-12
49.	Schoolrooms	5-7
50.	Shops and supermarkets	8-15
51.	Shower baths	15-20
52.	Stores and warehouses	3-6
53.	STP rooms	30, *Min*
54.	Squash courts	4, *Min*
55.	Swimming baths	10-15
56.	Toilets	6-10
57.	Underground vehicle parking	6, *Min*
58.	Utility rooms	15-30
59.	Welding shops	15-30

NOTES

1 The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below the ground.

2 The ventilation rate shall be as per **11.2.2** of Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code.

5.2.3 *Heat Balance of Body*

Especially in hot weather, when thermal environment inside the room is worsened by heat given off by machinery, occupants and other sources, the prime need for ventilation is to provide such thermal environment as will assist in the maintenance of heat balance of the body in order to prevent discomfort and injury to health. Excess of heat either from increased metabolism due to physical activity of persons or gains from a hot environment has to be offset to maintain normal body temperature (37°C). Heat exchange of the human body with respect to the surroundings is determined by the temperature and humidity gradient between the skin and the surroundings and other factors, such as age of persons, clothing, etc, and the latter depends on air temperature (dry bulb temperature), relative humidity, radiation from the solid surroundings and rate of air movement. The volume of outside air to be circulated through the room is, therefore, governed by the physical considerations of controlling the temperature, air distribution or air movement. Air movement and air distribution may, however, be achieved by recirculation of the inside air rather than bringing in all outside air. However, fresh air supply or the circulated air will reduce heat stress by dissipating heat from body by evaporation of the sweat, particularly when the relative humidity is high and the air temperature is near body temperature.

5.2.3.1 *Indices of thermal comfort*

Thermal comfort is that condition of thermal environment under which a person can maintain a body heat balance at normal body temperature and without perceptible sweating. Limits of comfort vary considerably according to studies carried out in India and abroad.

The thermal indices which find applications for Indian climate are as follows:

a) Effective temperature (ET),
b) Tropical summer index (TSI), and
c) Adaptive thermal comfort.

5.2.3.1.1 *Effective temperature (ET)*

Effective temperature is defined as the temperature of still, saturated air which has the same general effect upon comfort as the atmosphere under investigation. Combinations of temperature, humidity and wind velocity producing the same thermal sensation in an individual are taken to have the same effective temperature.

Initially two scales were developed, one of which referred to men stripped to the waist, and called the basic scale. The other applies to men fully clad in indoor clothing and called the normal scale of effective

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temperature. Bedfort (1946) proposed the use of globe temperature reading instead of the air temperature reading to make allowance for the radiant heat. This scale is known as the corrected effective temperature (CET) scale. No allowance, however, was made for the different rates of energy expenditure. The scale was compiled only for men either seated or engaged in light activity.

Figure 5 represents the corrected effective temperature nomogram. The CET can be obtained by connecting the appropriate points representing the dry bulb (or globe) and wet bulb temperatures and reading the CET value at the intersection of this line with the relevant air velocity curve from the family of curves for various air velocities running diagonally upwards from left to right.

The effective temperature scale may be considered to be reasonably accurate in warm climates where the heat stress is not high but it may be misleading at high levels of heat stress. There appears to be an inherent error in this scale if used as an index of physiological strain, the error increasing with the severity of the environmental conditions. For low and moderate degrees of heat stress, the effective temperature scales appear to assess climatic heat stress with an accuracy which is acceptable for most practical purposes.

5.2.3.1.2 *Tropical summer index (TSI)*

The TSI is defined as the temperature of calm air, at 50 percent relative humidity which imparts the same thermal sensation as the given environment. The 50 percent level of relative humidity is chosen for this index as it is a reasonable intermediate value for the prevailing humidity conditions. Mathematically, TSI (°C) is expressed as:

$$TSI = 0.745t_g + 0.308t_w - 2.06\sqrt{v} + 0.841$$

where

t_w = wet bulb temperature, in °C;

t_g = globe temperature, in °C; and

V = air speed, in m/s.

The thermal comfort of a person lies between TSI values of 25°C and 30°C with optimum condition at 27.5°C. Air movement is necessary in hot and humid weather for body cooling. A certain minimum desirable wind speed is needed for achieving thermal comfort at different temperatures and relative humidities. Such

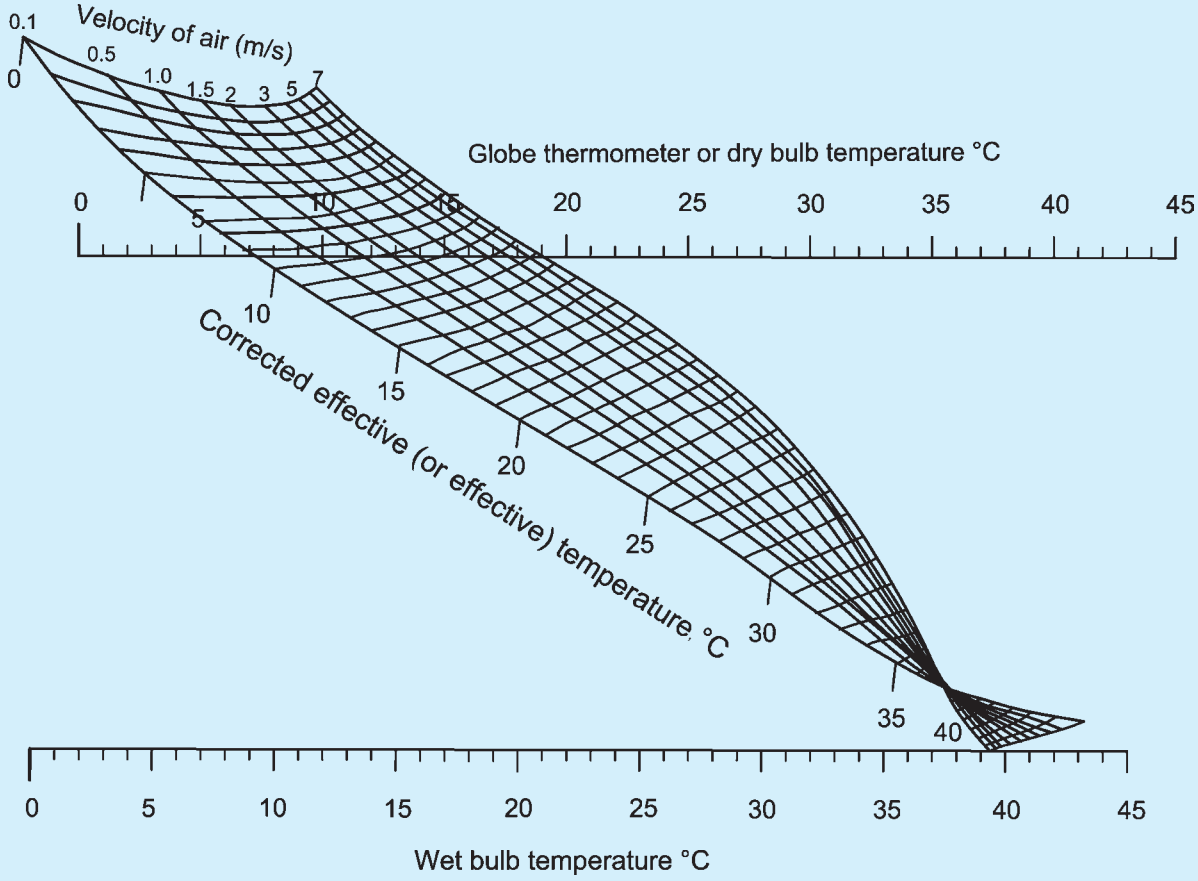


FIG. 5 CORRECTED EFFECTIVE TEMPERATURE NOMOGRAM

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wind speeds are given in Table 9. These are applicable to sedentary work in offices and other places having no noticeable sources of heat gain. Where somewhat warmer conditions are prevalent, such as in godowns and machine shops and work is of lighter intensity, and higher temperatures can be tolerated without much discomfort, minimum wind speeds for just acceptable warm conditions are given in Table 10. For obtaining values of indoor wind speed above 2.0 m/s, mechanical means of ventilation may have to be adopted (*see also* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code).

The warmth of the environment was found tolerable between 30°C and 34°C (TSI), and too hot above this limit. On the lower side, the coolness of the environment was found tolerable between 19°C and 25°C (TSI) and below 19°C (TSI), it was found too cold.

Table 9 Desirable Wind Speeds (m/s) for Thermal Comfort Conditions

(*Clause* 5.2.3.1.2)

Sl. No.	Dry Bulb Temperature °C	Relative Humidity Percent						
		30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	28	[1]	[1]	[1]	[1]	[1]	[1]	[1]
ii)	29	[1]	[1]	[1]	[1]	[1]	0.06	0.19
iii)	30	[1]	[1]	[1]	0.06	0.24	0.53	0.85
iv)	31	[1]	0.06	0.24	0.53	1.04	1.47	2.10
v)	32	0.20	0.46	0.94	1.59	2.26	3.04	[2]
vi)	33	0.77	1.36	2.12	3.00	[2]	[2]	[2]
vii)	34	1.85	2.72	[2]	[2]	[2]	[2]	[2]
viii)	35	3.20	[2]	[2]	[2]	[2]	[2]	[2]

[1] None.
[2] Higher than those acceptable in practice.

Table 10 Minimum Wind Speeds (m/s) for Just Acceptable Warm Conditions

(*Clause* 5.2.3.1.2)

Sl No.	Dry Bulb Temperature °C	Relative Humidity Percent						
		30	40	50	60	70	80	90
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	28	[1]	[1]	[1]	[1]	[1]	[1]	[1]
ii)	29	[1]	[1]	[1]	[1]	[1]	[1]	[1]
iii)	30	[1]	[1]	[1]	[1]	[1]	[1]	[1]
iv)	31	[1]	[1]	[1]	[1]	[1]	0.06	0.23
v)	32	[1]	[1]	[1]	0.09	0.29	0.60	0.94
vi)	33	[1]	0.04	0.24	0.60	1.04	1.85	2.10
vii)	34	0.15	0.46	0.94	1.60	2.26	3.05	[2]
viii)	35	0.68	1.36	2.10	3.05	[2]	[2]	[2]
ix)	36	1.72	2.70	[2]	[2]	[2]	[2]	[2]

[1] None.
[2] Higher than those acceptable in practice.

5.2.3.1.3 *Adaptive thermal comfort*

For details on adaptive thermal comfort, reference shall be made to Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of this Code.

5.2.3.2 There will be a limit of heat tolerance when air temperatures are excessive and the degree of physical activity is high. This limit is determined when the bodily heat balance is upset, that is, when the bodily heat gain due to conduction, convection and the radiation from the surroundings exceeds the bodily heat loss, which is mostly by evaporation of sweat from the surface of the body. The limits of heat tolerance for Indian workers are based on the study conducted by the Chief Adviser Factories, Government of India, Ministry of Labour and are given in his report on Thermal Stress in Textile Industry (Report No. 17) issued in 1956. According to this Report, where workers in industrial buildings wearing light clothing are expected to do work of moderate severity with the energy expenditure in the range 273 to 284 W, the maximum wet bulb temperature shall not exceed 29°C and adequate air movement subject to a minimum air velocity of 30 m/min shall be provided, and in relation to the dry bulb temperature, the wet bulb temperature of air in the work room, as far as practicable, shall not exceed that given in Table 11.

Table 11 Maximum Permissible Wet Bulb Temperatures for Given Dry Bulb Temperatures

(*Clause* 5.2.3.2)

Sl No.	Dry Bulb Temperature °C	Maximum Wet-Bulb Temperature °C
(1)	(2)	(3)
i)	30	29.0
ii)	35	28.5
iii)	40	28.0
iv)	45	27.5
v)	50	27.0

NOTES

1 These are limits beyond which the industry should not allow the thermal conditions to go for more than 1h continuously. The limits are based on a series of studies conducted on Indian subjects in psychrometric chamber and on other data on heat casualties in earlier studies conducted in Kolar Gold Fields and elsewhere.

2 Figures given in this table are not intended to convey that human efficiency at 50°C will remain the same as at 30°C, provided appropriate wet bulb temperatures are maintained. Efficiency decreases with rise in the dry bulb temperature as well, as much as possible. Long exposures to temperature of 50°C dry bulb/27°C wet bulb may prove dangerous.

3 Refrigeration or some other method of cooling is recommended in all cases where conditions would be worse than those shown in this table.

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5.3 Methods of Ventilation

General ventilation involves providing a building with relatively large quantities of outside air in order to improve general environment of the building. This may be achieved in one of the following ways:

a) Natural supply and natural exhaust of air;
b) Natural supply and mechanical exhaust of air;
c) Mechanical supply and natural exhaust of air; and
d) Mechanical supply and mechanical exhaust of air.

5.3.1 *Control of Heat*

Although it is recognized that general ventilation is one of the most effective methods of improving thermal environmental conditions in factories, in many situations, the application of ventilation should be preceded by and considered along with some of the following other methods of control. This would facilitate better design of buildings for general ventilation, either natural or mechanical or both, and also reduce their cost.

5.3.1.1 *Isolation*

Sometimes it is possible to locate heat producing equipment, such as furnaces in such a position as would expose only a small number of workers to hot environment. As far as practicable, such sources of heat in factories should be isolated.

In situations where relatively few people are exposed to severe heat stress and their activities are confined to limited areas as in the case of rolling mill operators and crane operators, it may be possible to enclose the work areas and provide spot cooling or supply conditioned air to such enclosures.

5.3.1.2 *Insulation*

A considerable portion of heat in many factories is due to the solar radiation falling on the roof surfaces, which, in turn, radiate heat inside the building. In such situations, insulations of the roof or providing a false ceiling or double roofing would be very effective in controlling heat. Some reduction can also be achieved by painting the roof in heat reflective shades.

Hot surfaces of equipment, such as pipes, vessels, etc, in the building should also be insulated to reduce their surface temperature.

5.3.1.3 *Substitution*

Sometimes, it is possible to substitute a hot process by a method that involves application of localized or more efficiently controlled method of heating. Examples include induction hardening instead of conventional heat treatment, cold riveting or spot welding instead of hot riveting, etc.

5.3.1.4 *Radiant shielding*

Hot surfaces, such as layers of molten metal emanate radiant heat, which can best be controlled by placing a shield having a highly reflecting surface between the source of heat and the worker, so that a major portion of the heat falling on the shield is reflected back to the source. Surfaces such as of tin and aluminium have been used as materials for shields. The efficiency of the shield does not depend on its thickness, but on the reflectivity and emissivity of its surface. Care should be taken to see that the shield is not heated up by conduction and for this purpose adequate provision should be made for the free flow upwards of the heated air between the hot surface and the shield by leaving the necessary air space and providing opening at the top and the bottom of the sides.

5.3.2 *Volume of Air Required*

The volume of air required shall be calculated by using both the sensible heat and latent heat gain as the bases. The larger of the two values obtained should be used in actual practice.

In places without sufficient wind speeds and/or in buildings where effective cross ventilation is not possible due to the design of the interior, the indoor air may be exhausted by a fan, with outdoor air entering the building through the open windows.

5.3.2.1 *Volume of air required for removing sensible heat*

When the amount of sensible heat given off by different sources, namely, the sun, the manufacturing processes, machinery, occupants and other sources, is known and a suitable value for the allowable temperature rise is assumed, the volume of outside air to be provided for removing the sensible heat may be calculated from:

$$Q_1 = \frac{2.976\ 8\ K_s}{t}$$

where

Q_1 = quantity of air, in m^3/h;
K_s = sensible heat gained, in W; and
t = allowable temperature rise, in °C.

5.3.2.2 Temperature rise refers mainly to the difference between the air temperatures at the outlet (roof exit) and at the inlet openings for outside air. As very little inlet data exist on allowable temperature rise values for supply of outside air in summer months, the values given in Table 12 related to industrial buildings may be used for general guidance.

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Table 12 Allowable Temperature Rise Values

(*Clause* 5.3.2.2)

Sl No.	Height of Outlet Opening m	Temperature Rise °C
(1)	(2)	(3)
i)	6	3 to 4.5
ii)	9	4.5 to 6.5
iii)	12	6.5 to 11

NOTES

1 The conditions are limited to light or medium heavy manufacturing processes, freedom from radiant heat and inlet openings not more than 3 to 4.5 m above floor level.

2 At the working zone between floor level and 1.5 m above floor level, the recommended maximum allowable temperature rise for air is 2°C to 3°C above the air temperature at the inlet openings.

5.3.2.3 *Volume of air required for removing latent heat*

If the latent heat gained from the manufacturing processes and occupants is also known and a suitable value for the allowable rise in the vapour pressure is assumed:

$$Q_2 = \frac{4\,127.26\,K_1}{h}$$

where

Q_2 = quantity of air, in m^3/h;

K_1 = latent heat gained, in W; and

h = allowable vapour pressure difference of mercury, in mm.

NOTE — In majority of the cases, the sensible heat gain will far exceed the latent heat gain, so that the amount of outside air to be drawn by ventilating equipment can be calculated in most cases on the basis of the equation given in **5.3.2.1**.

5.3.2.4 Ventilation is also expressed as $m^3/h/m^2$ of floor area. This relationship fails to evaluate the actual heat relief provided by a ventilation system, but it does give a relationship which is independent of building height. This is a more rational approach, because, with the same internal load, the same amount of ventilation air, properly applied to the work zone with adequate velocity, will provide the desired heat relief quite independently of the ceiling height of the space, with few exceptions. Ventilation rates of 30 to 60 $m^3/h/m^2$ have been found to give good results in many plants.

5.4 Natural Ventilation

The rate of ventilation by natural means through windows or other openings depends on,

a) direction and velocity of wind outside and sizes and disposition of openings (wind action); and

b) convection effects arising from temperature of vapour pressure difference (or both) between inside and outside the room and the difference of height between the outlet and inlet openings (stack effect).

5.4.1 *Ventilation of Non-Industrial Buildings*

Ventilation in non-industrial buildings due to stack effect, unless there is a significant internal load, could be neglected, except in cold regions, and wind action may be assumed to be predominant.

5.4.1.1 In hot dry regions, the main problem in summer is to provide protection from sun's heat so as to keep the indoor temperature lower than those outside under the sun. For this purpose windows and other openings are generally kept closed during day time and only minimum ventilation is provided for the control of odours or for removal of products of combustion.

5.4.1.2 In warm humid regions, the problem in the design of non-industrial buildings is to provide free passage of air to keep the indoor temperature as near to those outside in the shade as possible, and for this purpose the buildings are oriented to face the direction of prevailing winds and windows and other openings are kept open on both windward and leeward sides.

5.4.1.3 In winter months in cold regions, the windows and other openings are generally kept shut, particularly during night; and ventilation necessary for the control of odours and for the removal of products of combustion can be achieved either by stack action or by some infiltration of outside air due to wind action.

5.4.2 *Ventilation of Industrial Buildings*

In providing natural ventilation of all industrial buildings having significant internal heat loads due to manufacturing process, proper consideration should be given to the size and distribution of windows and other inlet openings in relation to outlet openings so as to give, with due regard to orientation, prevailing winds, size and configuration of the building and manufacturing processes carried on, maximum possible control of thermal environment.

5.4.2.1 In the case of industrial buildings wider than 30 m, the ventilation through windows may be augmented by roof ventilation.

5.4.3 *Design Guidelines for Natural Ventilation*

5.4.3.1 *By wind action*

1) A building need not necessarily be oriented perpendicular to the prevailing outdoor wind; it may be oriented at any convenient angle between 0° and 30° without losing any beneficial aspect of the breeze. If the prevailing wind is from East or West, building may be oriented at 45° to the incident wind so

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as to diminish the solar heat without much reduction in air motion indoors.

2) Inlet openings in the buildings should be well distributed and should be located on the windward side at a low level, and outlet openings should be located on the leeward side. Inlet and outlet openings at high levels may only clear the top air at that level without producing air movement at the level of occupancy.

3) Maximum air movement at a particular plane is achieved by keeping the sill height of the opening at 85 percent of the critical height (such as head level) for the following recommended levels of occupancy:
   a) For sitting on chair 0.75 m,
   b) For sitting on bed 0.60 m, and
   c) For sitting on floor 0.40 m.

4) Inlet openings should not as far as possible be obstructed by adjoining buildings, trees, sign boards or other obstructions or by partitions inside in the path of air flow.

5) In rooms of normal size having identical windows on opposite walls the average indoor air speed increases rapidly by increasing the width of window up to two-third of the wall width; beyond that the increase is in much smaller proportion than the increase of the window width. The air motion in the working zone is maximum when window height is 1.1m. Further increase in window height promotes air motion at higher level of window, but does not contribute additional benefits as regards air motion in the occupancy zones in buildings.

6) Greatest flow per unit area of openings is obtained by using inlet and outlet openings of nearby equal areas at the same level.

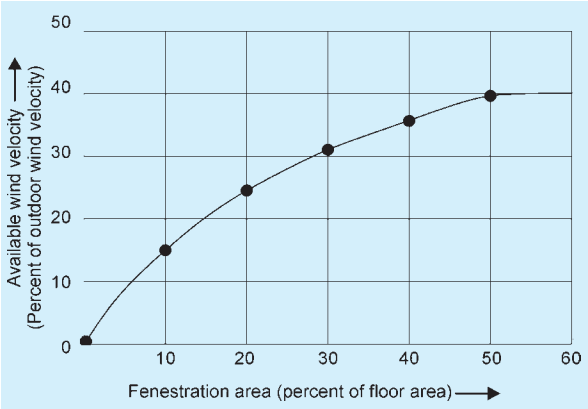


FIG. 6 EFFECT OF AREA OF OPENING ON AVERAGE INDOOR WIND VELOCITY

7) For a total area of openings (inlet and outlet) of 20 percent to 30 percent of floor area, the average indoor wind velocity is around 30 percent of outdoor velocity. Further increase in window size increases the available velocity but not in the same proportion as shown in Fig. 6. In fact, even under most favourable conditions the maximum average indoor wind speed does not exceed 40 percent of outdoor velocity.

8) Where the direction of wind is quite constant and dependable, the size of the inlet should be kept within 30 to 50 percent of the total area of openings and the building should be oriented perpendicular to the incident wind. Where direction of the wind is quite variable the openings may be arranged so that as far as possible there is approximately equal area on all sides. Thus no matter what the wind direction be, there would be some openings directly exposed to wind pressure and others to air suction and effective air movement through the building would be assured.

9) Windows of living rooms should open directly to an open space. In places where building sites are restricted, open space may have to be created in the buildings by providing adequate courtyards.

10) In the case of rooms with only one wall exposed to outside, provision of two windows on that wall is preferred to that of a single window.

11) Windows located diagonally opposite to each other with the windward window near the upstream corner give better performance than other window arrangements for most of the building orientations.

12) Horizontal louvers, that is, sunshades atop windows deflect the incident wind upward and reduce air motion in the zone of occupancy. A horizontal slot between the wall and horizontal louver prevents upward deflection of air in the interior of rooms. Provision of inverted L type (Γ) louver increases the room air motion provided that the vertical projection does not obstruct the incident wind (*see* Fig. 7).

13) Provision of horizontal sashes inclined at an angle of 45° in appropriate direction helps to promote the indoor air motion. Sashes projecting outward are more effective than projecting inward.

14) Air motion at working plane 0.4 m above the floor can be enhanced by 30 percent using a pelmet type wind deflector (*see* Fig. 8).

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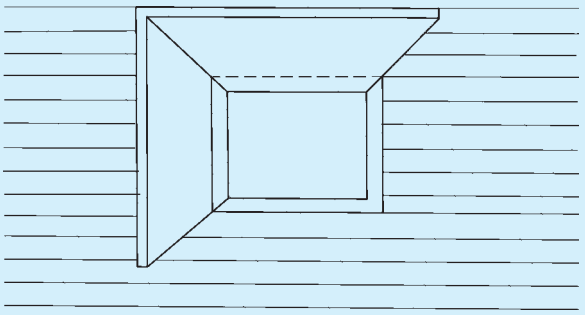


FIG. 7 L-TYPE LOUVER

15) Roof overhangs help promoting air motion in the working zone inside buildings.

16) In case of room with windows on one wall, with single window, the room wind velocity inside the room on the windward side is 10 percent of outdoor velocity at points up to a distance of one-sixth of room width from the window and then decreases rapidly and hardly any air movement is produced in the leeward half portion of the room. The average indoor wind velocity is generally less than 10 percent of outdoor velocity. When two windows are provided and wind impinges obliquely on them, the inside velocity increases up to 15 percent of the outdoor velocity.

17) Cross ventilation can be obtained through one side of the building to the other, in case of narrow buildings with the width common in the multistoreyed type by the provision of large and suitably placed windows or combination of windows and wall ventilators for the inflow and outflow of air.

18) *Verandah* open on three sides is to be preferred since it causes an increase in the room air motion for most of the orientations of the building with respect to the outdoor wind.

19) A partition placed parallel to the incident wind has little influence on the pattern of the air flow, but when located perpendicular to the main flow, the same partition creates a wind shadow. Provision of a partition with spacing of 0.3 m underneath helps augmenting air motion near floor level in the leeward compartment of wide span buildings.

20) Air motion in a building unit having windows tangential to the incident wind is accelerated when another unit is located at end-on position on downstream side (*see* Fig. 9).

21) Air motion in two wings oriented parallel to the prevailing breeze is promoted by connecting them with a block on downstream side.

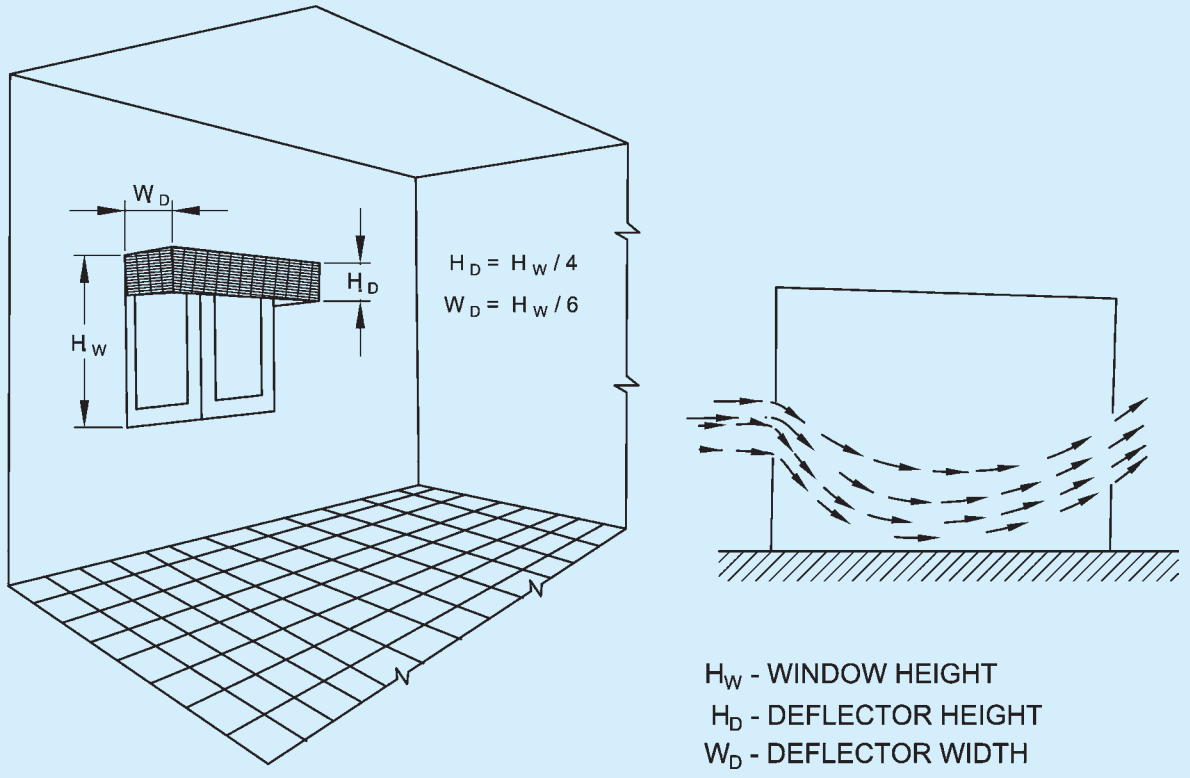


FIG. 8 SKETCH OF A PELMET TYPE WIND DEFLECTOR

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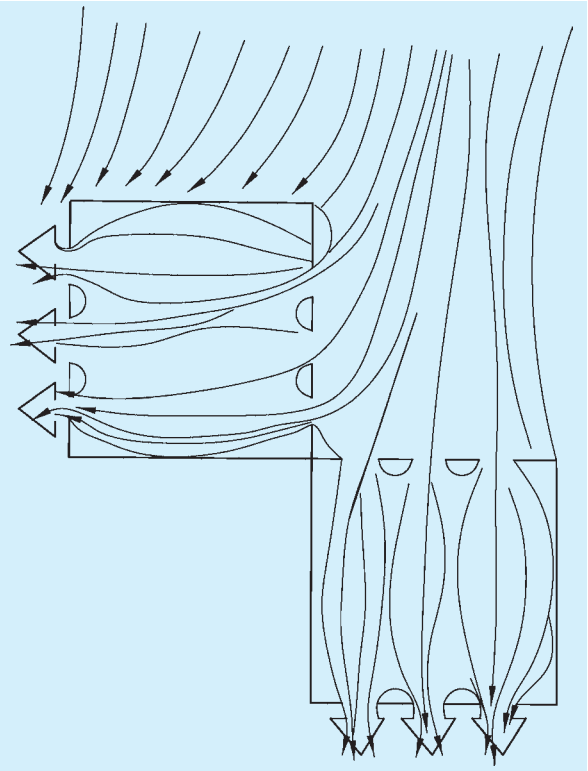


FIG. 9 TWO UNITS LOCATED AT THE END-ON POSITION

22) Air motion in a building is not affected by constructing another building of equal or smaller height on the leeward side; but it is slightly reduced if the leeward building is taller than the windward block.

23) Air motion in a shielded building is less than that in an unobstructed building. To minimise shielding effect, the distances between two rows should be 8 *H* for semi-detached houses and 10 *H* for long rows houses. However, for smaller spacing the shielding effect is also diminished by raising the height of the shielded building.

24) Hedges and shrubs defect the air away from the inlet openings and cause a reduction in indoor air motion. These elements should not be planted at a distance of about 8 m from the building because the induced air motion is reduced to minimum in that case. However, air motion in the leeward part of the building can be enhanced by planting a low hedge at a distance of 2 m from the building.

25) Trees with large foliage mass having trunk bare of branches up to the top level of window, deflect the outdoor wind downwards and promotes air motion in the leeward portion of buildings,

26) Ventilation conditions indoors can be ameliorated by constructing buildings on earth mound having a slant surface with a slope of 10° on upstream side.

27) In case of industrial buildings the window height should be about 1.6 m and width about two-third of wall width. These should be located at a height of 1.1 m above the floor. In addition to this, openings around 0.9 m high should be provided over two-third length of the glazed area in the roof lights.

28) Height of industrial buildings, although determined by the requirements of industrial processes involved, generally kept large enough to protect the workers against hot stagnant air below the ceiling as also to dilute the concentration of contaminant inside. However, if high level openings in roof or walls are provided, building height can be reduced to 4 m without in any way impairing the ventilation performance.

29) The maximum width up to which buildings of height usually found in factories, being effectively ventilated by natural means by wind action, is 30 m, beyond which sufficient reliance cannot be placed on prevailing winds. Approximately half the ventilating area of openings should be between floor level and a height of 2.25 m from the floor.

NOTE — For data on outdoor wind speeds at a place, reference may be made to 'The Climatic Data Handbook' prepared by Central Building Research Institute, Roorkee, 1999'.

5.4.3.2 *By stack effect*

Natural ventilation by stack effect occurs when air inside a building is at a different temperature than air outside. Thus in heated buildings or in buildings wherein hot processes are carried on and in ordinary buildings during summer nights and during pre-monsoon periods, the inside temperature is higher than that of outside, cool outside air will tend to enter through openings at low level and warm air will tend to leave through openings at high level. It would, therefore, be advantageous to provide ventilators as close to ceilings as possible. Ventilators can also be provided in roofs as, for example, cowl, vent pipe, covered roof and ridge vent.

5.5 Mechanical Ventilation

The requirements of mechanical ventilation shall be in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code.

5.6 Determining Rate of Ventilation

5.6.1 *Natural Ventilation*

This is difficult to measure as it varies from time to

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time. The amount of outside air through windows and other openings depends on the direction and velocity of wind outside (wind action) and/or convection effects arising from temperature or vapour pressure differences (or both) between inside and outside of the building (stack effect).

5.6.1.1 *Wind action*

For determining the rate of ventilation based on wind action the wind may be assumed to come from any direction within 45° of the direction of prevailing wind. Ventilation due to external wind is given by the following formula:

$$Q_w = K.A.V$$

where

Q_w = rate of air flow, in m^3/h;

K = coefficient of effectiveness, which may be taken as 0.6 for wind perpendicular to openings and 0.3 for wind at an angle less than 45° to the openings;

A = free area of inlet openings, in m^2; and

V = wind speed, in m/h.

NOTE — For wind data at a place, the local Meteorological Department may be consulted.

5.6.1.2 *Stack effect (thermal action)*

Ventilation due to convection effects arising from temperature difference between inside and outside is given by:

$$Q_T = 7.0\ A \sqrt{h\ (t_r - t_o)}$$

where

Q_T = rate of air flow, in m^3/h;

A = free area of inlet openings, in m^2;

h = vertical distance between inlets and outlets, in m;

t_r = average temperature of indoor air at height h, in °C; and

t_o = temperature of outdoor air, in °C.

NOTE — The equation is based on 0.65 times the effectiveness of openings. This should be reduced to 0.50, if conditions are not favourable.

5.6.1.3 When areas of inlet and outlet openings are unequal, the value of A may be calculated using the equation:

$$\frac{2}{A^2} = \frac{1}{A_{inlet}^{\ 2}} + \frac{1}{A_{outlet}^{\ 2}}$$

5.6.1.4 *Combined Effect of Wind and Thermal Action*

When both forces (wind and thermal) act together in the same direction, even without interference, the resulting air flow is not equal to the two flows estimated separately.

When acting simultaneously, the rate of air flow through the building may be computed by the following equation:

$$Q^2 = Q_w^{\ 2} + Q_t^{\ 2}$$

where

Q = resultant volume of air flow, in m^3/min;

Q_w = volume of air flow due to wind force, in m^3/min; and

Q_t = volume of air flow due to thermal force, in m^3/min.

Wind velocity and direction, outdoor temperature, and indoor distribution cannot be predicted with certainty, and refinement in calculation is not justified. A simple method is to calculate the sum of the flows produced by each force separately. Then using the ratio of the flow produced by thermal forces to the aforementioned sum, the actual flow due to the combined forces can be approximated from Fig. 10. When the two flows are equal, the actual flow is about 30 percent greater than the flow caused by either force acting independently (*see* Fig. 10).

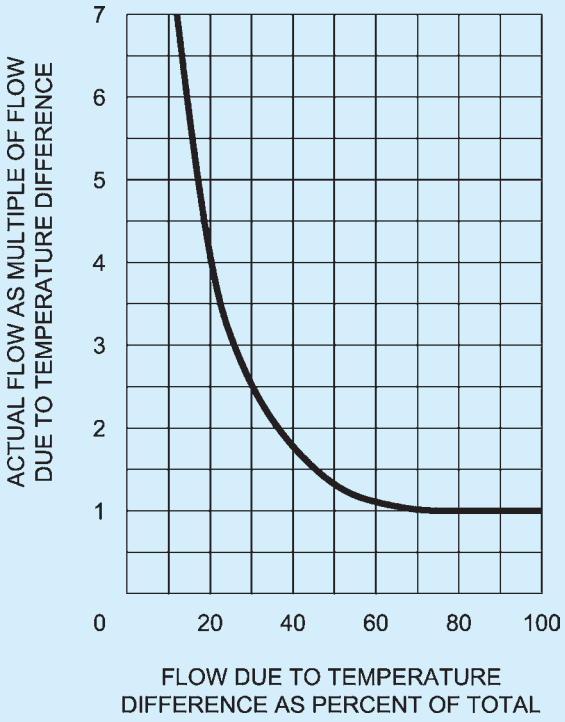


FIG. 10 DETERMINATION OF FLOW CAUSED BY COMBINED FORCES OF WIND AND TEMPERATURE DIFFERENCE

Judgment is necessary for proper location of openings in a building specially in the roof, where heat, smoke and fumes are to be removed. Usually, windward

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monitor openings should be closed, but if wind is so slight that temperature head can overcome it, all openings may be opened.

5.6.1.5 For method for determining the rate of ventilation based on probable indoor wind speed with typical illustrative example for residential building, reference may be made to **A-4** of good practice [9-1(6)].

5.6.2 *Mechanical Ventilation*

The determination of rate of ventilation in case of mechanical ventilation shall be done in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code.

5.6.3 *Combined effect of Different Methods of Ventilation*

When combination of two or more methods of general ventilation is used, the total rate of ventilation shall be reckoned as the highest of the following three, and this rule shall be followed until an exact formula is established by research:

a) 1.25 times the rate of natural ventilation,
b) Rate of positive ventilation, and
c) Rate of exhaust of air.

5.6.4 *Measurement of Air Movement*

The rate of air movement of turbulent type at the working zone shall be measured either with a Kata thermometer (dry silvered type) or heated thermometer or properly calibrated thermocouple anemometer. Whereas anemometer gives the air velocity directly, the Kata thermometer and heated thermometer give cooling power of air and the rate of air movement is found by reference to a suitable nomogram using the ambient temperature.

5.7 Energy Conservation in Ventilation System

5.7.1 Maximum possible use should be made of wind induced natural ventilation. This may be accomplished by following the design guidelines given in **5.7.1.1**.

5.7.1.1 Adequate number of circulating fans should be installed to serve all interior working areas during summer months in the hot dry and warm humid regions to provide necessary air movement at times when ventilation due to wind action alone does not afford sufficient relief.

5.7.1.1.1 The capacity of a ceiling fan to meet the requirement of a room with the longer dimension D metre should be about $55D$ m^3/min.

5.7.1.1.2 The height of fan blades above the floor should be $(3H + W)/4$, where H is the height of the room, and W is the height of work plane.

5.7.1.1.3 The minimum distance between fan blades and the ceiling should be about 0.3 m.

5.7.2 Electronic regulators should be used instead of resistance type regulators for controlling the speed of fans.

5.7.3 When actual ventilated zone does not cover the entire room area, then optimum size of ceiling fan should be chosen based on the actual usable area of room, rather than the total floor area of the room. Thus smaller size of fan can be employed and energy saving could be achieved.

5.7.4 Power consumption by larger fans is obviously higher, but their power consumption per square metre of floor area is less and service value higher. Evidently, improper use of fans irrespective of the rooms' dimensions is likely to result in higher power consumption. From the point of view of energy consumption, the number of fans and the optimum sizes for rooms of different dimensions are given in Table 13.

Table 13 Optimum Size/Number of Fans for Rooms of Different Sizes

(*Clause* 5.7.4)

Sl No.	Room Width m	**Optimum Size**, mm/Number of Fans for Room Length										
		4 m	5 m	6 m	7 m	8 m	9 m	10 m	11 m	12 m	14 m	16 m
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	3	1 200/1	1 400/1	1 500/1	1 050/2	1 200/2	1 400/2	1 400/2	1 400/2	1 200/3	1 400/3	1 400/3
ii)	4	1 200/1	1 400/1	1 200/2	1 200/2	1 200/2	1 400/2	1 400/2	1 500/2	1 200/3	1 400/3	1 500/3
iii)	5	1 400/1	1 400/1	1 400/2	1 400/2	1 400/2	1 400/2	1 400/2	1 500/2	1 400/3	1 400/3	1 500/3
iv)	6	1 200/2	1 400/2	900/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
v)	7	1 200/2	1 400/2	1 050/4	1 050/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vi)	8	1 200/2	1 400/2	1 200/4	1 200/4	1 200/4	1 400/4	1 400/4	1 500/4	1 200/6	1 400/6	1 500/6
vii)	9	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
viii)	10	1 400/2	1 400/2	1 400/4	1 400/4	1 400/4	1 400/4	1 400/4	1 500/4	1 400/6	1 400/6	1 500/6
ix)	11	1 500/2	1 500/2	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/4	1 500/6	1 500/6	1 500/6
x)	12	1 200/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 200/7	1 400/9	1 400/9
xi)	13	1 400/3	1 400/3	1 200/6	1 200/6	1 200/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9
xii)	14	1 400/3	1 400/3	1 400/6	1 400/6	1 400/6	1 400/6	1 400/6	1 500/6	1 400/9	1 400/9	1 500/9

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ANNEX A

(*Clause* 3.4.1)

METHOD OF CALCULATING SOLAR LOAD ON VERTICAL SURFACES OF DIFFERENT ORIENTATION

A-1 DETAILS OF CALCULATION

A-1.1 The solar energy above the earth's atmosphere is constant and the amount incident on unit area normal to sun's rays is called solar constant (1.360 8 kWm^{-2} or 2 $cal/cm^2/min$). This energy, in reaching the earth's surface, is depleted in, the atmosphere due to scattering by air molecules, water vapour, dust particles, and absorption by water vapour and ozone. The depletion varies with varying atmospheric conditions. Another important cause of depletion is the length of path traversed by sun's rays through the atmosphere. This path is the shortest when sun is at the zenith and, as the altitude of the sun decreases, the length of path in the atmosphere increases. Figure 11 gives the computed incident solar energy/hour on unit surface area normal to the rays under standard atmospheric conditions (*see* Note below) for different altitudes of the sun.

NOTE — The standard atmospheric conditions assumed for this computation are: cloud-free, 300 dust particles per cm^3, 15 mm of precipitable water, 2.5 mm of ozone, at sea level.

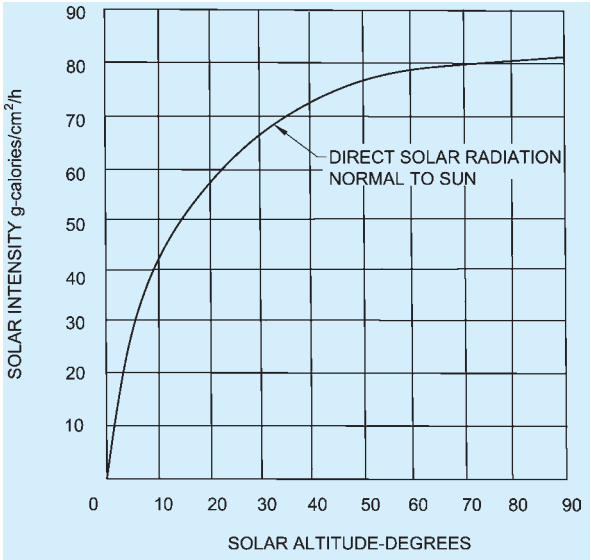


FIG. 11 DIRECT SOLAR INTENSITIES NORMAL TO SUN AT SEA LEVEL FOR STANDARD CONDITION (COMPUTED)

A-1.2 In order to calculate the solar energy on any surface other than normal to the rays, the altitude of the sun at that time should be known. The corresponding value of direct solar radiation (I_N) should then be found with the help of Fig. 12. The solar radiation incident on any surface (I_S) is given by:

$$I_S = I_N \left(\sin \beta \sin \phi + \cos \beta \cos \alpha \cos \phi\right)$$

where

β = solar altitude,

ϕ = angle tilt of the surface from the vertical (*see* Fig. 12), and

α = wall solar azimuth angle.

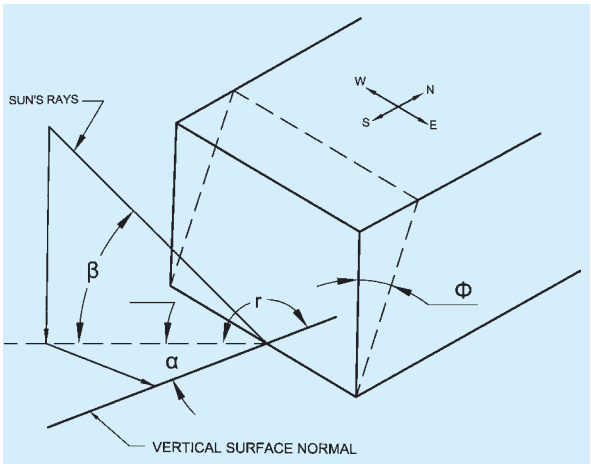


FIG. 12 DEFINITION OF SOLAR ANGLES

A-2 EXAMPLE TO FIND OUT ORIENTATION ON THE BASIS OF SOLAR LOAD

A-2.1 Example

A-2.1.1 As an example, a simple building with flat roof, 10 m × 20 m, and 4 m high is dealt with below. For the sake of generalization, no shading device or verandah is taken.

A-2.1.2 As the roof is horizontal, it will receive the same solar heat in any orientation.

A-2.1.3 The area of the vertical surfaces are 4 m × 10 m = *A* (say) and 4 m × 20 m = 2*A*. Since, the external wall surface are not in shade except when the sun is not shining on them, the total solar load in a day on a surface can be obtained by multiplying the total load per unit area per day (*see* Table 3) by the area of the surface. For four principal orientations of the building, the total solar load on the building is worked out in Table 14.

A-2.1.4 From Table 14, it can be seen that for the above type of building, orientation 3 (longer surface facing North and South) is appropriate as it affords maximum solar heat gain in winter and in summer. This is true for all places of India from the point of solar heat gain. By further increasing the length to breadth ratio, the

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Table 14 Solar Heat Gained Due to Orientation of Buildings

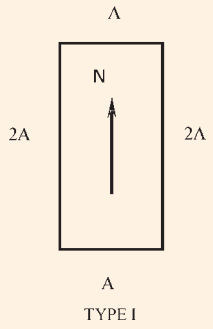
(*Clause* A-2.1.3)

		8° N THIRUVANANTHAPURAM		13° N CHENNAI	
		May 16	Dec 22	May 16	Dec 22
1.	North	2 177 × A = 2 177A	—	1 625 × A = 1 625A	—
	East	2 618 × 2A = 5 236A	2 177 × 2A = 4 354A	2 697 × 2A = 5 394A	2 019 × 2A = 4 038A
	South	—	4 164 × A = 4 164A	—	4 385 × A = 4 385A
	West	2 618 × 2A = 5 236A	2 177 × 2A = 4 354A	2 697 × 2A = 5 394A	2 019 × 2A = 4 038A
	Total	12 649A	12 872A	12 413A	12 461A
2.	NE	2 650 × A = 2 650A	410 × A = 410A	2 492 × A = 2 492A	315 × A = 315A
	SE	1 167 × 2A = 2 334A	3 391 × 2A = 6 782A	1 341 × 2A = 2 682A	3 423 × 2A = 6 846A
	SW	1 167 × 2A = 2 334A	3 391 × A = 3 391A	1 341 × A = 1 341A	3 423 × A = 3 423A
	NW	2 650 × 2A = 5 300A	410 × 2A = 820A	2 492 × A = 4 984A	315 × 2A = 630A
	Total	12 618A	11 403A	11 499A	11 214A
3.	North	2 177 × 2A = 4 354A	—	1 625 × 2A = 3 250A	—
	East	2 618 × A = 2 618A	2 177 × A = 2 177A	2 697 × A = 2 697A	2 019 × A = 2 019A
	South	—	4 164 × 2A = 8 328A	—	4 385 × 2A = 8 770A
	West	2 618 × A = 2 618A	2 177 × A = 2 177A	2 697 × A = 2 697A	2 019 × A = 2 019A
	Total	9 590A	12 602A	8 644A	12 808A
4.	NE	2 650 × 2A = 5 300A	—	2 492 × A = 4 984A	315 × 2A = 630A
	SE	1 167 × A = 1 167A	2 177 × A = 2 177A	1 341 × A = 1 341A	3 423 × A = 3 423A
	SW	1 167 × 2A = 2 334A	4 164 × 2A = 8 328A	1 341 × 2A = 2 682A	3 423 × 2A = 6 846A
	NW	2 650 × A = 2 650A	2 177 × A = 2 177A	2 492 × A = 2 492A	315 × A = 315A
	Total	11 451A	12 682A	11 499A	11 214A
		19° N MUMBAI		23° N KOLKATA	
		May 16	Dec 22	May 16	Dec 22
1.	North	962 × A = 962A	—	741 × A = 741A	—
	East	2 795 × 2A = 5 590A	1 830 × 2A = 3 660A	2 871 × 2A = 5 742A	1 703 × 2A = 3 406A
	South	—	4 574 × A = 4 574A	205 × A = 205A	4 637 × A = 4 637A
	West	2 795 × 2A = 5 590A	1 830 × 2A = 3 660A	2 871 × 2A = 5 742A	1 703 × 2A = 3 406A
	Total	12 142A	11 894A	12 430A	11 449A
2.	NE	2 255 × A = 2 255A	237 × A = 237A	2 192 × A = 2 192A	173 × A = 173A
	SE	1 640 × 2A = 3 280A	3 438 × 2A = 6 876A	1 845 × 2A = 3 690A	3 454 × 2A = 6 908A
	SW	1 640 × A = 1 640A	3 438 × A = 3 438A	1 845 × A = 1 845A	3 454 × A = 3 454A
	NW	2 255 × 2A = 4 510A	237 × 2A = 474A	2 192 × 2A = 4 384A	173 × 2A = 346A
	Total	11 685A	11 025A	12 111A	10 881A
3.	North	962 × 2A = 1 924A	—	741 × 2A = 1 482A	—
	East	2 795 × A = 2 795A	1 830 × A = 1 830A	2 871 × A = 2 871A	1 703 × A = 1 703A
	South	—	4 574 × 2A = 9 148A	205 × 2A = 410A	4 637 × 2A = 9 274A
	West	2 795 × A = 2 795A	1 830 × A = 1 830A	2 871 × A = 2 871A	1 703 × A = 1 703A
	Total	7 514A	12 808A	7 634A	12 680A
4.	NE	2 255 × 2A = 4 510A	237 × 2A = 474A	2 192 × 2A = 4 384A	173 × 2A = 346A
	SE	1 640 × A = 1 640A	3 438 × A = 3 438A	1 845 × A = 1 845A	3 454 × A = 3 454A
	SW	1 640 × 2A = 3 280A	3 438 × 2A = 6 876A	1 845 × 2A = 3 690A	3 454 × 2A = 6 908A
	NW	2 255 × A = 2 255A	237 × A = 237A	2 192 × A = 2 192A	173 × A = 173A
	Total	11 685A	11 025A	12 111A	10 881A

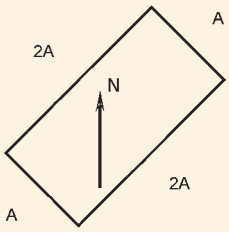
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Table 14 — (*Concluded*)

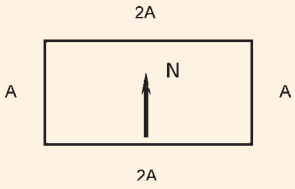
		29° N DELHI	
		May 16	Dec 22
1.	North	536 × A = 536A	—
	East	2 950 × 2A = 5 900A	1 467 × 2A = 2 934A
	South	741 × A = 741A	4 543 × A = 4 543A
	West	2 950 × 2A = 5 900A	1 467 × 2A = 2 934A
	Total	13 077A	10 411A
2.	NE	2 098 × A = 2 098A	110 × A = 110A
	SE	2 192 × 2A = 4 384A	3 265 × 2A = 6 530A
	SW	2 192 × A = 2 192A	3 265 × A = 3 265A
	NW	2 098 × 2A = 4 196A	110 × 2A = 220A
	Total	12 870A	10 125A
3.	North	536 × 2A = 1 072A	—
	East	2 950 × A = 2 950A	1 467 × A = 1 467A
	South	741 × 2A = 1 482A	4 543 × 2A = 9 086A
	West	2 950 × A = 2 950A	1 467 × A = 1 467A
	Total	8 454A	12 020A
4.	NE	2 098 × 2A = 4 196A	110 × 2A = 220A
	SE	2 192 × A = 2 192A	3 265 × A = 3 265A
	SW	2 192 × 2A = 4 384A	3 265 × 2A = 6 530A
	NW	2 098 × A = 4 196A	110 × A = 110A
	Total	12 870A	10 125A



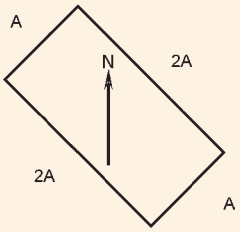
TYPE I



TYPE II



TYPE III



TYPE IV

advantage of this orientation will be more pronounced. It may also be noted that in higher altitudes, the relative merit of this orientation is more.

A-2.1.5 It is also seen that the total solar heat on the building is the same for orientation 2 and 4. But if the site considerations require a choice between these two, orientation 2 should be preferred at places north of latitude 23°N and orientation 4 at southern places. This is so because the total solar load per unit area in summer on the north western wall decreases with the increase in latitude and that on the south western wall increases. It would, therefore, be advantageous to face only smaller surface of the building to greater solar load in the summer afternoons, when the air temperature also is higher.

A-2.1.6 At hill stations, winter season cause more discomfort and so sole criterion for optimum orientation should be based on receiving maximum solar energy on building in winter.

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ANNEX B

(*Clauses* 4.2.5, 4.2.5.2, 4.2.5.4 *and* 4.2.6.1)

SKY COMPONENT TABLES

B-1 DESCRIPTION OF TABLES

B-1.1 The three sky component tables are as given below:

a) *Table* 15 — Percentage sky components on the horizontal plane due to a vertical rectangular opening for the clear design sky.

b) *Table* 16 — Percentage sky components on the vertical plane perpendicular to a vertical rectangular opening for the clear design sky.

c) *Table* 17 — Percentage sky components on the vertical plane parallel to a vertical rectangular opening for the clear design sky.

B-1.2 All the tables are for an unglazed opening illuminated by the clear design sky.

B-1.3 The values tabulated are the components at a point *P* distant from the opening on a line perpendicular to the plane of the opening through one of its lower corners, and *l* and *h* are the width and height respectively of the rectangular opening (*see* Fig. 13).

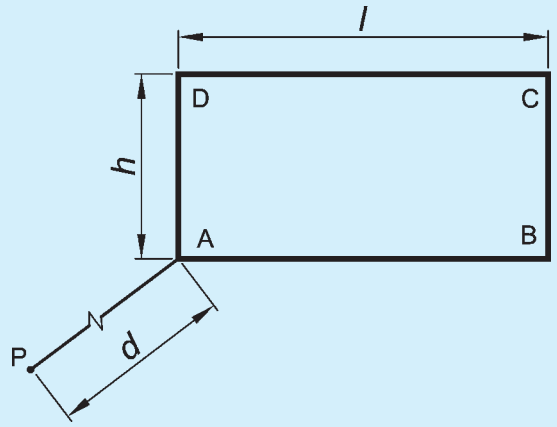


FIG. 13

B-1.4 Sky component for different *h*/*d* and *l*/*d* values are tabulated, that is, for windows of different size and for different distances of the point *P* from the window.

B-1.5 By suitable combination of the values obtained from the three tables, for a given point for a given window, the sky component in any plane passing through the point may be obtained.

B-1.6 Method of Using the Tables

B-1.6.1 Method of using the Tables to get the sky component at given point is explained with help of the following example.

B-1.6.2 *Example*

It is desired to calculate the sky component due to a vertical window ABCD with width 1.8 m and height 1.5 m at a point P on a horizontal plane 3.0 m from the window wall located as shown in the Fig. 14. Foot of the perpendicular N is 0.6 m below the sill and 0.9 m to the left of AD.

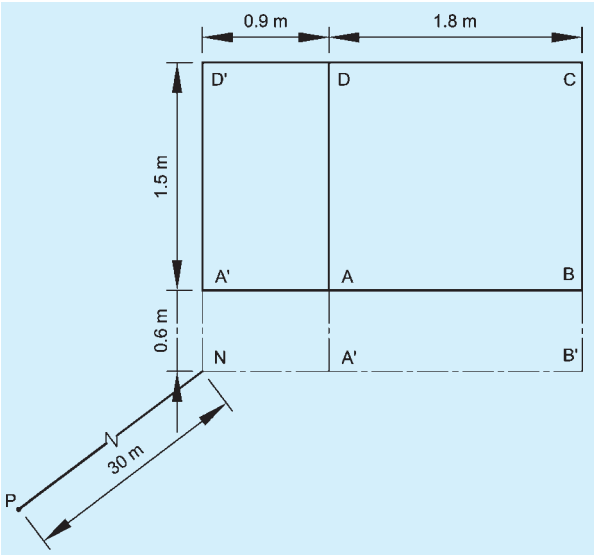


FIG. 14

Consider ABCD extended to NB′CD′

1) For NB′CD′
   $l/d = (1.8 + 0.9)/3 = 0.9$
   $h/d = (1.5 + 0.6)/3 = 0.7$
   $F_1 = 5.708$ percent (from Table 15)

2) For NA′DD′
   $l/d = 0.9/3 = 0.3$
   $h/d = (1.5 + 0.6)/3 = 0.7$
   $F_2 = 2.441$ percent (from Table 15)

3) For NB′BA′
   $l/d = (1.8 + 0.9)/3 = 0.9$
   $h/d = 0.6/3 = 0.2$
   $F_3 = 0.878$ percent (from Table 15)

4) For NA′AA′
   $l/d = 0.9/3 = 0.3$
   $h/d = 0.6/3 = 0.2$
   $F_4 = 0.403$ percent (from Table 15)

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Since ABCD = NB′CD′–NA′DD′–NB′BA′ + NA′AA′

Sky Component, $F = F_1 - F_2 - F_3 + F_4$
$= 5.708 - 2.441 - 0.878 + 0.403$
$= 2.792$

B-2 GENERAL INSTRUCTIONS

B-2.1 For irregular obstructions like row of trees parallel to the plane of the window, equivalent straight boundaries horizontal and vertical, may be drawn.

B-2.2 For extremely irregular obstruction or obstructions not in a plane parallel to the window, diagrammatic methods, such as Waldrams diagrams may have to be employed.

B-2.3 For bay windows, dormer windows or corner windows the effective dimensions of window opening computed should be taken when using the tables to find the sky components.

B-3 CALCULATION OF IRC

B-3.1 The internal reflected component is a variable quantity which varies from point to point in a room depending upon the interior finish. IRC value is maximum at the centre of the room and decreases elsewhere in all directions. For processing calculations of IRC at any given point of the room, special techniques have to be made out. The internal reflected component may be calculated by using the formula:

$$\text{IRC} = \frac{0.85W}{A(1-R)}(CR_{\text{fw}} + 10R_{\text{cw}})$$

where

W = window area;

C = constant of value 78 when there is no external obstruction but it has different values as shown in the following table when there are obstructions:

Angle of Obstruction Degree (1)	*Sky + External Obstruction,* C (2)
5	68.9
15	50.6
25	36.2
35	26.7
45	20.1
55	15.8
65	12.9
75	11.1
85	10.36

R_{fw} = average reflection factor of the floor and those parts of the wall below the plane of the mid-height of the window (excluding the window wall);

R_{cw} = average reflection factor of the ceiling and those parts of the wall above the plane of the mid-height of the window (excluding the window wall);

A = area of all the surfaces in the room (ceiling walls, floor and windows); and

R = average reflection factor of all surfaces in the room (ceiling, walls, floor and windows) expressed as a decimal part of unity.

B-3.2 Example

Consider two rooms of dimensions:

Room X = 6 m (l) × 5 m (w) × 3 m (ht)

Room Y = 3.7 m × 3 m × 3 m

Let the window area be 15 percent of the floor area and be glazed.

Window size in room X = 2.5 m × 1.8 m

Window size in room 3.7 m × 3 m

The window are on the Y = 6 m × 3 m side in room X and 3.7 m × 3 m side in room Y, and the sill heights are 0.9 m from floor level.

Reflection coefficients of:

walls and ceiling	= 70 percent
floor	= 20 percent
glazing	= 15 percent

Value of IRC in room X:

a) Total interior area, $A = 2\,(30 + 18 + 15)$
$= 126\ \text{m}^2$

b) Average reflection factor of interior:

$$R = \frac{61.5\times0.7 + 30\times0.7 + 30\times0.2 + 4.5\times0.15}{61.5 + 30 + 30 + 4.5} = 0.56$$

c) $1 - R = 0.44$

d) Mid-height of window is 1.83 m from floor, average reflection factor of room below 1.83 m level excluding the wall containing the window:

$$R_{\text{fw}} = \frac{29.28\times0.7 + 30\times0.2}{29.28 + 30} = 0.45$$

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e) Average reflection factor of room above 1.83 m level excluding the wall containing the window:

$$R_{cw} = \frac{18.72 \times 0.7 + 30 \times 0.7}{18.72 + 30} = 0.7$$

f) $$\text{IRC} = \frac{0.85 \times 4.5}{126 \times 0.44}(78 \times 0.45 + 10 \times 0.7)$$
$$= 2.904$$

Value of IRC in room Y:

a) Total interior area:

$$A = 2(3.7 \times 3 + 3.7 \times 3 + 3 \times 3) = 62.4 \text{ m}^2$$

b) Average reflection factor:

$$R = \frac{38 \times 55 \times 0.7 \times 3 \times 0.7 + 3.7 \times 3 \times 0.2 + 1.5 \times 1.1 \times 0.15}{38.55 + 11.1 + 11.1 + 1.65} = 0.596$$

c) Mid-height of window from floor = 1.46 m

d) Average reflection factor below 1.46 m level

$$R_{fw} = \frac{3.7 \times 3 \times 0.7 + 1.54 \times 9.7 \times 0.7}{11.1 + 14.94} = 0.7$$

e) Average reflection factor above 1.46 m level

$$R_{cw} = \frac{3.7 \times 3 \times 0.7 + 1.54 \times 9.7 \times 0.7}{11.1 + 14.94} = 0.7$$

f) $$\text{IRC} = \frac{0.85 \times 1.65}{62.4 \times 0.404}(78 \times 0.48 + 10 \times 0.7)$$
$$= 2.472$$

B-4 GENERAL NOTE ON DAYLIGHTING OF BUILDNG

B-4.1 The main aim of day lighting design is how to admit enough light for good visibility without setting up uncomfortable glare. No simple solution may be given as the sky varies so much in its brightness from hour to hour, and from season to season.

B-4.2 Different visual tasks need differing amounts of lights for the same visual efficiency. The correct amount of light for any task is determined by the following:

a) *Characteristics of the tasks* — Size of significant detail, contrast of detail with background and how close it is to the eyes;

b) *Sight of the worker* — For example, old people need more light;

c) Speed and accuracy necessary in the performance of work. If no errors are permissible, much more light is needed; and

d) *Ease and comfort of working* — Long and sustained tasks shall be done easily whereas workers can make a special effort for tasks of very short duration.

These factors have been made the subject of careful analysis as a result of which tables of necessary levels of illumination have been draw up.

B-4.3 Levels of lighting determined analytically shall be translated into levels of daylight and then into size of window opening or vice versa for checking the size of window assumed for required levels of daylight.

B-4.4 One of the many important factors involved in the translation is the lightness of the room surface. The illumination levels in a given room with a finite window will be higher when the walls are light coloured than when these are dark coloured. It is necessary, therefore, at an early stage to consider the colouring of the rooms of the building and not to leave this until later. Lighting is not merely a matter of window openings and quite half the eventual level of lighting may be dependent on the decoration in the room. Whatever may be the colour the occupant wants to use, it is most desirable to maintain proper values of reflectance factors for ceiling, wall and floors so that the level of daylight illumination is maintained.

Table 15 Percentage Sky Components on the Horizontal Plane Due to a Vertical Rectangular Opening for the Clear Design Sky

(*Clauses* B-1.1 *and* B-1.6.2)

l/d *h/d*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.036	0.071	0.104	0.133	0.158	0.179	0.198	0.213	0.225	0.235	0.243	0.250	0.256	0.261	0.264	0.268	0.270	0.272	0.274	0.276	0.284	0.286	0.287	0.288	0.288
0.2	0.141	0.277	0.403	0.516	0.614	0.699	0.770	0.829	0.878	0.918	0.950	0.977	0.999	1.018	1.033	1.046	1.056	1.065	1.072	1.079	1.110	1.118	1.122	1.125	1.125
0.3	0.300	0.589	0.859	1.102	1.315	1.499	1.653	1.782	1.888	1.976	2.048	2.108	2.157	2.197	2.231	2.259	2.282	2.302	2.318	2.333	2.401	2.421	2.429	2.436	2.437
0.4	0.460	0.905	1.322	1.702	2.041	2.337	2.590	2.804	2.984	3.134	3.258	3.361	3.446	3.516	3.574	3.623	3.664	3.699	3.728	3.753	3.873	3.909	3.922	3.935	3.937
0.5	0.604	1.189	1.741	2.247	2.700	3.099	3.444	3.740	3.992	4.204	3.383	4.553	4.659	4.765	4.853	4.928	4.990	5.043	5.088	5.126	5.312	5.366	5.387	5.408	5.410
0.6	0.732	1.443	2.114	2.732	3.289	3.781	4.211	4.582	4.900	5.171	5.401	5.596	5.761	5.901	6.020	6.121	6.208	6.281	6.344	6.397	6.661	6.739	6.769	6.798	6.802
0.7	0.844	1.665	2.441	3.159	3.808	4.385	4.891	5.330	5.708	6.034	6.311	6.548	6.751	6.924	7.071	7.198	7.307	7.400	7.481	7.551	7.902	8.006	8.047	8.087	8.092
0.8	0.942	1.858	2.727	3.532	4.262	4.914	5.488	5.989	6.423	6.798	7.119	7.395	7.632	7.836	8.011	8.162	8.292	8.405	8.502	8.587	9.029	9.164	9.217	9.268	9.276
0.9	1.026	2.025	2.974	3.855	4.657	5.375	6.011	6.567	7.051	7.470	7.832	8.144	8.413	8.645	8.846	9.019	9.170	9.301	9.415	9.515	10.045	10.214	10.280	10.345	10.355
1.0	1.099	2.169	3.188	4.135	5.000	5.776	6.465	7.071	7.600	8.060	8.458	8.803	9.102	9.361	9.585	9.780	9.950	10.098	10.228	10.343	10.957	11.162	11.243	11.323	11.335
1.1	1.161	2.294	3.372	4.377	5.296	6.124	6.861	7.510	8.079	8.576	9.008	9.383	9.709	9.992	10.239	10.454	10.642	10.806	10.951	11.078	11.776	12.017	12.114	12.209	12.224
1.2	1.215	2.401	3.531	4.586	5.553	6.425	7.204	7.893	8.498	9.027	9.489	9.892	10.243	10.549	10.816	11.050	11.254	11.434	11.593	11.732	12.509	12.786	12.900	13.013	13.030
1.3	1.262	2.493	3.668	4.767	5.775	6.687	7.503	8.226	8.863	9.422	9.912	10.339	10.713	11.040	11.326	11.577	11.797	11.992	12.163	12.314	13.167	13.478	13.609	13.742	13.762
1.4	1.302	2.573	3.787	4.924	5.968	6.915	7.764	8.517	9.183	9.769	10.283	10.733	11.127	11.473	11.777	12.044	12.279	12.487	12.670	12.833	13.758	14.102	14.251	14.404	14.427
1.5	1.337	2.643	3.891	5.060	6.136	7.114	7.991	8.772	9.664	10.073	10.609	11.080	11.493	11.857	12.176	12.458	12.707	12.927	13.122	13.295	14.289	14.666	14.832	15.006	15.033
1.6	1.367	2.703	3.981	5.179	6.283	7.287	8.190	8.996	9.710	10.341	10.897	11.386	11.817	12.196	12.531	12.826	13.088	13.319	13.525	13.708	14.768	15.176	15.359	15.555	15.585
1.7	1.394	2.756	4.060	5.283	6.412	7.440	8.366	9.192	9.927	10.577	11.151	11.657	12.104	12.498	12.846	13.154	13.427	13.669	13.885	14.078	15.199	15.638	15.838	16.056	16.091
1.8	1.417	2.803	4.129	5.375	6.526	7.574	8.520	9.366	10.119	10.786	11.376	11.898	12.359	12.766	13.127	13.446	13.730	13.983	14.208	14.409	15.590	16.058	16.274	16.516	16.554
1.9	1.438	2.844	4.190	5.456	6.626	7.693	8.656	9.520	10.289	10.972	11.577	12.112	12.587	13.006	13.378	13.708	14.002	14.264	14.498	14.707	15.944	16.441	16.673	16.937	16.980
2.0	1.456	2.880	4.244	5.527	6.714	7.798	8.778	9.656	10.440	11.137	11.755	12.303	12.789	13.220	13.603	13.943	14.246	14.516	14.758	14.975	16.265	16.790	17.037	17.325	17.372
3.0	1.559	3.087	4.553	5.937	7.223	8.403	9.478	10.448	11.321	12.103	12.804	13.431	13.993	14.496	14.947	15.353	15.718	16.048	16.346	16.676	18.301	19.051	19.432	19.943	20.046
4.0	1.600	3.168	4.676	6.100	7.426	8.646	9.759	10.768	11.678	12.498	13.235	13.897	14.493	15.030	15.514	15.951	16.347	16.706	17.033	17.330	19.241	20.142	20.623	21.322	21.495
5.0	1.620	3.208	4.735	6.179	7.525	8.765	9.897	10.925	11.854	12.693	13.448	14.128	14.742	15.296	15.798	16.252	16.664	17.040	17.382	17.695	19.740	20.740	21.293	22.148	22.393
10.0	1.648	3.263	4.818	6.289	7.662	8.930	10.089	11.144	12.100	12.965	13.747	14.454	15.094	15.674	16.201	16.681	17.118	17.518	17.885	18.222	20.491	21.681	22.390	23.676	24.238
INF	1.657	3.282	4.846	6.327	7.710	8.986	10.155	11.220	12.186	13.060	13.851	14.567	15.217	15.806	16.342	16.831	17.278	17.688	18.064	18.410	20.770	22.046	22.838	24.463	26.111

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Table 16 Percentage Sky Components on the Vertical Plane Perpendicular to a Vertical Rectangular Opening for the Clear Design Sky

(*Clause* B-1.1)

l/d *h/d*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.036	0.141	0.303	0.506	0.734	0.971	1.207	1.432	1.643	2.836	1.011	2.168	2.308	2.433	2.544	2.642	2.730	2.808	2.878	2.940	3.309	3.461	3.536	3.641	3.678
0.2	0.071	0.277	0.594	0.993	1.442	1.910	2.374	2.820	3.236	3.618	3.964	4.276	4.554	4.802	5.022	5.219	5.393	5.549	5.688	5.812	6.547	6.850	7.000	7.211	7.284
0.3	0.103	0.401	0.863	1.445	2.100	2.793	3.475	4.180	4.743	5.306	5.818	6.278	6.690	7.058	7.385	7.677	7.936	8.168	8.375	8.560	9.657	10.110	10.335	10.651	10.760
0.4	0.126	0.491	1.059	1.779	2.597	3.460	4.326	5.166	5.958	6.691	7.359	7.967	8.507	8.900	9.420	9.804	10.146	10.451	10.724	10.968	12.421	13.024	13.323	13.743	13.889
0.5	0.142	0.554	1.197	2.015	2.947	3.937	4.938	5.914	6.842	7.707	8.503	9.228	9.883	10.472	10.999	11.476	11.897	12.273	12.610	12.912	14.712	15.462	15.835	16.360	16.542
0.6	0.154	0.600	1.298	2.187	3.204	4.288	5.389	6.468	7.498	8.464	9.358	10.177	10.922	11.596	12.204	12.752	13.244	13.686	14.084	14.441	16.583	17.478	17.924	18.552	18.771
0.7	0.162	0.634	1.372	2.316	3.397	4.552	5.729	6.887	7.997	9.042	10.013	10.907	11.723	12.465	13.138	13.746	14.296	14.793	15.241	15.646	18.111	19.148	19.665	20.397	20.653
0.8	0.169	0.660	1.429	2.413	3.543	4.754	5.990	7.209	8.382	9.490	10.523	11.476	12.350	13.147	13.873	14.531	15.129	15.670	16.161	16.606	19.361	20.538	21.127	21.961	22.253
0.9	0.174	0.680	1.472	2.487	3.655	4.909	6.192	7.460	8.683	9.841	10.924	11.926	12.847	13.690	14.459	15.159	15.796	16.375	16.902	17.381	20.387	21.701	22.360	23.397	23.625
1.0	0.178	0.695	1.505	2.545	3.743	5.030	6.350	7.657	8.921	10.120	11.243	12.284	13.245	14.126	14.931	15.666	16.337	16.948	17.504	18.012	21.237	22.680	23.408	24.446	24.810
1.1	0.181	0.707	1.532	2.591	3.812	5.126	6.475	7.814	9.110	10.342	11.498	12.573	13.356	14.478	15.314	16.079	16.778	17.416	17.999	18.531	21.946	23.508	24.303	25.441	25.841
1.2	0.183	0.716	1.552	2.626	3.866	5.202	6.575	7.939	9.261	10.521	11.705	12.807	13.827	14.766	15.628	16.418	17.141	17.802	18.407	18.961	22.543	24.208	25.072	26.309	26.745
1.3	0.185	0.723	1.568	2.655	3.910	5.263	6.655	8.040	9.384	10.666	11.873	12.998	14.041	15.003	15.887	16.698	17.442	18.123	18.747	19.320	23.049	24.809	25.735	27.070	27.542
1.4	0.186	0.729	1.582	2.678	3.945	5.312	6.720	8.122	9.484	10.785	12.011	13.155	14.217	15.198	16.101	16.931	17.692	18.391	19.032	19.621	23.480	25.326	26.308	27.441	28.249
1.5	0.188	0.734	1.592	2.697	3.973	5.352	6.773	8.189	9.566	10.883	12.124	13.285	14.364	15.361	16.280	17.125	17.902	18.616	19.272	19.875	23.850	25.772	26.808	28.336	28.880
1.6	0.189	0.738	1.601	2.712	3.996	5.385	6.816	8.244	9.634	10.963	12.219	13.394	14.486	15.497	16.430	17.289	18.079	18.806	19.475	20.090	24.169	26.161	27.245	28.866	29.445
1.7	0.189	0.741	1.608	2.724	4.016	5.412	6.852	8.290	9.690	11.031	12.298	13.484	14.589	15.511	16.556	17.427	18.229	18.968	19.648	20.274	24.444	26.501	27.629	29.340	29.955
1.8	0.190	0.744	1.614	2.735	4.032	5.434	6.882	8.328	9.737	11.087	12.364	13.561	14.675	15.708	16.663	17.545	18.357	19.105	19.795	20.431	24.684	26.799	27.969	29.765	30.416
1.9	0.191	0.746	1.619	2.743	4.045	5.453	6.908	8.360	9.777	11.135	12.420	13.625	14.749	15.791	16.755	17.645	18.466	19.224	19.922	20.567	24.893	27.062	28.270	30.149	30.835
2.0	0.191	0.748	1.623	2.751	4.056	5.469	6.929	8.387	9.811	11.175	12.468	13.680	14.811	15.861	16.833	17.731	18.560	19.325	20.031	20.684	25.077	27.294	28.537	30.496	31.217
3.0	0.193	0.756	1.642	2.785	4.109	5.544	7.030	8.517	9.972	11.371	12.699	13.950	15.120	16.211	17.224	18.164	19.036	19.844	20.594	21.289	26.082	28.619	30.108	32.676	32.742
4.0	0.194	0.759	1.648	2.794	4.124	5.566	7.058	8.540	10.018	11.427	12.767	14.029	15.212	16.316	17.343	18.298	19.185	20.008	20.772	21.483	26.439	29.128	30.745	33.687	35.064
5.0	0.194	0.760	1.650	2.798	4.129	5.574	7.069	8.568	10.036	11.449	12.793	14.060	15.248	16.357	17.390	18.351	19.243	20.073	20.844	21.562	26.592	29.359	31.049	34.232	35.872
10.0	0.194	0.761	1.652	2.801	4.135	5.581	7.080	8.582	10.053	11.470	12.818	14.095	15.283	16.398	17.436	18.403	19.302	20.138	20.917	21.641	26.758	29.624	31.419	35.049	37.513
INF	0.194	0.761	1.652	2.802	4.136	5.582	7.081	8.584	10.056	11.473	12.822	14.095	15.288	16.404	17.443	18.411	19.311	20.148	20.928	21.654	26.785	29.672	31.490	35.274	39.172

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Table 17 Percentage Sky Components on the Vertical Plane Parallel to a Vertical Rectangular Opening for the Clear Design Sky

(*Clause* B-1.1)

l/d *h/d*	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	3.0	4.0	5.0	10.0	INF
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)
0.1	0.728	1.429	2.078	2.600	3.167	3.660	3.964	4.265	4.513	4.717	4.883	5.020	5.132	5.225	5.301	5.365	5.418	5.463	5.501	5.533	5.687	5.733	5.749	5.765	5.766
0.2	1.429	2.803	4.007	5.221	6.220	7.073	7.790	8.385	8.876	9.278	9.609	9.880	10.103	10.286	10.439	10.565	10.671	10.760	10.835	10.899	11.207	11.296	11.330	11.362	11.365
0.3	2.068	4.061	5.913	7.580	9.040	10.285	11.337	12.212	12.934	13.528	14.016	14.417	14.747	15.020	15.246	15.434	15.591	15.724	15.836	15.931	16.390	16.523	16.574	16.623	16.627
0.4	2.529	4.970	7.249	9.312	11.133	12.707	14.042	15.164	16.097	16.870	17.507	18.025	18.458	18.816	19.113	19.360	19.568	19.742	19.890	20.015	20.624	20.801	20.868	20.933	20.939
0.5	2.852	5.608	8.186	10.529	12.606	14.401	15.952	17.256	18.350	19.262	20.021	20.652	21.177	21.613	21.978	22.275	22.530	22.746	22.923	23.082	23.836	24.056	24.140	24.222	24.229
0.6	3.086	6.070	8.867	11.415	13.681	15.656	17.353	18.793	20.008	21.027	21.879	22.592	23.189	23.689	24.109	24.462	24.761	25.014	25.229	25.412	26.229	26.561	26.662	26.759	26.768
0.7	3.259	6.413	9.373	12.074	14.482	16.588	18.402	19.949	21.257	22.359	23.285	24.063	24.716	25.267	25.731	26.124	26.458	26.742	26.984	27.192	28.214	28.517	28.634	28.748	28.758
0.8	3.389	6.672	9.755	12.573	15.090	17.296	19.201	20.830	22.212	23.380	24.365	25.195	25.895	26.486	26.987	27.412	27.775	28.084	28.350	28.578	29.720	30.065	30.198	30.327	30.339
0.9	3.489	6.869	10.046	12.955	15.556	17.840	19.817	21.511	22.952	24.173	25.206	26.078	26.816	27.441	27.972	28.424	28.810	29.141	29.426	29.672	30.927	31.303	31.451	31.596	31.610
1.0	3.565	7.024	10.272	13.250	15.917	18.263	20.297	22.043	23.531	24.795	25.866	26.773	27.542	28.196	28.572	29.226	29.633	29.982	30.283	30.544	31.889	32.302	32.467	32.627	32.643
1.1	3.625	7.139	10.447	13.481	16.200	18.594	20.674	22.462	23.989	25.288	26.391	27.326	28.121	28.798	29.375	29.869	30.293	30.658	30.973	31.246	32.670	33.117	33.297	33.473	33.491
1.2	3.672	7.233	10.586	13.663	16.423	18.857	20.973	22.795	24.353	25.681	26.810	27.770	28.587	29.283	29.878	30.388	30.826	31.204	31.532	31.816	33.309	33.796	33.981	34.173	34.193
1.3	3.709	7.307	10.696	13.807	16.602	19.067	21.213	23.062	24.646	25.998	27.148	28.128	28.963	29.676	30.286	30.810	31.261	31.651	31.989	32.283	33.836	34.350	34.550	34.756	34.779
1.4	3.739	7.366	10.784	13.924	16.745	19.236	21.406	23.278	24.884	26.255	27.424	28.420	29.271	29.998	30.621	31.157	31.618	32.018	32.365	32.667	34.374	34.813	35.035	35.247	35.271
1.5	3.763	7.414	10.856	14.018	16.861	19.373	21.563	23.454	25.077	26.465	27.649	28.660	29.523	30.262	30.897	31.443	31.914	32.322	32.677	32.986	34.641	35.202	35.436	35.663	35.689
1.6	3.783	7.453	10.914	14.095	16.956	19.485	21.692	23.599	25.236	26.638	27.835	28.857	29.732	30.482	31.226	31.680	32.160	32.575	32.937	33.253	34.950	35.532	35.776	36.017	36.046
1.7	3.799	7.485	10.962	14.158	17.034	19.578	21.798	23.718	25.368	26.781	27.989	29.022	29.906	30.665	31.317	31.879	32.366	32.888	33.156	33.477	35.211	35.812	36.067	36.321	36.352
1.8	3.812	7.512	11.002	14.211	17.099	19.655	21.886	23.817	25.478	26.900	28.118	29.160	30.052	30.818	31.477	32.046	32.539	32.967	33.340	33.666	35.435	36.052	36.316	36.584	36.617
1.9	3.824	7.534	11.035	14.254	17.153	19.719	21.960	23.900	25.570	27.001	28.226	29.276	30.175	30.948	31.613	32.188	32.686	33.119	33.497	33.828	35.626	35.259	36.532	36.812	36.847
2.0	3.833	7.553	11.062	14.291	17.199	19.773	22.022	23.970	25.647	27.086	28.318	29.374	31.279	31.058	31.728	32.308	32.811	33.249	33.631	33.965	35.791	36.438	36.719	37.011	37.048
3.0	3.876	7.639	11.192	14.463	17.412	20.027	22.316	24.302	26.016	27.491	28.757	29.846	30.783	31.592	32.291	32.898	33.427	33.889	34.294	34.551	36.640	37.380	37.715	38.107	38.157
4.0	3.888	7.663	11.228	14.511	17.471	20.098	22.398	24.398	26.121	27.606	28.884	29.983	30.930	31.748	32.457	33.074	33.611	34.082	34.496	34.860	36.915	37.699	38.063	38.510	38.579
5.0	3.893	7.672	11.241	14.529	17.494	20.125	22.430	24.432	26.161	27.650	28.932	30.035	30.986	31.808	32.521	33.142	33.683	34.157	34.574	34.943	37.028	37.834	38.214	38.696	38.781
10.0	3.897	7681	11.254	14.546	17.515	20.150	22.459	24.466	26.199	27.693	28.978	30.085	31.041	31.867	32.584	33.208	33.753	34.231	34.652	35.024	37.144	37.978.	38.382	38.927	39.057
INF	3.898	7.682	11.256	44.548	17.518	20.154	22.464	24.471	26.205	27.699	28.985	30.093	31.049	31.876	32.593	33.218	33.764	34.243	34.664	35.037	37.162	38.003	38.411	38.978	39.172

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in first column within parentheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	7662 (Part 1) : 1974	Recommendations for orientation of buildings: Part 1 Non-industrial buildings
(2)	3646 (Part 1) : 1992	Code of practice for interior illumination: Part 1 General requirements and recommendations for building interiors (*first revision*)
(3)	2440 : 1975	Guide for daylighting of buildings (*second revision*)
(4)	6060 : 1971	Code of practice for daylighting of factory buildings
	7942 : 1976	Code of practice for daylighting of educational buildings
(5)	1944 (Parts 1 and 2) : 1970	Code of practice for lighting of public thoroughfares: Parts 1 and 2 For main and secondary roads (Group A and B) (*first revision*)
	Part 6 : 1981	Lighting for town and city centres and areas of civic importance (Group E)
	2672 : 1966	Code of practice for library lighting
	4347 : 1967	Code of practice for hospital lighting
	6074 : 1971	Functional requirements of hotels, restaurants and other food service establishments
	6665 : 1972	Code of practice for industrial lighting
	10894 : 1984	Code of practice for lighting of educational institutions
	10947 : 1984	Code of practice for lighting for ports and harbours
(6)	3362 : 1977	Code of practice for natural ventilation of residential buildings (*first revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 2 Electrical and Allied Installations

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 8/Section 2) covers essential requirements for electrical and allied installations in buildings.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005. In the first revision, general guidance for electrical wiring installation in industrial location where voltage supply normally exceeds 650 V was included. This Section was also updated based on the existing version of the Indian Standards. The importance of pre-planning and exchange of information among all concerned agencies from the earlier stages of building work was emphasized.

In the second revision of 2005, the title of this Section was modified from the erstwhile 'Electrical Installations' to 'Electrical and Allied Installations' to reflect the provisions included on certain allied installations. The significant changes incorporated in the last revision included, thorough change in the risk assessment procedure for lightning including some other changes in the provision of lightning protection of building; alignment of some of the provisions of wiring with the practices prevalent at that time; modification of definitions in line with terminologies used at national and international level and addition of some new definitions; incorporation of provisions on installation of distribution transformer inside the multi-storeyed building; introduction of concept of energy conservation in lighting and introduction of concept of various types of earthing in building installation.

All electrical installations in India come under the purview of *The Indian Electricity Act*, 2003 and the rules and regulations framed thereunder. In the context of the buildings, both buildings (the structure itself) and the building services (not just the electrical services, but all other services that use electricity or have an interface with the electrical system) are required to follow these. The erstwhile *Indian Electricity Rules*, 1956 were superseded by various Central Electricity Authority Regulations. While revising the provisions of this Section of the Code, care has been taken to align the same with the provisions of the relevant regulations, particularly, *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010, amended in 2015. In this revision, in addition to above, the following major modifications have been incorporated:

a) Various new terms and their definitions have been added and existing terms and definitions have also been updated based on current developments at national and international level.
b) Provisions relating to location and other requirements relating to layout, environmental and safety aspects for different substation apparatus/equipment and generating sets have been reviewed and updated.
c) Provisions relating to location of compact substations have been added.
d) Requirements for electrical supply system for life and safety services have been included.
e) Provisions relating to reception and distribution of supply and wiring installations have been updated with due cognizance to Indian Standards formulated for various wiring systems.
f) Provisions relating to installation of energy meters have been updated.
g) Discrimination, cascading and limitation concepts for the coordination of protective devices in electrical circuits have been introduced.
h) Socket outlets with suitable circuit breakers, conforming to following Indian Standards have been recommended for industrial and commercial applications, either indoors or outdoors:
    1) lS/lEC 60309-1:2002 'Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements'; and
    2) lS/lEC 60309-2:2002 'Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional Interchangeability Requirements for Pin and Contact-Tube Accessories'.
j) Provisions relating to earthing/grounding have been substantially revised and updated.
k) Provisions relating to lightning protection of buildings have been revamped based on the current national and international developments.
m) Provisions relating to renewable energy sources for building, such as solar PV system; aviation obstacle

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lights; electrical supply for electric vehicle charging and car park management; etc, have been included.

n) New provisions relating to electrical installations for construction sites and demolition sites have been included.

p) New provisions relating to protection of human beings from electrical hazards and protection against fire in the building due to leakage current have been included.

q) Typical formats for checklists for handing over and commissioning of substation equipment and earthing pit have been included.

This Section has to be read together with Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code for making provision for the desired levels of illumination as well as ventilation for different locations in different occupancies; and also with Part 4 'Fire and Life Safety' of the Code for list of emergency fire and life safety services and other sections of Part 8 'Building Services' and Part 9 'Plumbing Services' for electricity related requirements and integration thereof. Utmost importance should be given in the installation of electrical wiring to prevent short circuiting and the hazards associated therewith.

Notwithstanding the provisions given in this Section and the National Electrical Code, 2011 the provisions of the *Indian Electricity Act*, 2003 and the rules and regulations framed thereunder have to be necessarily complied with.

The information contained in this Section is largely based on the following Indian Standards/Special Publication:

IS 732 : 1989	Code of practice for electrical wiring installations (*third revision*) (*under revision*)
IS 3043 : 1987	Code of practice for earthing (*first revision*) (*under revision*)
IS 4648: 1968	Guide for electrical layout in residential buildings
IS 12032 (Part 11) : 1987	Specification for graphical symbols for diagrams in the field of electro technology: Part 11 Architectural and topographical installation plan and diagrams
IS/IEC 62305-1 : 2010	Protection against lightning: Part 1 General principles
IS/IEC 62305-2 : 2010	Protection against lightning: Part 2 Risk management
IS/IEC 62305-3 : 2010	Protection against lightning: Part 3 Physical damage to structures and life hazard
IS/IEC 62305-4 : 2010	Protection against lightning: Part 4 Electrical and electronic systems within structures
SP 30 : 2011	National Electrical Code, 2011 (*first revision*)

It may be noted that some of the above standards are currently under revision. The revised version when available should also be referred.

Considerable assistance has also been drawn from following International Standards while formulating this Section:

IEC 60364-4-41 : 2005	Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock
IEC 60364-4-43 : 2008	Low-voltage electrical installations — Part 4-43: Protection for safety — Protection against overcurrent
IEC 60364-4-44 : 2007	Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances
IEC 60364-5-51 : 2005	Electrical installations of buildings — Part 5-51: Selection and erection of electrical equipment — Common rules
IEC 60364-5-54 : 2011	Low-voltage electrical installations — Part 5-54: Selection and erection of electrical equipment — Earthing arrangements and protective conductors
IEC 60364-7 series	Low-voltage electrical installations — Part 7: Requirements for special installations or locations
IEC 61439-1 : 2011	Low-voltage switchgear and controlgear assemblies and bus trunking — Part 1: General rules
IEC 61439-2 : 2011	Low-voltage switchgear and controlgear assemblies and bus trunking — Part 2: Power switchgear and controlgear assemblies
IEC 61439-6 : 2012	Low-voltage switchgear and controlgear assemblies and bus trunking — Part 6: Busbar trunking systems (busways)

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All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section of the Code.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 2 Electrical and Allied Installations

1 SCOPE

This Code (Part 8/Section 2) covers the essential requirements for electrical installations in buildings to ensure efficient use of electricity including safety from fire and shock. This Section also includes general requirements relating to lightning protection of buildings and brief provisions on certain allied installations.

2 TERMINOLOGY AND CONVENTIONAL SYMBOLS

2.1 For the purpose of this Section, the following definitions shall apply. For definition of other terms, reference may be made to accepted standards [8-2(1)].

2.1.1 *Accessory* — A device, other than current using equipment, associated with such equipment or with the wiring of an installation.

2.1.2 *Apparatus* — Electrical apparatus including all machines, appliances and fittings in which conductors are used or of which they form a part.

2.1.3 *Appliance* — An item of current using equipment other than a luminaire or an independent motor.

2.1.4 *Back-up Protection* — Protection which is intended to operate when a system fault is not cleared or abnormal condition not detected in the required time, because of failure or inability of other protection to operate or failure of appropriate circuit-breaker to trip.

2.1.5 *Barrier* — A part providing a defined degree of protection against contact with live parts, from any usual direction of access.

2.1.6 *Basic Protection* — Protection against electric shock under fault-free condition.

NOTE — For low voltage installations, systems and equipment, basic protection generally corresponds to protection against direct contact that is 'contact of persons or live parts'.

2.1.7 *Bonding Conductor* — A protective conductor providing equipotential bonding.

2.1.8 *Bonding Ring Conductor (BRC)* — A bus earthing conductor in the form of a closed ring.

NOTE — Normally the bonding ring conductor, as part of the bonding network, has multiple connections to the common bonding network (CBN) that improves its performance.

2.1.9 *Bunched* — Cables are said to be 'bunched' when two or more are contained within a single conduit, duct, ducting, or trunking, or, if not enclosed, are not separated from each other.

2.1.10 *Buried Direct* — A cable laid in the ground in intimate contact with the soil.

2.1.11 *Busbar Trunking System* — A type-tested assembly, in the form of an enclosed conductor system comprising solid conductors separated by insulating materials. The assembly may consist of units such as:

a) Busbur trunking units, with or without tap-off facilities;
b) Tap-off units where applicable; and
c) Phase-transposition, expansion, building-movement, flexible, end-feeder and adaptor units.

2.1.12 *Bypass Equipotential Bonding Conductor* — Bonding conductor connected in parallel with the screens of cables.

2.1.13 *Cable* — A length of single-insulated conductor (solid or stranded), or two or more such conductors, each provided with its own insulation, which are laid up together. The insulated conductor or conductors may or may not be provided with an overall mechanical protective covering.

2.1.14 *Cable, Circuit Integrity* — A cable which continues to function, that is, maintains the continuity of the circuit under circumstances of fire (against a specified temperature and period of the test).

NOTE — For circuit integrity cable requirements reference may be made to accepted standard [8-2(2)], which prescribes a fire survival test at 750°C for 3 h.

2.1.15 *Cable, Flame Retardant (FR)* — A cable which is flame retardant as per the accepted standard [8-2(3)].

2.1.16 *Cable, Flame Retardant Low Smoke and Halogen* (FR-LSH) — A cable which is flame retardant and emits low smoke and halogen as per the accepted standard [8-2(3)].

2.1.17 *Cable, Flexible* — A cable containing one or more cores, each formed of a group of wires, the diameters of the cores and of the wires being sufficiently small to afford flexibility.

2.1.18 *Cable, Metal-Sheathed* — An insulated cable with a metal sheath.

2.1.19 *Cable, PVC Sheathed-Insulated* — A cable in which the insulation of the conductor is a polyvinylchloride (PVC) compound; with PVC sheath also providing mechanical protection to the conductor core or cores in the cable.

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2.1.20 *Cable, Weatherproof* — A cable so constructed that when installed in uncovered locations, it will withstand all kinds of weather variations (*see* **2.1.186** for definition of weatherproof).

2.1.21 *Cable, XLPE* — A cable in which the insulation of the conductor is cross-linked polythene and the mechanical protection is provided for the core or cores by a sheath of a polyvinyl chloride compound.

2.1.22 *Cable Armoured* — A cable provided with a wrapping of metal (usually in the form of tape or wire) serving as a mechanical protection.

2.1.23 *Cable Bracket* — A cable support consisting of single devices fixed to elements of building or plant construction.

2.1.24 *Cable Channel* — An enclosure situated above or in the ground, open or ventilated or closed, and having dimensions which do not permit the access of persons but allow access to the conductor and/or cables throughout their length during and after installation.

NOTE — A cable channel may or may not form part of the building construction.

2.1.25 *Cable Cleat* — A component of a support system which consists of elements spread at intervals along the length of the cable or conduits and which mechanically retains the cable or conduit.

2.1.26 *Cable Coupler* — A means enabling the connection, at will, of two flexible cables. It consists of a connector and a plug.

2.1.27 *Cable Ducting* — A manufactured enclosure of metal or insulating material, other than conduit or cable trunking, intended for the protection of cables which are drawn-in after erection of the ducting, but which is not specifically intended to form part of a building structure.

2.1.28 *Cable Ladder* — A cable support occupying less than 10 percent of the plan area and consisting of a series of supporting elements rigidly fixed to each other or to a main supporting member or members.

2.1.29 *Cable Raceways* — An enclosed channel of metal or non-metallic materials designed expressly for holding wires, cables or busbars, with openable/ maintainable construction having provision of ventilation. These include electrical non-metallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways and wireways.

2.1.30 *Cable Tray* — A cable support consisting of a continuous base with raised edges and no covering. A cable tray is considered to be non-perforated, where less than 30 percent of the material is removed from the base.

2.1.31 *Cable Trunking* — A factory made closed support and protection system into which conductors and/or cables are laid after removal of the cover.

2.1.32 *Cable Tunnel* — An enclosure (corridor) containing supporting structures for conductors and/or cables and joints and whose dimensions allow free access to persons throughout the entire length.

2.1.33 *Cartridge Fuse Link* — A device comprising a fuse element or several fuse elements connected in parallel enclosed in a cartridge usually filled with an arc-extinguishing medium and connected to terminations. The fuse link is the part of a fuse which requires replacing after the fuse has operated.

2.1.34 *Ceiling Rose* — A fitting (usually used to attach to the ceiling) designed for the connection between the electrical installation wiring and a flexible cord (which is in turn connected to a lampholder).

2.1.35 *Circuit* — An assembly of electrical equipment supplied from the same origin and protected against overcurrent by the same protective device(s). Circuits are categorized as follows:

a) *Category 1 circuit* — A circuit (other than a fire alarm annunciation or emergency lighting circuit and other circuits required to work during fire in a building) operating at low voltage and supplied directly from a mains supply system.

b) *Category 2 circuit* — With the exception of Category 3 circuits, any circuit for extra low-voltage (ELV)/telecommunication [for example, radio, telephone, sound distribution, building management system (BMS), public address system (PAS), intruder alarm, bell and call and data transmission circuits)] which is supplied from a safety source.

c) *Category 3 circuit* — A fire alarm circuit or an emergency lighting circuit and other circuits required to work during fire in a building.

2.1.36 *Circuit Breaker* — A mechanical switching device, capable of making, carrying and breaking currents under normal circuit conditions and also of making, carrying for a specified time, and breaking currents under specified abnormal circuit conditions such as those of short circuit.

NOTE — A circuit breaker is usually intended to operate infrequently, although some types are suitable for frequent operation.

2.1.36.1 *Miniature circuit breaker (MCB)* — A compact mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions and also making and carrying currents for specified times and automatically breaking currents

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under specified abnormal circuit conditions, such as those of overload and short circuits.

2.1.36.2 *Circuit breaker, linked* — A circuit breaker, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

2.1.36.3 *Moulded case circuit breaker (MCCB)* — A circuit breaker having a supporting housing of moulded insulating material forming an integral part of the circuit breaker.

2.1.36.4 *Air circuit breaker (ACB)* — A circuit breaker in which the contacts open and close in air at atmospheric pressure.

2.1.36.5 *Residual current operated circuit breaker* — A mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specified conditions.

2.1.36.5.1 *Residual current operated circuit breaker with integral overcurrent protection* (*RCBO*) — A residual current operated circuit breaker designed to perform the functions of protection against overload and/or short-circuit.

2.1.36.5.2 *Residual current operated circuit breaker without integral overcurrent protection* (*RCCB*) — A residual current operated circuit breaker not designed to perform the functions of protection against overload and/or short-circuits.

NOTE — Similar function is provided by earth leakage circuit breaker (ELCB).

2.1.37 *Circuit, Final Sub* — An outgoing circuit connected to one-way distribution board and intended to supply electrical energy at one or more points to current, using appliances without the intervention of a further distribution board other than a one-way board. It includes all branches and extensions derived from that particular way in the board.

2.1.38 *Circuit Integrity Cable Support and Fixing Materials* — Supports and fixing materials for supporting circuit integrity cable (*see* **2.1.14**), which continues in service after exposure to fire for a specified duration.

2.1.39 *Compact Substation or Prefabricated Substation* — Prefabricated and type-tested assembly which can to be operated from inside (walk-in type) or outside (non-walk-in type) comprising components such as power transformer, high-voltage switchgear and controlgear, low-voltage switchgear and controlgear, corresponding interconnections (cable, busbar or other) and-auxiliary equipment and circuits located next to each other, maintaining segregation and integrity of each compartment in which they are located along with external interconnecting cables, earthing, protections, etc. The components shall be enclosed, by either a common enclosure or by an assembly of enclosures.

NOTE — *See* accepted standard [8-2(4)] for requirements of prefabricated substation.

2.1.40 *Conductor of a Cable or Core* — The conducting portion consisting of a single wire or group of wires, assembled together and in contact with each other or connected in parallel.

2.1.41 *Conductor, Aerial* — Any conductor which is supported by insulators above the ground and is directly exposed to the weather.

NOTE — Following four classes of aerial conductors are recognized:

a) Bare aerial conductors,
b) Covered aerial conductors,
c) Insulated aerial conductors, and
d) Weatherproof neutral-screened cable.

2.1.42 *Conductor, Bare* — A conductor not covered with insulating material.

2.1.43 *Conductor, Earthed* — A conductor with no provision for its insulation from earth.

2.1.44 *Conductor, Insulated* — A conductor adequately covered with insulating material of such quality and thickness as to prevent danger.

2.1.45 *Conduit* — A part of a closed wiring system, a circular or non-circular cross-section for conductors and/or cables in electrical installations, allowing them to be drawn in and/or replaced. Conduits should be sufficiently closed-jointed so that the conductors can only be drawn in and not inserted laterally.

2.1.46 *Connector* — The part of a cable coupler or of an appliance coupler which is provided with female contact and is intended to be attached to the flexible cable connected to the supply.

2.1.47 *Connector Box or Joint Box* — A box forming a part of wiring installation, provided to contain joints in the conductors of cables of the installations.

2.1.48 *Connector for Portable Appliances* — A combination of a plug and socket arranged for attachment to a portable electrical appliance or to a flexible cord.

2.1.49 *Consumer's Terminals* — The ends of the electrical conductors situated upon any consumer's premises and belonging to him, at which the supply of energy is delivered from the service line.

2.1.50 *Continuous Operating Voltage* (U_c) — Maximum rms voltage which may be continuously applied to a surge protection device's mode of protection. This is equal to rated voltage.

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2.1.51 *Cord, Flexible* — A flexible cable having a large number of (typically 16 or 23 or 46 or 89, etc) strands of conductors of small cross-sectional area. Two flexible cords twisted together are known as twin 'flexible cord'.

NOTE — Large number of fine strands of wires for each conductor makes the conductor capable of withstanding frequent bends thereby improving their flexibility.

2.1.52 *Core of a Cable* — A single conductor of a cable with its insulation but not including any mechanical protective covering.

2.1.53 *Current Carrying Capacity of a Conductor* — The maximum current which can be carried by a conductor under specified conditions without its steady state temperature exceeding a specified value.

2.1.54 *Current Using Equipment* — Equipment which converts electrical energy in to another form of energy, such as light, heat, or motive power.

2.1.55 *Cut-out* — Any appliance for automatically interrupting the transmission of energy through any conductor when the current rises above a pre-determined amount.

2.1.56 *Damp Situation* — A situation in which moisture is either permanently present or intermittently present to such an extent as likely to impair the effectiveness of an installation conforming to the requirements for ordinary situations.

2.1.57 *Danger* — Danger to health or danger to life or limb from shock, burn or injury from mechanical movement to persons (and livestock where present), or from fire attendant upon the use of electrical energy.

2.1.58 *Dead* — A portion of an electrical circuit (normally expected to carry a voltage) at or near earth potential or apparently disconnected from any live system. A circuit apparently disconnected from all sources is expected to be at earth potential; but capacitive storage of charge in cables, capacitors, etc, can keep the electric circuit at a significant voltage (and often dangerous voltages from aspects of shock). Such circuits with storage components will be dead only on connection to earth.

2.1.59 *Design Current* (*of a Circuit*) — The magnitude of the current intended to be carried by the circuit in normal service.

2.1.60 *Direct Contact* — Contact of persons or live stock with live parts which may result in electric shock.

2.1.61 *Direct Earthing System* — A system of earthing in which the parts of an installation are so earthed as specified, but are not connected within the installation to the neutral conductor of the supply system or to earth through the trip coil of an earth leakage circuit-breaker.

2.1.62 *Disconnector* — A mechanical switching device which, in the open position, complies with the requirements specified for the isolation function.

NOTES

1 A disconnector is otherwise known as isolator.

2 A disconnector is capable of opening and closing a circuit when either a negligible current is broken or made, or when no significant change in the voltage across the terminals of each pole of the disconnector occurs. It is also capable of carrying currents under normal circuit conditions and carrying for a specified time, current under abnormal conditions, such as those of short-circuit.

2.1.63 *Discrimination* (*Over-Current Discrimination*) — Coordination of the operating characteristics of two or more over-current protective devices should be such that, on the incidence of over-currents within stated limits, the device intended to operate would be the device closest to the point of fault or abnormality, and if proper discrimination is achieved within these limits, only that device closest should operate, while the other circuit breakers upstream do not operate, thereby ensuring that there is minimum area of power supply which is interrupted.

NOTES

1 Protective devices should have discrimination so that only the affected part (minimum section) of the circuit is isolated, even though a number of protective devices may be in the path of the over current.

2 The electrical network requires the discrimination for all the fault circuits, including overload, short-circuit, etc. The downstream device should take care of the fault up to the level of ultimate short-circuit breaking capacity, I_{cu} of the downstream breaker which should be equal to the bus which is connected.

3 Distinction is made between series discrimination involving different over-current protective devices passing substantially the same over-current and network discrimination involving identical protective devices passing different proportions of the over-current.

4 Different types of protective devices may have to be used to ensure effective discrimination in circuits where proper and effective discrimination is necessary. Apart from the built-in sensors and actuators in circuit breakers, external relays operating on different parameters, and comparison of parameters between two or more points will have to be used for complex installations.

5 *See also* relevant parts of the accepted standard [8-2(5)].

2.1.64 *Distance Area or Resistance Area (for an Earth Electrode Only)* — The surface area of ground (around an earth electrode) on which a significant voltage gradient may exist.

2.1.65 *Diversity Factor* — A measure of the probability that a particular piece of equipment will turn on coincidentally to another piece of equipment. For aggregate systems it is defined as the ratio of the sum of the individual non-coincident maximum loads of

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various subdivisions of the system to the maximum demand of the complete system.

2.1.66 *Duct* — A closed passage way formed underground or in a structure and intended to receive one or more cables which may be drawn in.

2.1.67 *Ducting* — *See* **2.1.27**.

2.1.68 *Earth* — The conductive mass of the earth, whose electric potential at any point is conventionally taken as zero.

2.1.69 *Earth Continuity Conductor* — The conductor, including any clamp, connecting to the earthing lead or to each other, those parts of an installation which are required to be earthed. It may be in whole or in part, the metal conduit or the metal sheath or armour of the cables, or the special continuity conductor of a cable or flexible cord incorporating such a conductor.

2.1.70 *Earthed Concentric Wiring* — A wiring system in which one or more insulated conductors are completely surrounded throughout their length by a conductor, for example a sheath, which acts as a PEN conductor.

2.1.71 *Earth Electrode* — A conductor or group of conductors in intimate contact with the ground to provide a low resistance path for flow of current to earth.

2.1.72 *Earth Electrode Network* — Part of an earthing arrangement comprising only the earth electrodes and their interconnections.

2.1.73 *Earth Electrode Resistance* — The resistance of an earth electrode to earth.

2.1.74 *Earth Fault* — An unintended and undesirable connection of phase/neutral conductor to earth. When the impedance is negligible, the connection is called a dead earth fault.

2.1.75 *Earth Fault Current* — A current resulting from a fault of negligible impedance between a line conductor and an exposed conductive part or a protective conductor.

2.1.76 *Earthing* — Connection of the exposed conductive parts of an installation to the main earthing terminal of that installation.

2.1.77 *Earthing Conductor* — A protective conductor connecting the main earth terminal (or equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing.

2.1.78 *Earthing Lead* — The final conductor by which the connection to the earth electrode is made.

2.1.79 *Earth Leakage Current* — A current which flows to earth, or to extraneous conductive parts, in a circuit which is electrically sound.

NOTE — This current may have a capacitive component including that resulting from the deliberate use of capacitors.

2.1.80 *Earthing Resistance*, *Total* — The resistance between the main earthing terminal and the earth.

2.1.81 *Electrical Equipment* (*abb: Equipment*) — Any item for such purposes as generation, conversion, transmission, distribution or utilization of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring materials, accessories, and appliances.

2.1.82 *Electrically Independent Earth Electrodes* — Earth electrodes located at such a distance from one another that the maximum current likely to flow through one of them does not significantly affect the potential of the other(s).

2.1.83 *Electrical Supply System for Life and Safety Services* — A supply system intended to maintain the operation of essential parts of an electrical installation and equipment,

a) for health and safety of persons and livestock; and

b) to avoid damage to the environment and to other equipment.

NOTES

1 The supply system includes the source and the circuit(s) up to the terminals of the electrical equipment.

2 *See also* Part 4 'Fire and Life Safety' of the Code regarding emergency fire and life safety services.

2.1.84 *Electric Shock* — A dangerous patho-physiological effect resulting from the passing of an electric current through a human body or an animal.

2.1.85 *Emergency Switching* — Rapid cutting off of electrical energy to remove any hazard to persons, livestock, or property which may occur unexpectedly.

2.1.86 *Enclosed Distribution Board* — An enclosure containing bus bars with one or more control and protected devices for the purpose of protecting, controlling or connecting more than one outgoing circuits fed from one or more incoming circuits.

2.1.87 *Enclosure* — A part providing protection of equipment against certain external influences and, in any direction, protection against direct contact.

2.1.88 *Equipotential Bonding* — Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.

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NOTE — In a building installation equipotential bonding conductors shall interconnect the following conductive parts:

a) Protective conductor,
b) Earth continuity conductor, and
c) Risers of air conditioning system and heating systems (if any).

2.1.89 *Exposed Conductive Part* — A conductive part of electrical equipment, which can be touched and which is not normally live, but which may become live under fault conditions.

2.1.90 *Exposed Metal* — All metal parts of an installation which are easily accessible other than,

a) parts separated from live parts by double insulation;
b) metal name-plates, screw heads, covers, or plates, which are supported on, or attached, or connected to substantial non-conducting material only in such a manner that they do not become alive in the event of failure of insulation of live parts and whose means of fixing do not come in contact with any internal metal; and
c) parts which are separated from live parts by other metal parts which are themselves earthed or have double insulation.

2.1.91 *External Influence* — Any influence external to an electrical installation which affects the design and safe operation of that installation.

2.1.92 *Extraneous Conductive Part* — A conductive part not forming part of the electrical installation and liable to introduce a potential, generally the earth potential.

2.1.93 *Fault* — A circuit condition in which current flows through an abnormal or unintended path. This may result from an insulation failure or a bridging of insulation. Conventionally the impedance between live conductors or between lives conductors and exposed or extraneous conductive parts at the fault position is considered negligible.

2.1.94 *Fault Current* — A current resulting from a fault.

2.1.95 *Fault Protection* — Protection against electric shock under single fault conditions.

NOTE — For low voltage installation, system's and equipment's fault protection generally corresponds to protection against indirect contact, mainly with regards to failure of basic insulation. Indirect contact is 'contact of persons or livestock with exposed-conductive parts which have become live under fault conditions'.

2.1.96 *Final Circuit* — A circuit connected directly to current using equipment, or to socket outlets or other outlet points for the connection of such equipment.

2.1.97 *Fire Survival Distribution Board* — A distribution board which continues in service after exposure to fire to the required system rating.

2.1.98 *Fitting, Lighting* — A device for supporting or containing a lamp or lamps [for example, fluorescent or incandescent or halogen or compact fluorescent lamp (CFL) or light emitting diode (LED)] together with any holder, shade, or reflector, for example, a bracket, a pendant with ceiling rose, an electrolier, or a portable unit.

2.1.99 *Fixed Equipment* — Equipment fastened to a support or otherwise secured.

2.1.100 *Flameproof Enclosure* — An enclosure which will withstand without injury any explosion of inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus (and recognized overloads, if any, associated therewith) and will prevent the transmission of flame which may ignite any inflammable gas that may be present in the surrounding atmosphere.

NOTES

1 Hazardous areas are classified into different zones, depending upon the extent to which an explosive atmosphere may exist at that place. In such areas, flame proof switchgear, fittings, accessories, have to be used/installed in flameproof enclosure.

2 An electrical apparatus is not considered as flameproof unless it complies with the appropriate statutory regulations.

3 Other types of fittings are also in vogue in wiring installations, for example, 'increased safety'.

2.1.101 *Functional Earthing* — Connection to earth necessary for proper functioning of electrical equipment.

2.1.102 *Fuse* — A device which, by melting of one or more of its specially designed and proportioned components, opens the circuit in which it is inserted by breaking the current when this exceeds a given value for a sufficient time. The fuse comprises all the parts that form the complete device.

2.1.103 *Fuse Carrier* — The movable part of a fuse designed to carry a fuse link.

2.1.104 *Fuse Element* — A part of a fuse designed to melt when the fuse operates.

2.1.105 *Fuse Link* — A part of fuse, including the fuse element(s), which requires replacement by a new or renewable fuse link after the fuse has operated and before the fuse is put back into service.

2.1.106 *Hand-Held Equipment* — Portable equipment intended to be held in the hand during normal use, in which the motor, if any, forms an integral part of the equipment.

NOTE — A hand held equipment is an item of equipment, the functioning of which requires constant manual support or guidance.

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2.1.107 *Harmonics (Current and Voltage)* — All alternating current which is not absolutely sinusoidal is made up of a fundamental and a certain number of current and voltage harmonics [multiples of 50 Hz (basic frequency)] which are the cause of its deformation (distortion) when compared to the theoretical sine-wave.

2.1.108 *Hazardous Live Part* — A live part which can give, under certain condition of external influence, an electric shock.

2.1.109 *Impulse Current* — A parameter used for the classification test for SPDs; it is defined by three elements, a current peak value, a charge Q and a specific energy W/R.

2.1.110 *Impulse Withstand Voltage* — The highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified condition.

2.1.111 *Indirect Contact* — Contact of persons or livestock with exposed conductive parts made live by a fault and which may result in electric shock.

2.1.112 *Industrial Plugs and Sockets* — Plugs and socket-outlets, cable couplers and appliance couplers, primarily intended for industrial use, either indoors or outdoors.

NOTE — For the purpose of this Code, industrial plugs and sockets conforming to lS/lEC 60309-1:2002 'Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements'; and lS/lEC 60309-2:2002 'Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional Interchangeability Requirements for Pin and Contact Tube Accessories' shall be used for industrial purpose.

2.1.113 *Inflammable Material* — A material capable of being easily ignited.

2.1.114 *Installation (Electrical)* — An assembly of associated electrical equipment to fulfill a specific purpose or purposes and having coordinated characteristics.

2.1.115 *Insulated* — Insulated shall mean separated from adjacent conducting material or protected from personal contact by a non-conducting substance or an air space, in either case offering permanently sufficient resistance to the passage of current or to disruptive discharges through or over the surface of the substance or space, to obviate danger or shock or injurious leakage of current.

2.1.116 *Insulation* — Suitable non-conducting material, enclosing, surrounding or supporting a conductor.

2.1.116.1 *Insulation, basic* — Insulation applied to live parts to provide basic protection against electric shock and which does not necessarily include insulation used exclusively for functional purposes.

2.1.116.2 *Insulation, double* — Insulation comprising both basic and supplementary insulation.

NOTE — Double insulation for small hand held equipment allows them to be used without a safety earth connection, without shock risk such hand held equipment.

2.1.116.3 *Insulation, reinforced* — Single insulation applied to live parts, which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in the relevant standard.

NOTE — The term 'single insulation' does not imply that the insulation is a homogeneous piece. It may comprise several layers which cannot be tested singly as supplementary or basic insulation.

2.1.116.4 *Insulation, supplementary* — Independent insulation applied in addition to basic insulation in order to provide protection against electric shock in the event of a failure of basic insulation.

2.1.117 *Isolation* — Cutting off an electrical installation, a circuit, or an item of equipment from every source of electrical energy.

2.1.118 *Isolator* — A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.

2.1.119 *Junction Box* — A box forming a part of wiring installation, intended to conceal electrical connections and joints of conductors/ cables in order to protect the connection from external influences such as direct contact, dust, water, moisture, UV radiation, etc, depending upon the protection requirement of the space or utility.

2.1.120 *LEMP Protection Measures (SPM)* — Measures taken to protect internal systems against the effects of LEMP.

2.1.121 *Lightning Electromagnetic Impulse (LEMP)* — All electromagnetic effects of lightning current *via* resistive, inductive and capacitive coupling that create surges and radiated electromagnetic fields.

2.1.122 *Lightning Protection* — Complete system for protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM.

2.1.123 *Lightning Protection Level (LPL)* — A number related to a set of lightning current parameters values relevant to the probability that the associated maximum and minimum design values will not be exceeded in naturally occurring lightning.

NOTE — Lightning protection level is used to design protection measures according to the relevant set of lightning current parameters.

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2.1.124 *Lightning Protection System (LPS)* — Complete system used to reduce physical damage due to lightning flashes to a structure.

2.1.124.1 *External lightning protection system* — Part of the LPS consisting of an air-termination system, a down-conductor system and an earth-termination system.

2.1.124.2 *Internal lightning protection system* — Part of the LPS consisting of lightning equipotential bonding and/or electrical insulation of external LPS.

2.1.125 *Lightning Protection Zone* — Zone where the lightning electromagnetic environment is defined.

2.1.126 *Live or Alive* — Electrically charged so as to have a potential different from that of earth.

2.1.127 *Locations, Industrial* — Locations where tools and machinery requiring electrical wiring are installed for manufacture or repair.

2.1.128 *Locations, Non-Industrial* — Locations other than industrial locations, and shall include residences, offices, shops, showrooms, stores and similar premises requiring electrical wiring for lighting, or similar purposes.

2.1.129 *Leakage Current* — Electric current in an unwanted conductive path under normal operating conditions.

2.1.130 *Line Conductor* — A conductor of an a.c. system for the transmission of electrical energy other than a neutral conductor or a PEN conductor. This also means the equivalent conductor of a d.c. system unless otherwise specified in this Code.

2.1.131 *Live Part* — A conductor or conductive part intended to be energised in normal use including a neutral conductor but, by convention, not a PEN conductor.

2.1.132 *Low Voltage Switchgear and Controlgear Assembly* — A combination of one or more low voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, etc, completely assembled under the responsibility of the manufacturer with all the internal electrical and mechanical interconnections and structural parts. The components of the assembly may be electromechanical or electronic.

2.1.133 *Luminaire* — Equipment which distributes, filters or transforms the light from one or more lamps, and which includes any parts necessary for supporting, fixing and protecting the lamps, but not the lamps themselves, and, where necessary, circuit auxiliaries together with the means for connecting them to the supply.

NOTE — For the purposes of this Code a batten lampholder, or a lampholder suspended by flexible cord, is a luminaire.

2.1.134 *Main Earthing Terminal* — The terminal or bar which is the equipotential bonding conductor of protective conductors, and conductors for functional earthing, if any, to the means of earthing.

2.1.135 *Meshed Bonding Network* (*MESH-BN*) — Bonding network in which all associated equipment frames, racks and cabinets and usually the d.c. power return conductor are bonded together as well as at multiple points to the CBN and may have the form of a mesh.

2.1.136 *Mobile Equipment* — Electrical equipment which is moved while in operation or which can be easily moved from one place to another while connected to the supply.

2.1.137 *Monitoring* — Observation of the operation of a system or part of a system to verify correct functioning or detect incorrect functioning by measuring system variables and comparing the measured value with the specified value.

2.1.138 *Multiple Earthed Neutral System* — A system of earthing in which the parts of an installation specified to be earthed are connected to the general mass of earth and, in addition, are connected within the installation to the neutral conductor of the supply system.

2.1.139 *Neutral Conductor* — Includes the conductor of a three-phase four-wire system; the conductor of a single-phase or d.c. installation, which is earthed by the supply undertaking (or otherwise at the source of the supply), and the middle wire or common return conductor of a three-wire d.c. or single-phase a.c. system.

2.1.140 *Origin of an Electrical Installation* — The point at which electrical energy is delivered to an installation.

NOTE — An electrical installation may have more than one origin.

2.1.141 *Overcurrent* — A current exceeding the rated value. For conductors the rated value is the current carrying capacity.

2.1.142 *Overload Current (of a Circuit)* — An overcurrent occurring in a circuit in the absence of an electrical fault.

2.1.143 *PEN Conductor* — A conductor combining the functions of both protective conductor and neutral conductor.

2.1.144 *Phase Conductor* — *See* **2.1.130.**

2.1.145 *Plug* — A device, provided with contact pins, which is intended to be attached to a flexible cable,

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and which can be engaged with a socket outlet or with a connector.

2.1.146 *Point (in Wiring)* — A termination of the fixed wiring intended for the connection of current using equipment.

2.1.147 *Portable Equipment* — Equipment which is moved while in operation or which can easily be moved from one place to another while connected to the supply.

2.1.148 *Protection, Ingress* — The degree of protection against intrusions (body parts such as hands and fingers), dust, accidental contact and water.

NOTE — The classification of degrees of ingress protection provided by enclosures for electrical equipment shall be as per the accepted standard [8-2(6)].

2.1.149 *Protection*, *Mechanical Impact* — The degrees of protection provided by enclosures for electrical equipment against external mechanical impacts.

NOTE — The classification of degrees of protection against mechanical impact provided by enclosures for electrical equipment shall be as per IEC 62262:2002 'Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)'.

2.1.150 *Prospective Fault Current* (I_{pf}) — The value of overcurrent at a given point in a circuit resulting from a fault of negligible impedance between live conductor having a difference of potential under normal operating conditions, or between a live conductor and an exposed-conductive part.

2.1.151 *Protective Conductor* — A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts:

a) Exposed conductive parts,
b) Extraneous conductive parts,
c) Main earthing terminal, and
d) Earthed point of the source, or an artificial neutral.

2.1.152 *Protective Conductor Current* — Electric current appearing in a protective conductor, such as leakage current or electric current resulting from an insulation fault.

2.1.153 *Protective Earthing* — Earthing of a point or points in a system or in equivalent for the purpose of safety.

2.1.154 *Protective Separation* — Separation of one electric circuit from another by means of,

a) double insulation;
b) basic insulation and electrically protective screening (shielding); or
c) reinforced insulation.

2.1.155 *Rated Current* — Value of current used for specification purposes, established for a specified set of operating conditions of a component, device, equipment or system.

2.1.156 *Rated Impulse Withstand Voltage Level* (U_w) — The level of impulse withstand voltage assigned by the manufacturer to the equipment, or to part of it, characterizing the specified withstand capability of its insulation against overvoltage.

2.1.157 *Residual Current* — The algebraic sum of the instantaneous values of current flowing through all live conductors of a circuit at a point of the electrical installation.

2.1.158 *Residual Current Device (RCD)* — A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions.

2.1.159 *Residual Operating Current* — Residual current which causes the residual current device to operate under specified conditions.

2.1.160 *Service* — The conductors and equipment required for delivering energy from the electric supply system to the wiring system of the premises served.

2.1.161 *Shock Current* A current passing through the body of a person or an animal and having characteristics likely to cause dangerous patho-physiological effects.

2.1.162 *Short-Circuit Current* — An overcurrent resulting from a fault of negligible impedance between live conductors having a difference in potential under normal operating conditions.

2.1.163 *Space Factor* — The ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (including insulation and sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed. The effective overall cross-sectional area of a non-circular cable is taken as that of a circle of diameter equal to the major axis of the cable.

2.1.164 *Standby Supply System* — A system intended to maintain supply to the installation or part thereof, in case of interruption of the normal supply, for reasons other than safety of persons.

NOTE — Standby supplies are necessary, for example, to avoid interruption of continuous industrial processes or data processing.

2.1.165 *Stationary Equipment* — Either fixed equipment or equipment not provided with a carrying handle and having such a mass that it cannot easily be moved.

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2.1.166 *Step Voltage* — The potential difference between two points on the earth's surface, separated by distance of one pace, that will be assumed to be one metre in the direction of maximum potential gradient.

2.1.167 *Socket-Outlet* — A device, provided with female contacts, which is intended to be installed with the fixed wiring, and intended to receive a plug.

NOTE — A luminaire track system is not regarded as a socket-outlet system.

2.1.168 *Surge* — A transient created by LEMP that appears as an overvoltage and/or an overcurrent.

2.1.169 *Surge Protective Devices* (*SPD*) — A device intended to limit transient overvoltages and divert surge currents. It contains at least one non-linear component.

2.1.170 *Switch* — A mechanical switching device capable of making, carrying and breaking current under normal circuit conditions, which may include specified operating overload conditions; and also of carrying for a specified time currents under specified abnormal circuit conditions, such as those of short circuit.

NOTE — A switch may also be capable of making, but not breaking, short-circuit currents.

2.1.171 *Switchboard* — An assembly of switchgear with or without instruments, but the term does not apply to a group of local switches in a final circuit.

NOTE — The term 'switchboard' includes a distribution board.

2.1.172 *Switch Disconnector* — A switch which, in the open position, satisfies the isolating requirements specified for a disconnector.

NOTE — A switch disconnector is otherwise known as an isolating switch.

2.1.173 *Switch Disconnector Fuse* — A composite unit, comprising a switch with the fuse contained in or mounted on the moving member of the switch.

2.1.174 *Switch, Linked* — A switch, the contacts of which are so arranged as to make or break all poles simultaneously or in a definite sequence.

2.1.175 *Switchgear* — An assembly of main and auxiliary switching apparatus for operation, regulation, protection or other control of electrical installations.

2.1.176 *System* (*Electrial*) — An electrical system consisting of a single source or multiple sources running in parallel of electrical energy and an installation. Types of system are identified as follows, depending upon the relationship of the source, and of exposed-conductive parts of the installation, to earth:

a) *TN system* — A system having one or more points of the source of energy directly earthed, the exposed conductive-parts of the installation being connected to that point by protective conductors.

b) *TN-C system* — A system in which neutral and protective conductors are combined in a single conductor throughout the system.

c) *TN-S system* — A system having separate neutral and protective conductor throughout the system.

d) *TN-C-S system* — A system in which neutral and protective conductors are combined in a single conductor in part of the system.

e) *TT system* — A system having one point of the source of energy directly earthed, the exposed-conductive-parts of the installation being connected to the earth electrodes electrically independent of the earth electrodes of the source.

f) *IT system* — A system having no direct connection between live parts and earth, the exposed-conductive-parts of the electrical installation being earthed.

2.1.177 *Touch Voltage* — The potential difference between the ground potential rise (GPR) of a grounded metallic structure and the surface potential at the point where a person could be standing while at the same time having a hand in contact with the grounded metallic structure. Touch voltage measurements can be 'open circuit' (without the equivalent body resistance included in the measurement circuit) or 'closed circuit' (with the equivalent body resistance included in the measurement circuit) voltage by which an installation or part of an installation is designated.

2.1.178 *Usable Wall Space* — All portions of a wall, except that occupied by a door in its normal open position, or occupied by a fire place opening, but excluding wall spaces which are less than 1 m in extent measured along the wall at the floor line.

2.1.179 *Utility Building* — A standalone separate single or two storied service building structure outside the main building structure meant for only accommodating services' spaces, such as electric substation, diesel generator plant room, a.c. plant room, plumbing plant room, sewerage treatment plant, medical gases, electrical and mechanical maintenance rooms. Such buildings do not have any permanent occupancy other than by personnel on duty.

2.1.180 *Voltage, Nominal (of an Installation)* — Voltage by which an installation or part of an installation is designated.

2.1.181 *Voltage, Extra Low (ELV)* — The voltage which does not normally exceed 50 V.

2.1.182 *Voltage, Low* (*LV*) — The voltage which normally exceeds 50 V but does not normally exceed 250 V.

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2.1.183 *Voltage, Medium* (*MV*) — The voltage which normally exceeds 250 V but does not exceed 650 V.

2.1.184 *Voltage, High (HV)* — The voltage which normally exceeds 650 V but less than or equal to 33 kV.

2.1.185 *Voltage, Extra High (EHV)* — The voltage, which normally exceeds 33 kV.

2.1.186 *Weatherproof* — Accessories, lighting fittings, current-using appliances and cables are said to be of the weatherproof type with ingress protection according to the application, if they are so constructed that when installed in open situation they will withstand the effects of rain, snow, dust and temperature variations.

2.2 Conventional Symbols

The architectural symbols that are to be used in all drawings, wiring plans, etc, for electrical installations in buildings shall be as given in Annex A.

For other graphical symbols used in electrotechnology, reference may be made to good practice [8-2(1)].

3 GENERAL REQUIREMENTS

3.1 Conformity with *The Electricity Act*, 2003 and *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010 as Amended Up-to-Date

The installation shall generally be carried out in conformity with the requirements of *The Electricity Act*, 2003 as amended up-to-date and the *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010 framed thereunder and as amended from time-to-time; and also the relevant regulations of the Electric Supply Authority concerned as amended from time-to-time. Extracts from the *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010 (as amended in 2015), referred to in this Section, are given in Annex B.

3.2 Materials

All materials, fittings, appliances, etc, used in electrical and allied installations, shall conform to Part 5 'Building Materials' of the Code and other concerned Indian Standards.

3.3 Coordination with Local Supply Authority

a) In all cases, that is, whether the proposed electrical work is a new installation or extension of an existing one, or a modification involving major changes, the electricity supply undertaking shall be consulted about the feasibility, etc, at an early date. The wattage per square metre and permissible diversity consideration shall be defined as per the type of building (residential, commercial, mercantile, industrial, retail, convention, exhibition, hotel, hospital, institution, flatted factory, group housing, etc). The wattage per square feet shall be defined considering probable loads as per city grading such that future loading into the development is accounted.

b) *Addition to an Installation* — An addition, temporary or permanent, shall not be made to the authorized load of an existing installation, until it has been definitely ascertained that the current carrying capacity and the condition of existing accessories, conductors, switches, etc, affected, including those of the supply authority are adequate for the increased load. The size of the cable/conductor shall be suitably selected on the basis of the ratings of the protective devices. Ratings of protective devices and their types shall be based on the installed load, switching characteristics and power factor.

Load assessment and application of suitable diversity factor to estimate the full load current shall be made as a first step. This should be done for every circuit, submain and feeder. Power factor, harmonics (*see* **5.3.6.6**) and efficiency of loads shall also be considered. Diversity factor assumed shall be based on one's own experience or as per table under **4.2.2.2**. Allowance should be made for about 15 percent to 20 percent for extension in near future. The wiring system should be adopted taking into account the environmental requirements and hazards, if any in the building. The sizes of wiring cables are decided not merely to carry the load currents, but also to withstand thermal effects of likely overcurrents, short circuit and also to ensure acceptance level of voltage drop.

3.4 Power Factor Improvement in Consumers' Installation

3.4.1 Conditions of supply of electricity boards or licensees stipulate the lower limit of power factor which is generally 0.90 or better.

3.4.2 Principal causes of low power factor are many. For guidance to the consumers of electric energy who take supply at low and medium voltages for improvement of power factor, reference shall be made to good practice [8-2(7)].

3.5 Execution of Work

Unless otherwise exempted under the appropriate regulation of the *CEA (Measures relating to Safety and Electricity Supply) Regulations*, 2010 as amended from time-to-time, the work of electrical installations shall be carried out by a licensed electrical contractor and

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under the direct supervision of a person holding a certificate of competency and by persons holding a valid permit issued and recognized by any State government.

3.6 Safety procedures and practices shall be kept in view during execution of the work in accordance with good practice [8-2(8)].

3.7 Safety provisions given in Part 4 'Fire and Life Safety' of the Code shall be followed.

4 PLANNING OF ELECTRICAL INSTALLATIONS

4.1 General

The design and planning of an electrical wiring installation involve consideration of all prevailing conditions, and is usually influenced by the type and requirements of the consumer. Various utility services including LV systems namely intercom, data cabling (*see* Part 8 'Building Services, Section 6 Information and Communication Enabled Installations' of the Code), CCTV, fire alarm shall also be taken into account with anticipated future requirements. A competent electrical design engineer should be involved at the planning stage with a view to providing for an installation that will prove adequate for its intended purpose and ensure safety, reliability and energy efficiency in its use. The information/requirements given in **3** shall also be kept into consideration while designing and planning an electrical wiring installation. With the proliferation of the use of electrical and electronic devices in buildings as well as the increase in the generation/distribution capacities of power systems, the hazards of energy feed to a fault or defect in the electrical installation have increased. Reliability of power supply and continued supply even under abnormal conditions are becoming very important not only for the operation of services and activities in a building, but also for the life safety of occupants. Reference is drawn to Part 0 'Integrated Approach — Prerequisite for Applying Provisions of the Code' of the Code, which defines the requirements of interdisciplinary coordination right from the sketch design of the building. Electricity is linked to all services and addition of standby and emergency power supply systems adds to the complexity, thus requiring proper coordinated design. Generally it is not difficult to provide proper pathways and equipment installation spaces, if an integrated approach is taken from the beginning. The designs should also have to keep the availability of optimum access to installations to ensure proper maintenance. Considering various utility services and to avoid conflict amongst them, it is most important to estimate space requirement for electrical work including LV systems, at planning stage and allocate it in consultation with an architect/civil engineer.

4.1.1 The design and planning of an electrical wiring installation shall take into consideration the following:

a) Type of supply, building utility, occupancy, envisaged load and the earthing arrangement available;
b) Provisioning of air conditioning systems in present and/or future loading;
c) Climatic condition, such as cooling air temperature, moisture or such other conditions which are likely to affect the installation adversely;
d) Possible presence of inflammable or explosive dust, vapour or gas;
e) Degree of electrical and mechanical protection necessary;
f) Importance of continuity of service including the possible need for standby supply;
g) Probability of need for modification or future extension;
h) Probable operation and maintenance cost taking into account the electricity supply tariffs available;
j) Relative cost of various alternative methods;
k) Need for radio and telecommunication interference suppression;
m) Ease of maintenance;
n) Safety aspects;
p) Energy conservation;
q) Importance of proper discrimination between protective devices for continuity of supply and limited isolation of only the affected portion; and
r) Reliability of power supply and redundancy (of sources and distribution paths) to cater to the needs for emergency power and standby power for continued operation of systems as well as integration of alternate sources of energy such as diesel generation, solar energy, wind power, etc.

4.1.2 All electrical apparatus shall be suitable for the services these are intended for.

4.1.3 *Coordination*

Proper coordination and collaboration between the architect, civil engineer, electrical engineer and mechanical engineer shall be effected from the planning stage of the installation. The electrical engineer shall be conversant with the needs of the electrical supply provider for making electrical supply arrangement. Electrical supplier's installation, as per Regulations, needs to be segregated from consumer's installation. Wherever required, prior approval of drawings shall be taken from concerned electrical supplier/electrical inspector. Further, depending on load and regulation

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provisions, consumer will need to submit to the electrical supplier the details regarding the accommodation of substation including transformers, switch-rooms, standby power, solar photovoltaic panels, lightning scheme for the approval. Additional information may be sought by the Authority regarding cable ducts, rising mains and distribution cables, sub-distribution boards, openings and chases in floors and walls for all required electrical installations, etc.

4.1.4 Before starting wiring and installation of fittings and accessories, information should be exchanged between the owner of the building/architect/ consultant/ electrical contractor and the local supply authority in respect of tariffs applicable, types of apparatus that may be connected under each tariff, requirement of space for installing meters, switches, etc, and for total load requirements of lights, fans and power.

4.1.5 While planning an installation, consideration should be taken of the anticipated increase in the use of electricity for lighting, general purpose socket-outlet, kitchen equipment, air conditioning, utility sockets, heating, etc.

It is essential that adequate provision should be made for all the services which may be required immediately and during the intended useful life of the building, for the householder, who may otherwise be tempted to carry out extension of the installation himself or to rely upon use of multi-plug adaptors and long flexible cords, both of which are not recommended.

4.2 Substation and Switchrooms

4.2.1 *Location and Other Requirements*

The location and other requirements of a substation and switchrooms shall be as given below:

1) Availability of power lines nearby may be kept in view while deciding the location of the substation.
2) The substation should preferably be located in a separate utility building and may be adjacent to the generator room, if any. Location of substation in the basement should be avoided, as far as possible.
3) In case there is only one basement in a building, the substation/switchroom shall not be provided in the basement. Also, the floor level of the substation shall not be lowest point of the basement.
4) Ideal location for an electrical substation for a group of buildings will be at the electrical load centre. Generally the load centre will be somewhere between the geometrical centre and the air conditioning plant room, as air conditioning plant room will normally be the largest load, if the building(s) are centrally air conditioned.
5) In order to prevent storm water entering the transformer and switch rooms through the soak-pits, the floor level of the substation/ switchroom shall be at least 300 mm above the highest flood water level that may be anticipated in the locality. Also, facility shall be provided for automatic removal of water.
6) Substation shall not be located immediately above or below plumbing water tanks or sewage treatment plant (STP) water tanks at the same location.
7) All door openings from substation, electrical rooms, etc, should open outwards. Vertical shutters (like fire rated rolling shutters) may also be acceptable provided they are combined with a single leaf door opening outwards for exit in case of emergency. For large substation room/electrical room having multiple equipment, two or more doors shall be provided which shall be remotely located from each other.
8) If substation is located at a height 1 000 m above MSL, then adequate derating of equipment shall be considered.
9) In case of HV panel and transformers located at different floors or at a distance more than 20 m, HV isolator shall be provided at transformer end.
10) In case transformer and main MV/LV panel room are located at different floors or are at a distance more than 20 m, MV/LV isolator shall be provided at transformer end. In case transformer and main MV/LV panel room are located at different floors, the designer should also take care of the safety requirements caused by lack of direct visibility of the status of the controlling switch. To cater to the safety requirements under different conditions of operation as well as maintenance, it may be necessary to provide additional isolator or an emergency push button in the vicinity to trip the supply. Decision has to be taken based on the possible risks.
11) No services or ventilation shafts shall open into substation or switch room unless specific to substation or switch room.
12) *Oil-filled installation* — Substations with oil-filled equipment require great consideration for the fire detection, protection and suppression. Oil-filled transformers require a suitable soak pit with gravity flow to contain the oil in the event of the possibility of oil spillage from the transformer on its failure. Installation of oil-filled equipment shall meet the following requirements:

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i) Substations with oil-filled equipment/ apparatus [transformers and high voltage panels] shall be either located in open or in a utility building. They shall not be located in any floor other than the ground floor or the first basement of a utility building. They shall not be located below first basement slab of utility building. They shall have direct access from outside the building for operation and maintenance of the equipment.

ii) Substations/Utility buildings (where the substation or oil-filled transformer is located) shall be separated from the adjoining buildings including the main building by at least 6 m clear distance to allow passage of fire tender between the substation/utility building and adjoining building/main building.

iii) There shall be no interconnecting basement with the main building underneath the oil-filled transformers.

iv) Provisions for oil drainage to a point at a lower level and separated by adequate fire barrier shall be provided. If there is a floor directly below the ground floor level or first basement where the oil-filled transformers and oil-filled circuit breakers are placed, then they shall be separated by a fire barrier of appropriate fire rating as per Part 4 'Fire and Life Safety' of the Code and proper oil drainage system shall be provided to avoid possible leakage of oil into the lower floor.

v) Substation equipment having more than 2 000 litre of oil whether located indoors in the utility building or outdoors shall have baffle walls of 4 h fire rating between apparatus (*see also* Part 4 'Fire and Life Safety' of the Code for fire safety related requirements).

vi) Provisions shall be made for suitable oil soak-pit, and where use of more than 9 000 litre of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing the same. Special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur.

vii) In respect of all oil type transformers located at basement, a kerb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a ruptured transformer into other parts of the basement in the event of the possibility of oil spillage from the transformer on its failure.

viii) Adequate fire barriers or deflectors shall be provided to avoid flames from the substation reaching or affecting the upper floors (*see also* Part 4 'Fire and Life Safety' of the Code).

ix) For transformers having large oil content (more than 2 000 litre), Rule 44(2) of the *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010 as amended from time-to-time shall apply (*see* Annex B).

13) *Dry-type installation* — In case electric substation has to be located within the main multi-storeyed building itself for unavoidable reasons, it shall be a dry-type installation with very little combustible material, such as, a dry type transformer with vacuum (or SF_6) breakers as HT switchgear and ACB or MCCB as medium voltage (MV) switchgear. Such substations shall be located on the ground level or on first basement, and shall have direct access from the outside of the building for operation and maintenance of the equipment.

Exceptionally, in case of functional buildings, such as air traffic control towers, data centres and buildings of height more than 100 m having high electrical load requirement, dry-type installations/substations may also be provided at upper level. This measure will decrease the current flow and short-circuit rating at various points, thereby reducing vulnerability to fire. In such cases, a base substation shall be located at ground floor/first basement to cater to the main MV/LV panel which feeds life and safety services loads as defined in **4.2.1** (29). The base substation shall be located in such a way to provide direct access to the firemen in case of any emergency. The power supply control to any substation or transformer located at upper floors shall be from the base substation so that in case of fire, the electrical supply can be easily disconnected to avoid additional losses.

14) The power supply HV cables voltage shall not be more than 12 kV and a separate dedicated and fire compartmented shaft should be provided for carrying such high voltage cables to upper floors in a building. These shall not be mixed with any other shaft and suitable fire detection and suppression measures shall be provided throughout the length of the cable on

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each floor.

15) The provision for installation and removal of substation equipment should be provided from inside or outside the building without disturbing the associated major equipment in the substation.

16) In case of compact substation {*see* accepted standard [8-2(4)]}, design and location of the substation shall ensure safety of the people around the compact substation installed along walkways, playgrounds, etc. Compact substation with incomer voltage of 12 kV or less, when located in open areas shall have fencing or barrier (of any metal based protection, such as wire mesh or chain link, which is duly earthed) against unauthorized contact possibility around it at a minimum distance of 750 mm around it with access for maintenance from all four sides. For incomer voltage more than 12 kV and less than 24 kV the fencing distance from substation may be 1 000 mm minimum. In case of more than 24 kV incomer, the distance may be further increased accordingly. The fencing design should take care of the servicing and maintenance requirements of the substation equipment.

17) In case of two transformers (dry type or transformers with oil quantity less than 2 000 litre) located next to each other without intermittent wall, the distance between the two shall be minimum 1 500 mm for 11 kV, minimum 2 000 mm for 22 kV and minimum 2 500 mm for 33 kV. Beyond 33 kV, two transformers shall be separated by baffle wall of 4 h fire rating.

18) Horizontal routing of HT cable through functional/occupied areas should be avoided in view of safety.

19) If dry type transformer is used, it may be located adjacent to medium voltage switchgear in the form of unit type substation. In such a case, no separate room or fire barrier for the transformer is required either between transformers or between transformer and the switchgear, thereby decreasing the room space requirement; however, minimum distances as specified in **4.2.1** (17) shall be maintained between the apparatus depending upon voltage ratings. Layout of equipment should take care of the need that any one piece of equipment or sub-assembly can be taken out of service and out of the installed location, while keeping the remaining system in service. Working space for access for maintenance of equipment, while keeping an adjoining section of the substation live to maintain power supply to essential loads, may require additional space between such sections of equipment.

20) In places where flooding can occur and water level may go above 1 000 mm, the base substation may be located on one level above the ground level of a utility building. In such cases, one feeder should feed ground level and levels below with automatic tripping of the feeder to avoid electrocution in case of live electricity coming in contact with water. Designers shall use their discretion in special cases and depending on the degree of reliability, redundancy and the category of load and make suitable provisions.

    NOTE — In cases, where the substation is located one level above ground level of utility building, this should be after due evaluation of the other risks posed by such a location combined with the concurrence for such a decision from State Electricity Authority comprising the electrical inspectorate and the distribution licensee and the fire service.

21) For acoustical enclosures/treatment, reference may be made to Part 8 'Building Services', Section 4 'Acoustics, Sound Insulation and Noise Control' of the Code.

22) The minimum recommended spacing between the walls and the transformer periphery from the point of proper ventilation shall be in accordance with good practice [8-2(9)] (*see also* Fig. 1A). The actual spacing may be different than those given in the figure, depending on the circumstances, such as access to the accessories. Other requirements relating to installation of transformers shall also be in accordance with good practice [8-2(9)].

23) *High voltage switch room/space* — The design should take care of HV equipment space and clearance required around for maintenance and personnel safety as given in **5.3.6.8**. This room may preferably have direct access from outside. In case of substation having one transformer and one source of supply, the owner shall provide one high voltage switch. In case of single point supply with two or more transformers, the number of switch required will be one for incoming supply and one for each transformer. Additional space may be provided keeping in mind future requirement, if any. In case of duplicate supply, two switches shall be provided with mechanical/electrical inter locking arrangement. In case the number of incoming and outgoing switches exceed five, bus coupler of suitable capacity should invariably be provided.

24) *Medium voltage switch room/space* — The floor area required in respect of medium voltage switchgear room may be determined keeping in

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view the number and type of incoming/outgoing bus coupler switches including likely expansion in future and space requirement as given in **5.3.6.8**. The additional requirements of MV switchroom when located separate from the substation shall be as per **4.2.4**.

25) Other requirements relating to installation of switchgears and controlgears as given in good practice [8-2(10)] shall also be complied with.

26) The minimum height of substation room/HV switch room/MV switch room shall be arrived at considering 1 200 mm clearance requirement from top of the equipment to the below of the soffit of the beam (*see also* Annex C). In case cable entry/exit is from above the equipment (transformer, HV switchgear, MV switchgear), height of substation room/HV switch room/MV switch room shall also take into account requirement of space for turning radius of cable above the equipment height.

27) All the rooms shall be provided with partitions up to the ceiling and shall have proper ventilation. Special care should be taken to dissipate transformer heat and where necessary fresh air louvers at lower level and exhaust fans at higher level shall be provided at suitable locations.

28) In case of cable trench in substation/HV switch room/MV switch room, the same shall be adequately drained to ensure no water is stagnated at any time with live cables.

29) *Power supply to emergency fire and life safety systems* — Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment, shall be planned for efficient and reliable power and control supply to the following systems and equipment where provided:

   i) Fire pumps;
   ii) Pressurization and smoke venting; including its ancillary systems such as dampers and actuators;
   iii) Fireman's lifts (including all lifts).
   iv) Exit signage lighting;
   v) Emergency lighting;
   vi) Fire alarm system;
   vii) Public address (PA) system (relating to emergency voice evacuation and annunciation);
   viii) Magnetic door hold open devices; and
   ix) Lighting in fire command centre and security room.

   Power supply to these systems and equipment shall be from normal and emergency (standby generator) power sources with change over facility. It shall be ensured that in case the power supply is from HT source/HT generation, transformers should be planned in stand-by capacity to ensure continuity of power to such systems. Wherever transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables shall be taken to all transformers. The generator shall be capable of taking starting current of all the fire and life safety systems and equipment as above. Where parallel HV/LV supply from a separate substation fed from different grid is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

   The power supply to the panel/distribution board of these fire and life safety systems shall be through fire proof enclosures or circuit integrity cables or through alternate route in the adjoining fire compartment to ensure that supply of power is reliable to these systems and equipment. It is to be ensured that the cabling from the adjoining fire compartment is to be protected within the compartment of vulnerability. The location of the panel/ distribution board feeding the fire and life safety system shall be in fire safe zone ensuring supply of power to these systems.

   Cables for fire alarm and PA system shall be laid in metal conduits or armoured to provide physical segregation from the power cables.

30) Other requirements as given in *Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations*, 2010 as amended shall also be complied with. The fire safety requirements for substation and electrical rooms, including fire rating requirements of substations enclosure, that is, walls, floor, ceiling, openings, doors, etc, as given in Part 4 'Fire and Life Safety' of the Code shall also be complied with.

4.2.2 *Layout of Substation*

4.2.2.1 In allocating the area of substation, it is to be noted that the flow of electric power is from supply company's meter room to HV room, then to transformer and finally to the MV switchgear room. The layout of the room and trenches of required depth shall be in accordance with this flow, so as to optimize the cables, bus-trunking, etc. Visibility of equipment controlled from the operating point of the controlling switchgear is also a desirable feature, though it may not be achievable in case of large substations. Substations shall not be located

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at or across expansion joints. The rooms/spaces required in a substation shall be provided as given below:

a) *Supply company's meter room*, generally at the periphery of the premise with direct access from the road/outside;
b) *HV isolation room*, required in case the substation is away from the meter room and is planned adjacent to meter room for disconnecting supply in case of any repair required between meter room and substation;
c) *HV panel room/space*, located adjacent to transformer;
d) *Transformer room/space*, separate space in case of oil-filled transformer and combined space in case of dry type transformer;
e) *MV isolation room/space*, required in case MV panel is away from transformer or on a different level for isolating supply in case of any repair required between transformer and MV switchgear; and
f) *Main MV panel room/space*, required for distribution to different facility/utility in a building.

A typical layout of a substation is shown in Fig. 1B.

4.2.2.2 *Capacity and size of substation*

The capacity of a substation depends upon the area of the building and its type. The capacity of substation may be determined based on the load requirements (*see also* **3.3**). Ratings of electrical equipment as given in **6.1,** may be assumed, unless the values are known or specified and diversity requirements as given below may be used for load assessment:

Sl No.	*Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies*	*Typical Allowances for Diversity Based on: Type of Building*		
		Individual House Hold Installations, Including Individual Dwelling of a Block	Small Shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, etc
(1)	(2)	(3)	(4)	(5)
i)	Lighting	66 percent of total current demand	90 percent of total current demand	75 percent of total current demand
ii)	Heating and power [*see also* Sl No. (iii) to (iv)]	100 percent of total current demand up to 10 A + 50 percent of any current demand in excess of 10 A	100 percent of full load of largest appliance + 75 percent of remaining appliances	100 percent of full load of largest appliance + 80 percent of second largest appliance + 60 percent of remaining appliances
iii)	Cooking appliances	10 A + 30 percent full load of connected cooking appliances in excess of 10 A + 6 A if socket-outlet incorporated in the unit	100 percent of full load of largest appliance + 80 percent of full load of second largest appliance + 60 percent of full load of remaining appliances	100 percent of full load of largest appliance + 80 percent of full load of second largest appliance + 60 percent of full load of remaining appliances
iv)	Motors (other than lift motors which are subject to special consideration)		100 percent of full load of largest motor + 80 percent of full load of second largest motor	100 percent of full load of largest motor + 50 percent of full load of remaining motors

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Sl No.	*Purpose of Final Circuit Fed from Conductors or Switchgear to which Diversity Applies*	*Typical Allowances for Diversity Based on: Type of Building*		
		Individual House Hold Installations, Including Individual Dwelling of a Block	Small Shops, Stores, Offices and Business Premises	Small Hotels, Boarding Houses, etc
(1)	(2)	(3)	(4)	(5)
			+ 60 percent of full load of remaining motors	
v)	Water heater [instantaneous type[1)]]	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances	100 percent of full load of largest appliance + 100 percent of full load of second largest appliance + 25 percent of full load of remaining appliances
vi)	Water heater (thermostatically controlled)	No diversity allowable[2)]		
vii)	Floor warming installations	No diversity allowable[2)]		
viii)	Water heaters thermal storage space heating installations	No diversity allowable[2)]		
ix)	Standard arrangements of final circuits in accordance with good practice [8-2(11)]	100 percent of the current demand of the largest circuit + 40 percent of the current demand of every other circuit	100 percent of the current demand of the largest circuit + 50 percent of the current demand of every other circuit	
x)	Socket outlets other than those included in Sl No. (ix) and stationary equipment other than those listed above	100 percent of the current demand of the largest point + 40 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every other point	100 percent of the current demand of the largest point + 75 percent of the current demand of every point in main rooms (dining rooms, etc) + 40 percent of the current demand of every other point

NOTE — Diversity may be considered , if multiple units of water he ater are there in an individual house -hold installation, including individual dwelling of a block

[1)] For the purpose of the table, an instantaneous water heater is deemed to be a water heater of any loading which heats water only while the tap is turned o n and therefore uses electricity intermittently.

[2)] It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

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After calculating the electrical load on the above basis, an overall load factor of 70 to 90 percent is to be applied to arrive at the minimum capacity of substation. A future load may also be considered for substation sizing (*see* **3.3**). The area required for substation and transformer room for different capacities is given in Annex C for general guidance. For reliability, it is recommended to split the load into more than one transformer and also provide for standby transformer as well as multiple sources, bus-section, etc.

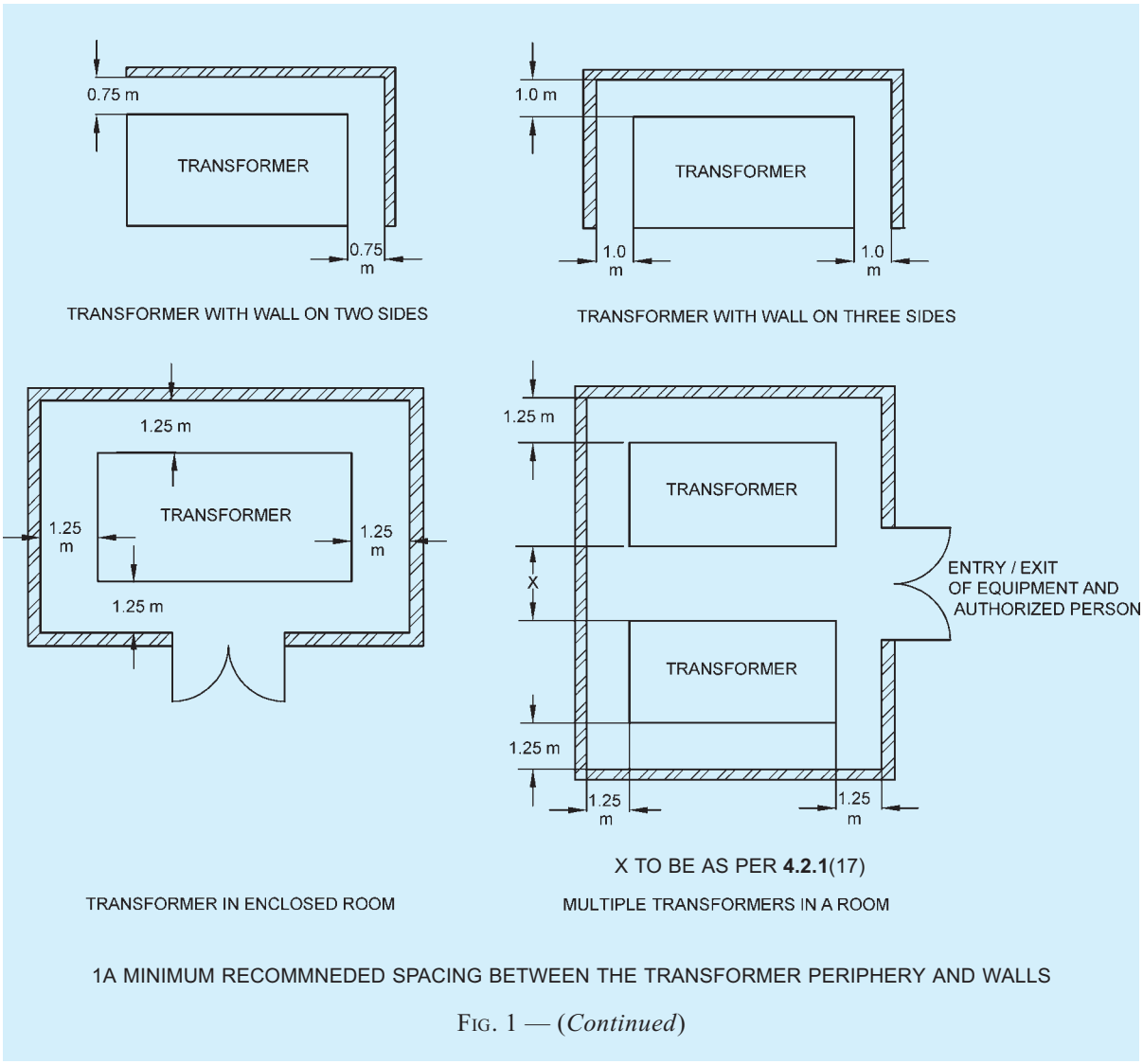
4.3 Emergency Power Backup System

4.3.1 *Location*

The emergency power supply (such as generating sets) should not be allowed to be installed above ground floor or below the first basement level of the building. In case of DG set located in basement, the ceiling of the DG room shall be the ground floor slab. It is preferable to install the standby generator in utility building. If installed in the enclosed space, facilities for forced ventilation shall be provided such that there is minimum derating of the equipment. The generating set should preferably be housed adjacent to MV switchgear in the substation building to enable transfer of electrical load efficiently and also to avoid transfer of vibration and noise to the main building.

4.3.2 *Room for Emergency Power Backup System*

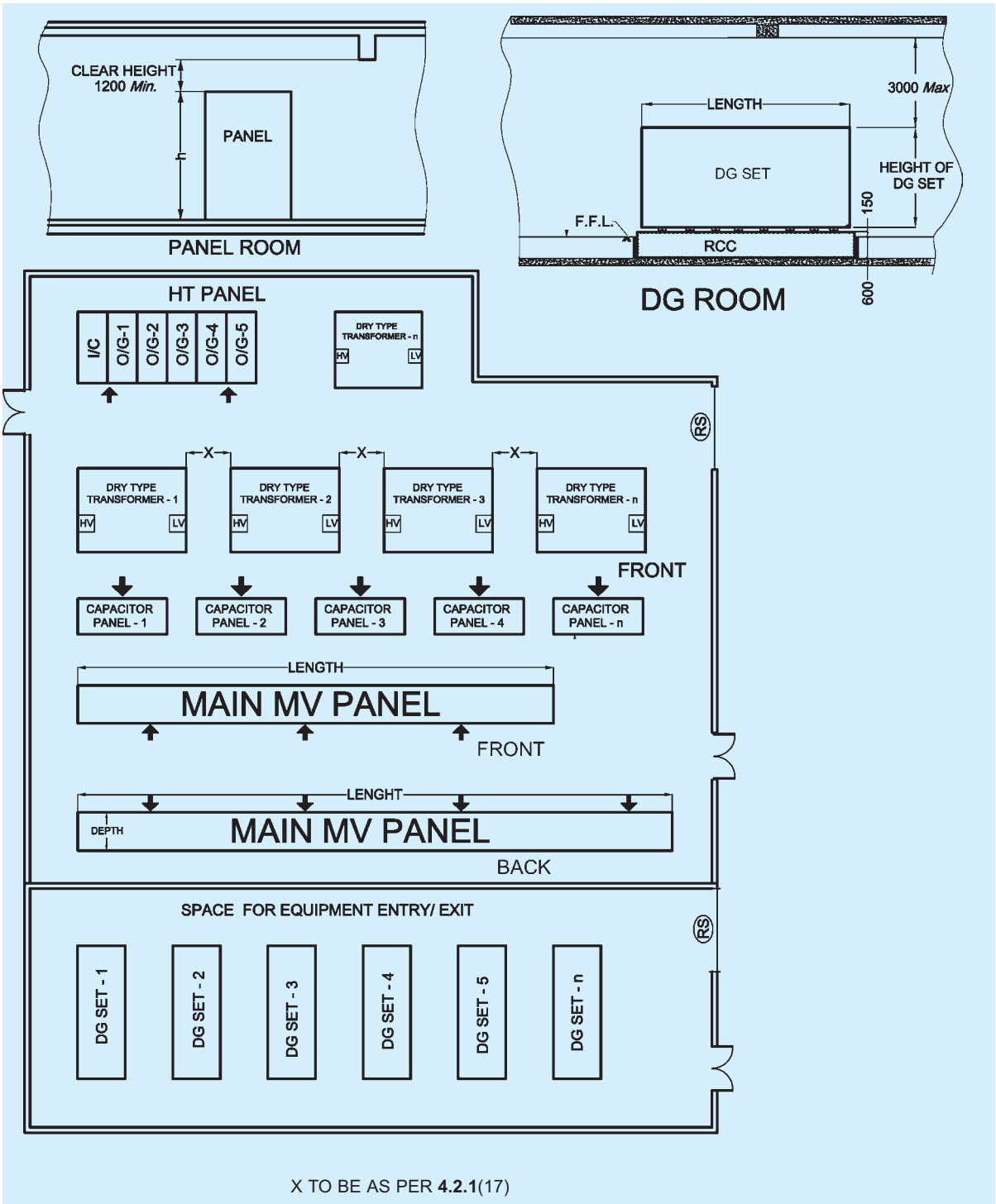
The capacity of standby generating set shall be sized for emergency fire and life safty systems [*see* **4.2.1** (29)] and other utilities as required and identified for functional requirement of the building. Having chosen the capacity and number of generating sets, required space may be provided for their installation (*see* Annex D for general guidance). There shall be provision of separate direct escape and entry from outside so that in case of fire, electrical supplies can be disconnected to



1A MINIMUM RECOMMNEDED SPACING BETWEEN THE TRANSFORMER PERIPHERY AND WALLS

FIG. 1 — (*Continued*)

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X TO BE AS PER **4.2.1**(17)

All dimensions in millimetres.

1B TYPICAL LAYOUT OF SUBSTATION WITH DRY TYPE EQUIPMENT IN A SINGLE ROOM

FIG. 1 TYPICAL LAYOUT OF SUBSTATION INCLUDING MINIMUM RECOMMENDED SPACING OF TRANSFORMER PERIPHERY FROM WALLS

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avoid additional losses which may be caused due to electrical supply, present at the time of fire. The height of diesel generating (DG) set rooms shall however be not more than 3 000 mm above the DG set height, unless required due to DG room ventilation requirements. Adequate space shall be provided for storing of fuel. Facilities including space at appropriate positions, relative to the location of the installed equipment has to be kept in the layout design for removal of equipment or sub-assemblies for repair or maintenance. When it is located at a place, other than the ground level with direct equipment access, a hatch or ramp shall be provided.

4.3.3 *Installation and Other Requirements*

Following installation and other requirements shall also be complied with:

a) Day-oil tanks for the DG sets shall be in compliance with *The Petroleum Act*, 1934.

b) The emergency installation shall comply with the norms laid down by the Central Pollution Control Board (CPCB) and shall also be in compliance with *The Petroleum Act*, 1934 and guidelines of Oil Industry Safety Directorate (OISD). Compartmentation for fire protection with detection and first-aid protection measures is essential.

NOTE — Different type of fire safety requirements exists for the diesel engine and generator for the oil storage area and for the switchgear (*see also* Part 4 'Fire and Life Safety 'of the Code).

c) Acoustic enclosure for DG sets/acoustic lining of the DG room and ventilation system for DG room shall be in line with the requirements of CPCB. If DG set is located outdoors, it shall be housed in acoustics enclosure as per the requirements of CPCB norms. For acoustical enclosures/treatment, reference shall also be made to Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code.

d) The generator house should have proper ventilation for engine combustion requirements and as well as for the body heat removal apart from the heat removal from radiator or cooling tower, fire fighting equipment, etc. The other requirements given in Part 4 'Fire and Life Safety' of the Code for room for emergency power backup system including DG set room shall also be complied with.

e) Other environmental requirements under the provisions of *Environment Protection Rules*, 1986 and norms laid down by CPCB, as amended from time-to-time shall be taken into account particularly from the aspect of engine emissions including the height of exhaust pipe and permitted noise levels/controls.

4.4 Location of MV/LV Switch Room Other than in Substation

In large installations other than where a substation is provided, a separate switch room shall be provided; this shall be located as close to the electrical load centre as possible, on the ground floor or on the first basement level of the building. Suitable cable trays shall be laid with minimum number of bends from the points of entry of the main supply cable to the position of the main switchgear. The switch room shall also be placed in such a position that riser shafts may readily be provided therefrom to the upper floors of the building in one straight vertical run. In larger buildings, more than one riser shaft may be required and then horizontal trays may also be required for running cables from the switch room to the foot of each rising main. Such cable trays shall either be reserved for specific voltage grades or provided with a means of segregation for medium, low and extra low voltage installations, such as call-bell systems, telephone installations, fire detection and alarm system, security systems, data cables and announcement or public address system. Cables/wires for emergency fire and life safety services and their routing shall be in accordance with **4.2.1** (29) and Part 4 'Fire and Life Safety' of the Code so that these services are maintained even in the event of a fire.

4.5 Location and Requirements of Distribution Panels

All distribution panels, switchgears shall be installed in readily accessible position. The electrical control gear distribution panels and other apparatus, which are required on each floor may conveniently be mounted adjacent to the rising mains, and adequate space considering clearances required as per **5.3.6.8** shall be provided at each floor for this purpose.

4.6 Substation Safety

The owner and the operator of any substation shall be collectively and severally be responsible for any lapse or neglect leading to an accident or an incidence of an avoidable abnormality and shall take care of the following safety requirements:

a) Enclose the substation or similar equipment where necessary to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access;

b) Enclose any part of the substation which is open to the air, with a fence (earthed efficiently at both ends) or wall not less than 1 800 mm (preferably not less than 2 400 mm) in height;

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to prevent, so far as is reasonably practicable, danger of electric shock or unauthorized access;

c) Ensure that there are at all times displayed,
   1) sufficient safety signs of such size and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances;
   2) a notice which is placed in a conspicuous position and which gives the location or identification of the substation, the name of each generator or distributor who owns or operates the substation equipment making up the substation and the telephone number where a suitably qualified person appointed for this purpose by the generator or distributor will be in constant attendance; and
   3) such other signs, which are of such size and placed in such positions, as are necessary to give due warning of danger having regard to the siting of, the nature of, and the measures taken to ensure the physical security of, the substation equipment;

d) Take all reasonable precautions to minimize the risk of fire associated with the equipment; and

e) Ensure that, in addition to provisions mentioned in (c), name and emergency telephone number of the authorized personnel shall also be displayed at the substation and instructions covering schematic diagram; requirements of switchgear interlocking, if any; and permission requirements, if any, for load limitations on (incoming) feeders; be also prominently displayed.

4.7 Overhead Lines, Wires and Cables

All erections/alterations having relation to overhead lines, wires and cables shall comply with Central Electricity Authority regulations and the following. However, in case of any conflict, the regulations shall prevail.

4.7.1 *Height Requirement*

4.7.1.1 While overhead lines may not be relevant within buildings, regulations related to overhead lines are of concern from different angles as follows:

a) Overhead lines may be required in building complexes, though use of underground cables is the preferred alternative.

b) Overhead lines may be passing through the site of a building. In such a case the safety aspects are important for the construction activity in the vicinity of the overhead line as well as portions of low height buildings that may have to be constructed below the overhead lines. Overhead lines running adjacent to buildings pose hazard from the aspect of certain maintenance activity (such as use of a ladder on external face of a building) causing temporary compromise of the minimum safety clearance.

4.7.1.2 If at any time subsequent to the erection of an overhead line, whether covered with insulating material or not, or underground cable, any person who proposes to erect a new building or structure or to raise any road level or to carry out any other type of work whether permanent or temporary or to make in or upon any building, or structure or road, any permanent or temporary addition or alteration, in proximity to an overhead line or underground cable, such person and the contractor whom he employs to carry out the erection, addition or alteration, shall give intimation in writing of his intention to do so, to the supplier or owner and to the Electrical Inspector and shall furnish therewith a scale drawing showing the proposed building, structure, road or any addition or alteration and scaffolding thereof required during the construction. In this connection, Regulation 63 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

4.7.1.3 Any person responsible for erecting an overhead line will keep informed the authority(s) responsible for services in that area for telecommunication, gas distribution, water and sewage network, roads so as to have proper coordination to ensure safety. He shall also publish the testing, energizing programme for the line in the interest of safety.

4.7.1.4 For minimum distance (vertical and horizontal) of electric lines/wires/cables from buildings, reference may be made to Part 3 'Development Control Rules and General Building Requirements' of the Code. In this connection, Regulations 58, 60, 61, and 65 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

4.7.1.5 Regulation 64 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time, which govern conditions related to the storage of material including storage of construction material at a construction site, or other materials in a building in

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vicinity of overhead lines and underground cables, shall also be complied with (*see* Annex B).

4.7.2 *Position, Insulation and Protection of Overhead Lines*

4.7.2.1 Any part of an overhead line which is not connected with earth and which is not ordinarily accessible shall be supported on insulators or surrounded by insulation. Any part of an overhead line which is not connected with earth and which is ordinarily accessible shall be,

a) made dead; or
b) so insulated that it is protected, so far it is reasonably practicable, against mechanical damage or interference; or
c) adequately protected to prevent danger.

4.7.2.2 Any person responsible for erecting a building or structure which will cause any part of an overhead line which is not connected with earth to become ordinarily accessible shall give reasonable notice to the licensee or distributor who owns or operates the overhead line of his intention to erect that building or structure.

The expression 'ordinarily accessible' means the overhead line might be reachable by hand if any scaffolding, ladder or other construction was erected or placed on/in, against or near to a building or structure.

4.7.2.3 Any bare conductor not connected with earth, which is part of a low voltage overhead line, shall be situated throughout its length directly above a bare conductor which is connected with earth.

4.7.3 *Precautions against Access and Warnings of Dangers*

4.7.3.1 Every support carrying a high voltage overhead line shall be fitted with anti-climbing devices to prevent any unauthorized person from reaching a position at which any such line will be a source of danger. In this connection, Regulation 73(3) of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

4.7.3.2 Every support carrying a high voltage overhead line, and every support carrying a low voltage overhead line incorporating bare phase conductors, shall have attached to it sufficient safety signs and placed in such positions as are necessary to give due warning of such danger as is reasonably foreseeable in the circumstances.

4.7.3.3 Poles supporting overhead lines near the road junctions and turnings shall be protected by a masonry or earth fill structure or metal barricade, to prevent a vehicle from directly hitting the pole, so that the vehicle, if out of control, is restrained from causing total damage to the live conductor system, likely to lead to a hazardous condition on the road or footpath or building.

4.7.4 *Fitting of Insulators to Stay Wires*

Every stay wire which forms part of, or is attached to, any support carrying an overhead line incorporating bare phase conductors (except where the support is a lattice steel structure or other structure entirely of metal and connected to earth) shall be fitted with an insulator, no part of which shall be less than 3 m above ground or above the normal height of any such line attached to that support.

4.8 Maps of Underground Networks

4.8.1 Any person or organization or authority laying cables shall contact the local authority in charge of that area and find out the layout of,

a) water distribution pipe lines in the area;
b) sewage distribution network;
c) telecommunication network,
d) gas pipeline network; and
e) existing power cable network,

and plan the cable network in such a manner that the system is compatible, safe and non-interfering either during its installation or during its operation and maintenance. Plan of the proposed cable installation shall be brought to the notice of the other authorities referred above.

4.8.2 Suitable cable markers and danger sign as will be appropriate for the safety of the workmen of any of the systems shall be installed along with the cable installation. Cable route markers shall be provided at every 20 m and also at turnings and/or crossings.

4.8.3 Notification of testing and energization of the system shall also be suitably publicized for ensuring safety.

4.8.4 Any person or organization or authority associated with the operation and maintenance of services in a complex is required to have a complete integrated diagram or drawings of all services with particular emphasis on the hidden pipes, cables, etc, duly kept up-to-date by frequent interaction with all agencies associated with the maintenance work.

Organization or agency responsible for laying cables shall have and, so far it is reasonably practicable, keep up-to-date, a map or series of maps indicating the position and depth below surface level of all networks or parts thereof which he owns or operates. Where adequate mapping has not been done and the excavation

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for cable laying reveals lines pertaining to any of the other services, record of three dimensional location should be marked and recorded. Even where mapping exists, it may be examined if the records have become obsolete due to change such as, in road level. Any map prepared or kept shall be available for inspection by any authority, such as municipality, water supply, sewage, service providers, general public provided they have a reasonable cause for requiring reference to any part of the map.

4.8.5 Any agency working on any one or more service (occupying the underground space for service pipes, cables, etc) should keep the other agencies informed of the work so that an inadvertent action will not cause a disruption of service. Each agency should be responsible for keeping the latest information with the central authority of such records and should be responsible to ensure that the modifications, if any are duly updated and notified among the other agencies.

5 DISTRIBUTION OF SUPPLY AND CABLING

5.1 General

5.1.1 In the planning and design of an electrical wiring installation, due consideration shall be made of all the prevailing conditions. It is recommended that advice of a competent electrical engineer be sought at the initial stage itself with a view to providing an installation that will prove adequate for its intended purpose, be reliable, safe and efficient.

5.1.2 A certain redundancy in the electrical system is necessary and has to be built in from the initial design stage itself. The extent of redundancy will depend on the type of load, its criticality, normal hours of use, quality of power supply in that area, coordination with the standby power supply, capacity to meet the starting current requirements of large motors, etc.

5.1.3 In modern building technology, following high demands are made of the power distribution system and its individual components:

a) Long life and good service quality;
b) Safe protection in the event of fire;
c) Low fire load;
d) Flexibility in load location and connection, but critical in design;
e) Low space requirement; and
f) Minimum effort involved in carrying out retrofits.

5.1.4 The high load density in modern large buildings and high rise buildings demands compact and safe solution for the supply of power. The use of busbar trunking system is ideal for such applications. Busbar trunking can be installed in vertical risers shafts or horizontally in passages for transmission and distribution of power. They allow electrical installations to be planned in a simple and neat manner. In the building complexes, additional safety demands with respect to fire barriers and fire load can also be met with the use of busbar trunking. Busbar trunking system also reduces the combustible material near the area with high energy in comparison with other distribution systems such as cables and makes the building safe from the aspect of vulnerability to fire of electrical origin. In addition, unlike cable systems the reliability of a busbar trunking system is very high. These systems also require very little periodic maintenance. Choice of busbar trunking for distribution in buildings can be made on the basis of,

a) reduced fire load (drastically reduced in comparison to the cable system);

NOTE — Insulation materials of cables are required to be fire resistant and an essential performance requirement is that the insulation material may burn or melt and flow when directly exposed to a temperature (or fire) higher than what it is class designated for, but should not continue to burn after the flame or the source of heat or file is withdrawn. Even if the above fire resistant property is exhibited by the cable insulation, a large collection of cables will make the cable insulation fail to exhibit this retardant property. While specific guidelines for limiting number of cable and bunching is not available and in such cases the switch over to a bus trunking system is the proper alternative.

b) reduced maintenance over its entire lifetime;
c) longer service lifetime in comparison with a cable distribution; and
d) enhanced reliability due to rigid bolted joints and terminations and extremely low possibility of insulation failure.

5.2 System of Supply

5.2.1 All electrical apparatus shall be suitable for the voltage and frequency of supply.

5.2.2 In case of connected load of 100 kVA and above, the relative advantage of high voltage three-phase supply should be considered. Though the use of high voltage supply entails the provisions of space and the capital cost of providing suitable transformer substation at the consumer's premises, the following advantages are gained:

a) advantage in tariff;
b) more effective earth fault protection for heavy current circuits;
c) elimination of interference with supplies to other consumers permitting the use of large size motors, welding plant, etc; and
d) better control of voltage regulation and more constant supply voltage.

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NOTE — Additional safety precautions required to be observed in HV installations shall also be kept in view.

In many cases there may be no choice available to the consumer, as most of the licensees have formulated their policy of correlating the supply voltage with the connected load or the contract demand. Generally the supply is at 240 V single phase up to 5 kVA, 415/240 V 3-phase from 5 kVA to 100 kVA, 11 kV (or 22 kV) for loads up to 5 MVA and 33 kV or 66 kV for consumers of connected load or contract demand more than 5 MVA.

5.2.3 In very large industrial buildings where heavy electric demands occur at scattered locations, the economics of electrical distribution at high voltage from the main substation to other subsidiary transformer substations or to certain items of plant, such as large motors and furnaces, should be considered. The relative economy attainable by use of medium or high voltage distribution and high voltage plant is a matter of expert judgment and individual assessment in light of experience by a professionally qualified electrical engineer.

5.3 Substation Equipment and Accessories

Substations require an approval by the Electrical Inspectorate. Such approval is mandatory before energizing the substation. It is desirable to get the approval for the general layout, schematic layout, protection plan, etc, before the start of the work from the Inspectorate. All substation equipment and accessories and materials, etc, shall conform to relevant Indian Standards, wherever they exist, otherwise the consumer (or his consultant) shall specify the standards to which the equipment to be supplied confirms and that shall be approved by the authority. Manufacturers of equipment have to furnish certificate of conformity as well as type test certificates for record, in addition to specified test certificates for acceptance tests and installation related tests for earthing, earth continuity, load tests and tests for performance of protective gear.

5.3.1 *Supply Company's High Voltage Meter Board*

In case of single point high voltage metering, energy meters shall be installed in building premise as per **4.2.2.1**, at such a place which is readily accessible to the owner/operator of the building and the Authority. The supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency. In this connection, *Central Electricity Authority (Installation and Operation of Meters) Regulations*, 2006, as amended from time-to-time shall be complied with.

5.3.2 *High Voltage Switchgear*

5.3.2.1 The selection of the type of high voltage switchgear for any installation *inter alia* depends upon the following:

a) Voltage of the supply system;
b) Prospective short-circuit current at the point of supply;
c) Size and layout of electrical installation;
d) Accommodation available; and
e) Nature of industry.

Making and breaking capacity of switchgear shall be commensurate with short-circuit potentialities of the supply system and the supply authority shall be consulted on this subject. HV switchgear and controlgear shall conform to the accepted standards [8-2(14)] and other relevant Indian Standards.

5.3.2.2 Guidelines on various types of switchgear equipment and their choice for a particular application shall be in accordance with good practice [8-2(12)].

5.3.2.3 In extensive installations of switchgear (having more than four incoming supply cables or having more than 12 circuit breakers), banks of switchgears shall be segregated from each other in order to prevent spreading of the risk of damage by fire or explosion arising from switch failure. Where a busbar section switch is installed, it shall also be segregated from adjoining banks in the same way {*see* good practice [8-2(13)]}.

5.3.2.4 It should be possible to isolate any section from the rest of the switchboards such that work might be undertaken on this section without the necessity of making the switchboard dead. Isolating switches used for the interconnection of sections or for the purpose of isolating circuit-breakers of other apparatus, shall also be segregated within its compartment so that no live part is accessible when work in a neighbouring section is in progress.

5.3.2.5 In the case of double or ring main supply, switchgears with interlocking arrangement shall be provided to prevent simultaneous switching of two different supply sources. Electrical and/or mechanical interlocks may preferably be provided.

5.3.3 *HV Cables*

5.3.3.1 The sizing of the cable shall depend upon the method of laying cable, current to be carried, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle, thermal resistivity of the soil and the operating voltage {*see also* good practice [8-2(15)]}.

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5.3.3.2 All HV cables shall be installed in accordance with good practice [8-2(15)]. The HV cables shall either be laid on the cable rack/built-up concrete trenches/ tunnel/basement or directly buried in the ground depending upon the specific requirement. When HV cable is hanging/running below the basement ceiling slab, the cable shall be laid in a fire rated enclosure/ cable tray. The advice of the cable manufacturer with regard to installation, jointing and sealing should also be followed.

5.3.4 *High Voltage Bus Bar Trunking/Ducting*

HV bus bar system is used for transporting power between HV generators, transformers and the infeed main switchgear of the main HV switchgear.

Generally three types of bus ducts, namely non-segregated, segregated and isolated phase bus duct are used. The non-segregated bus ducts consist of three phase bus bars running in a common enclosure made of steel or aluminium. The enclosure shall provide safety for the operational personnel and shall reduce chances of faults. HV interconnecting bus bar trunking for a.c. voltage above 1 kV up to and including 36 kV shall conform to accepted standard [8-2(16)]. The enclosures shall be effectively grounded.

Segregated phase bus ducts are similar to non-segregated phase ducts except that metal or isolation barriers are provided between phase conductors to reduce chances of phase to phase faults. However, it is preferable to use metal barriers.

In the case of isolated bus ducts, each phase conductor shall be housed in a separate non-magnetic enclosure. The bus duct shall be made of sections which are assembled together at site to make complete assembly. The enclosure shall be of either round or square shape and welded construction. The enclosures of all phases in general should be supported on a common steel structure.

Seismic supports shall be provided for busbar trunking having continuous straight lengths of more than 24 m at a single stretch.

The bus duct system shall be coordinated with connecting switchgear so as to provide adequate protection.

When busbar trunking is crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part 4 'Fire and Life Safety' of the Code).

5.3.5 *Transformers*

5.3.5.1 General design objective while selecting the transformer(s) for a substation should be to provide at least two or more transformers, so that a certain amount of redundancy is built in, even if a standby system is provided. The total installed transformer capacity shall be at least 15 to 20 percent higher than the anticipated maximum demand. With growing emphasis on energy conservation, the system design is made for both extremes of loading. During the periods of lowest load in the system, it would be desirable to operate only one transformer and to subsequently switch on the additional transformers as the load increases during the day. Total transformer capacity is generally selected on the basis of present load, possible future load, operation and maintenance cost and other system conditions. The selection of the maximum size (capacity) of the transformer is guided by the short-circuit making and breaking capacity of the switchgear used in the medium voltage distribution system. Maximum size limitation is important from the aspect of feed to a downstream fault. The transformers shall conform to accepted standards [8-2(17)] and other relevant Indian Standards.

5.3.5.2 For reasons of reliability and redundancy it is normal practice to provide at least two transformers for any important installation. Interlinking by tie lines is an alternative to enhance reliability/redundancy in areas where there are a number of substations in close vicinity, such as a campus with three or four multi-storeyed blocks, each with a substation. Ring main type of distribution is preferred for complexes having a number of substations.

5.3.6 *Medium or Low Voltage Switchgear and Controlgear and their Assemblies*

5.3.6.1 The selection of the type of medium or low voltage switchgear for any installation *inter alia* depends upon the following:

a) Voltage of the distribution system;
b) Prospective circuit current at the point at which the switchgear is proposed;
c) Prospective short-circuit current at which the switchgear is proposed;
d) Accommodation available; and
e) Nature of industry.

The switchgear and controlgear and their assemblies so selected shall comply with the relevant accepted standards [8-2(18)], other relevant Indian Standards, IEC 61439 (Part 1) : 2011 'Low-voltage switchgear and controlgear assemblies — Part 1: General rules' (*under publication* as adopted Indian Standard) and IEC 61439 (Part 2): 2011 'Low-voltage switchgear and controlgear assemblies — Part 2: Power switchgear and controlgear assemblies' (*under publication* as adopted Indian Standard).

5.3.6.2 Switchgear (and its protective device) shall

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have breaking capacity not less than the anticipated fault level in the system at that point. System fault level at a point in distribution systems is predominantly dependent on the transformer size and its reactance. Parallel operation of transformers increases the fault level.

5.3.6.3 Where two or more transformers are to be installed in a substation to supply a medium voltage distribution system, the distribution system shall be divided into separate sections, each of which shall be normally fed from one transformer only unless the medium voltage switchgear has the requisite short-circuit capacity. Provision may, however, be made to interconnect separate sections, through a bus coupler in the event of failure or disconnection of one transformer. *See* **4.2** for details of location and requirements of substation.

5.3.6.4 Isolation and controlling circuit breaker shall be interlocked so that the isolator cannot be operated unless the corresponding breaker is in open condition. The choice between alternative types of equipment may be influenced by the following considerations:

a) In certain installations supplied with electric power from remote transformer substations, it may be necessary to protect main circuits with circuit-breakers operated by earth fault, in order to ensure effective earth fault protection.

b) Where large electric motors, furnaces or other heavy electrical equipment is installed, the main circuits shall be protected from short-circuits by switch disconnector fuse or circuit breakers. For motor protection, the combination of contactor overload device and fuse or circuit breakers shall have total coordination at least for motor ratings up to 10 kW, and for ratings above 10 kW, it shall be Type 2 coordination in accordance with relevant part of accepted standards [8-2(18)]. Wherever necessary, back up protection and earth fault protection shall be provided to the main circuit.

c) Where means of isolating main circuits is separately required, switch disconnector fuse or switch disconnector may form part of main switchboards.

5.3.6.5 It shall be mandatory to provide power factor improvement capacitor at the substation bus. Suitable capacitor may be selected in consultation with the capacitor as well as switchgear manufacture depending upon the nature of electrical load anticipated on the system. Necessary switchgear/ feeder circuit breaker shall be provided for controlling of capacitor bank.

Power factor of individual motor may be improved by connecting individual capacitor banks in parallel. For higher range of motors, which are running continuously without much variation in load, individual power factor correction at load end is advisable.

NOTE — Care should be taken in deciding the kVAr rating of the capacitor in relation to the magnetizing kVA of the motor. Over rating of the capacitor may cause injury to the motor and capacitor bank. The motor still rotating after disconnection from the supply, may act as generator by self-excitation and produce a voltage higher than supply voltage. If the motor is again switched on before the speed has fallen to about 80 percent of the normal running speed, the high voltage will be superimposed on the supply circuits and will damage both the motor and the capacitor.

As a general rule, the kVAr rating of the capacitor should not exceed the no-load magnetizing kVA of the motor.

Generally it will be necessary to provide an automatic control for switching on the capacitors matching the load power factor and the bus voltage. Such a scheme will be necessary as capacitors permanently switched in the circuit may cause over voltage at times of light load. Capacitor panel shall be provided with adequate ventilation facility.

5.3.6.6 Harmonics on the supply systems are becoming a greater problem due to the increasing use of electronic equipment, computer, fluorescent lamps, LEDs and CFLs (both types have control/driver circuits operating in switch mode), mercury vapour and sodium vapour lighting, TV, microwave ovens, latest air conditioners, refrigerators, controlled rectifier and inverters for variable speed drives, power electronics and other non-linear loads. Harmonics may lead to almost as much current in the neutral as in the phases. This current is almost third, fifth, seventh and ninth harmonic. In such cases, phase rectification devices may be considered at the planning stage itself for the limits of harmonic voltage distortion.

With the wide spread use of thyristor and rectifier based loads, there is a necessity of providing a full size neutral; but this requirement is generally limited to the 3-phase 4-wire distribution generally in the 415/240 V.

5.3.6.7 *MV/LV Bus bar chambers*

Bus bar chambers, which feed two or more circuits, shall be controlled by a main disconnector (TP&N)

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or TPN MCB to enable them to be disconnected from the supply.

5.3.6.8 Sufficient clearances as below shall be provided for isolating the switchboard to allow access for servicing, testing and maintenance (*see* Fig. 2):

a) A clear space of not less than 1 m in width shall be provided in front of the switchboard.

NOTE — In case the board has a shutter in the front for aesthetic reasons, provided the opening of the shutter shall satisfy the requirement of working/safety space of 1 m in front of the switchgear.

b) If there are any attachments or bare connections at the back of the switchboard, the space, if any, behind the switchboard shall be either less than 200 mm or more than 750 mm in width, measured from the farthest protruding part of any attachment or conductor.

c) If the space behind the switchboard exceeds 750 mm in width, there shall be a passageway from either end of the switchboard, clear to a height of 1.8 m.

d) If two switchboards are facing each other, a minimum distance of 2.0 m shall be maintained between them.

The connections between the switchgear mounting and the outgoing cable up to the wall shall be enclosed in a protection pipe.

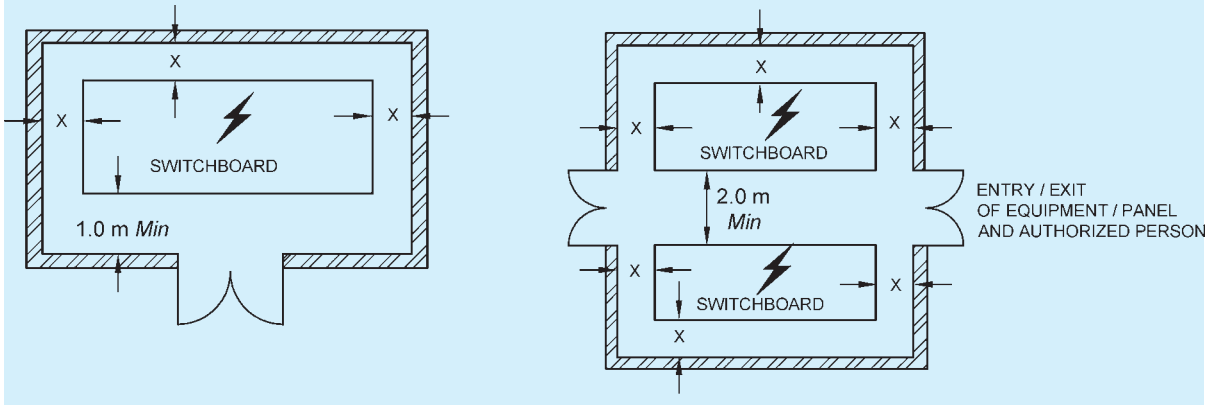
There shall be a clear distance of not less than 250 mm between the board and the insulation cover, the distance being increased for larger boards in order that on closing of the cover, the insulation of the cables is not subjected to damage and no excessive twisting or bending in any case. The cable alley in the metal board should enable within prescribed limit twisting or bending of cable such that insulation of the cables is not subjected to damage.

In this connection, for installation of voltages exceeding 250 V, Regulation 37 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

5.3.6.9 Sufficient additional space shall be allowed in substations and switchrooms to allow operation and maintenance. Sufficient additional space shall be allowed for temporary location and installation of standard servicing and testing equipment. Space should also be provided to allow for anticipated future extensions.

5.3.6.10 Panels in a room or cubicle or in an area surrounded by wall/fence, access to which is controlled by lock and key shall be accessible to authorized persons only.

Such installations shall be efficiently protected by fencing not less than 1 800 mm in height or other means so as to prevent access to the electric supply lines and apparatus therein by an undesignated person and the



NOTE — X to be measured from the fathest protruding part of any attachment or conductor.

FIG. 2 CLEARANCES AROUND SWITCHBOARDS IN ENCLOSED ROOM

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fencing of such area shall be earthed efficiently. Sufficient clearances as per **5.3.6.8** shall be provided between the switchboard and the wall/fence.

5.3.6.11 Except main LV panel, it will be preferable to locate the sub-panels/distribution boards/sub-meter boards near the load centre. Further, it should be ensured that these panels are easily approachable. The panels should have clear access from common areas excluding staircase.

Where the switchboard is erected in a room of a building isolated from the source of supply or at a distance from it, adequate means of control and isolation shall be provided both near the boards and at the origin of supply. Sufficient clearances as per **5.3.6.8** shall be provided.

5.3.6.12 All switchboards shall be of metal clad totally enclosed type or any insulated enclosed pattern.

5.3.7 *Medium or Low Voltage Cables*

5.3.7.1 The sizing of the cable shall depend upon the current to be carried, method of laying cable, permissible maximum temperature it shall withstand, voltage drop over the length of the cable, the prospective short-circuit current to which the cable may be subjected, the characteristics of the overload protection gear installed, load cycle, thermal resistivity of the soil and the operating voltage {*see also* good practice [8-2(11)]}.

It is desirable to use flame retardant cables and wires in electrical distribution systems. Availability of flame retardant low smoke and halogen cable may also be noted and considered accordingly.

It is recommended to use four core cable in place of three and half core to minimize heating of neutral core due to harmonic content in the supply system and also avoidance of overload failures. All cables shall be installed in accordance with good practice [8-2(11)]. The advice of the cable manufacturer with regard to installation, jointing and sealing should also be followed.

In final circuits where cable size of 16 mm^2 and below are used, these shall be 4 core cables only to avoid the possibility of neutral overload, (except for equipment such as motors, heaters which offer balanced 3 phase load and do not require a neutral connection. As a result it is not desirable to use half-size neutral conductor as possibility of neutral conductor overload due to harmonics is likely. Larger feeders (size greater than 16 mm^2) may revert to use 3½ core cables.

5.3.7.2 *Colour identification of cores of non-flexible cables* {*see also* good practice [8-2(19)]}

The colour of cores of non-flexible cables shall be in accordance with the following:

Sl No.	*Function*	*Colour Identification of Core of Rubber of PVC Insulated Non-flexible Cable, or of Sleeve or Disc to be Applied to Conductor or Cable Code*
(1)	(2)	(3)
i)	Protective or earthing	Green and yellow (*see* Note 1)
ii)	Phase of a.c. single-phase circuit	Red [or yellow or blue (*see* Note 2)]
iii)	Neutral of a.c. single or three-phase circuit	Black
iv)	Phase R of 3-phase a.c. circuit	Red
v)	Phase Y of 3-phase a.c. circuit	Yellow
vi)	Phase B of 3-phase a.c. circuit	Blue
vii)	Positive of d.c. 2-wire circuit	Red
viii)	Negative of d.c. 2-wire circuit	Black
ix)	Outer (positive or negative) of d.c. 2-wire circuit derived from 3-wire system	Red
x)	Positive of 3-wire system (positive of 3-wire d.c. circuit)	Red
xi)	Middle wire of 3-wire d.c. circuit	Black
xii)	Negative of 3-wire d.c. circuit	Blue
xiii)	Functional earth-telecommunication	Cream

NOTES

1 Bare conductors are also used for earthing and earth continuity conductors. But it is preferable to use insulated conductors with green coloured insulation with yellow stripes.

2 As alternative to the use of red, yellow or blue colour may be used, if desired in large installations, up to the final distribution board.

3 For armoured PVC-insulated cables and paper-insulated cables, *see* relevant Indian Standard.

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5.3.7.3 *Colour, identification of cores of flexible cables and flexible cords* {*see also* good practice [8-2(19)]}

The colour of cores of flexible cables and flexible cords shall be in accordance with the following:

Sl No.	*Number of Cores*	*Function of Core*	*Colour(s) of Core*
(1)	(2)	(3)	(4)
i)	1	Phase	Brown[1)]
		Neutral	(Light) Blue
		Protective or earthing	Green and yellow
ii)	2	Phase	Brown
		Neutral	(Light) Blue[1)]
iii)	3	Phase	Brown
		Neutral	(Light) Blue[1)]
		Protective or earthing	Green and yellow
iv)	4 or 5	Phase	Brown or black[1)]
		Neutral	(Light) Blue[1)]
		Protective or earthing	Green and yellow

[1)] Certain alternatives are allowed in wiring regulations.

5.3.8 *MV/LV Bus bar Trunking/Rising Mains*

5.3.8.1 Where heavy loads and/or multiple distribution feeders are required to be supplied, busbar/rising main systems are preferred. The busbars are available for continuous run from point to point or with tap offs at standard intervals and have to be chosen as per specific requirement. Seismic supports shall be provided for bus trunking having continuous straight lengths of more than 24 m at a single stretch. There are following two types of MV/LV bus duct systems for power distribution:

a) Conventional type; and
b) Compact and sandwich type.

5.3.8.1.1 *Conventional type bus duct*

These are used for large power handling between transformer and switchgear or between switchgear and large power loads such as compressor drive motor, etc. This type is generally used in plant rooms, riser shafts, substations, etc. These are generally air insulated with intermediate ceramic support insulators enclosed in a metallic enclosure, which should be earthed. They have the least amount of combustible material. However, when these are crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part 4 'Fire and Life Safety' of the Code).

Conventional type bus ducts with non-metallic enclosures are also available. However, such bus ducts shall be used only, if essential and with appropriate additional care.

5.3.8.1.2 *Compact type bus duct*

Compact type bus ducts are used within areas of the building which have space restrictions, etc, for aesthetic and functional reasons. These are either air insulated or sandwich type. They may be used in false ceiling spaces or even in corridors and shafts for distribution without any false ceiling as they provide an aesthetically acceptable finish to merge with other building elements such as beams, ducts or pipes in functional buildings.

The insulation material in such ducts are generally glass fibre tape or epoxy encapsulation in combination with ceramic supports/spacers. These bus ducts should be duly enclosed by a metallic enclosure, which should be earthed.

In case of compact air insulated type bus ducts crossing different fire compartments, they shall have fire barriers of same rating as that of the compartment (*see also* Part 4 'Fire and Life Safety' of the Code).

5.3.8.2 The bus duct system shall be coordinated with connecting switchgear so as to provide adequate protection.

5.3.8.3 Seismic supports shall be provided for busbar trunking having continuous straight lengths of more than 24 m at a single stretch.

5.3.8.4 Where the number of individual units/flats/shops/offices on a floor in a building are more than 24, multiple rising mains are recommended for power distribution.

5.3.8.5 The low voltage bus bar trunking shall conform to accepted standard [8-2(20)].

5.4 Reception and Distribution of Main Supply

5.4.1 *Control at Point of Commencement of Supply*

5.4.1.1 The supplier shall provide a suitable metering switchgear in each conductor of every service line other than an earthed or earth neutral conductor or the earthed conductor of a concentric cable within a consumer's premises, in an accessible position and such metering switchgear shall be contained within adequately enclosed fireproof receptacle. Where more than one consumer is supplied through a common service line, such consumer shall be provided with an independent metering switchgear at the point of rigid junction to the common service. Every electric supply line other than the earthed or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall be protected by a suitable switchgear by its

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owner. In this connection, Regulation 14 and 41 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

In case of high rise buildings, the supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the 3-phase, 4-wire circuit and fixed in a conspicuous position at not more than 1.7 m above the ground so as to completely isolate the supply to the building in case of emergency. In this connection, Regulation 36 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

The supplier shall provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply. In this connection, Regulation 16 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductor shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto. This requirement shall however not apply in case of,

a) a link for testing purposes, or
b) a switch for use in controlling a generator or transformer.

In this connection, Regulation 15 (ii) of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time shall also be complied with (*see* Annex B).

The neutral shall also be distinctly marked.

5.4.1.2 The main switch shall be easily accessible and situated as near as practicable to the termination of service line.

5.4.1.3 Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, an indication of a permanent nature shall be provided for identification in accordance with Regulation 15 (i) of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time (*see* Annex B).

5.4.1.4 *Energy meters*

5.4.1.4.1 Energy meters conforming to accepted standards [8-2(21)] and other relevant Indian Standards shall be installed in all buildings at such a place which is readily accessible to the owner/operator/occupant of the building and the Authority. Meters should not be located at an elevated area or a depressed area that does not have access by means of a stairway of normal rise. The height of meter display shall be between 750 mm and 1 800 mm. In case the meter is provided with a secondary display unit, this requirement applies to the secondary display unit only. A minimum clearance of 50 mm should be maintained around the meter itself for better inspection. This includes the space between two meters, or between meter and the mounting box, or between two mounting boxes as the case may be. The energy meters should either be provided with a protecting covering, enclosing it completely except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged arrangement for locking. Additionally, for outdoor installations, the meters and associated accessories shall be protected by appropriate enclosure of level of protection IP 55 and ensuring compliance with above conditions. The enclosure should preferably be light coloured.

In large multi-storeyed buildings, installation of a large number of energy meters at the ground floor (or first basement) switch-room for the convenience of the meter-reader poses high fire hazard. More than 24 energy meters on one switchboard is undesirable. In such cases, where number of energy meters to be installed for feeding exceeds 24, energy meters shall be installed at each floor and therefore, the rising main (bus trunking) with tapping point at individual floor shall be provided for meters.

The energy meters shall be protected by suitable circuit breaker. The provisions of **5.3.6.8** shall apply in case of energy meters installed in boards.

5.4.1.4.2 Main sources of energy, as given below shall be metered, as required at entry into the premise/control panel:

1) Utility grid points (high voltage/medium voltage/low voltage),
2) Captive generator sets, and
3) On-site renewable energy system (if installed/ operational).

5.4.1.4.3 Testing, evaluation, installation and maintenance of energy meters shall be in accordance with the good practice [8-2(22)].

5.4.1.4.4 *Centralized metering system*

Smart metering and energy monitoring in a centralized

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metering system are used to monitor, measure, and control the demand of electrical loads in a building. These systems are designed specifically for the control and monitoring of those facilities in a building which have significant electrical consumption, such as heating, ventilation, air conditioning, lifts, pumps, and lighting installations at multiple locations in a campus. The scope may span from a single building to a group of buildings, such as residential apartments under common ownership, large multi-storeyed buildings, malls, university campuses, office buildings, retail store networks, factories, or any building with multi-tenanted occupancy. These systems provide metering, submetering and monitoring functions to allow facility and building managers to gather data and insight that allow them to make more informed decisions about demand management and demand control across their sites.

For such buildings with centralized metering, several main meters and sub-meters with following requirements should be provided:

a) Main meters should be digital energy meters with high accuracy, high sampling rates and power quality parameters, that is, harmonics, etc, for meters installed at incomer level.
b) Separate sub-meters should be provided for all energy end uses and functional areas that individually account for reasonable energy consumption in the building. These may include, but are not limited to, sub-meters for HVAC system; common area lighting, raw power, UPS, other common utility; lifts and escalators, pumps, external and internal lighting, individual units/flats/shops/ offices; etc.
c) The sub-meters should be able to communicate data for monitoring. At a minimum, the sub-metering infrastructure should facilitate the aggregation of total energy use.
d) Adequate smart metering and energy monitoring infrastructure should be installed in order to help monitor operational energy use and costs and to enable continuous energy performance improvement.

Smart metering and energy monitoring system that can display the following parameters should be installed with two-way communicable smart meters:

1) Hourly energy demand and use;
2) Energy breakdown and mix and energy consumption patterns;
3) Power quality analysis;
4) Energy consumption by process, department, building, floor, etc;
5) Comparison of actual energy use with targets or historical trends and benchmark energy key performance indicators; and
6) Reporting on energy efficiency achieved.

These systems should also have the ability to utilize near-real-time or time-of-use pricing through integration of smart meters with the monitoring and control system. The system should be capable of supporting predictive demand for better demand management and proactive demand control.

5.4.1.4.5 The *Central Electricity Authority (Installation and Operation of Meters) Regulations* 2006, as amended from time-to-time shall also be complied with.

5.4.2 *Main Switches and Switchboard*

5.4.2.1 All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply. Every switch shall have suitable ingress protection level rating (IP), so that its operation is satisfactory and safe in the environment of the installation.

NOTE — Woodwork shall not be used for the construction or mounting of switches and switch boards installed in a building.

5.4.2.2 *Location*

The main switchboard shall comply with the following requirements relating to its location:

a) The location of the main board should be such that it is easily accessible to firemen and other personnel to quickly disconnect the supply in case of emergencies. If the room is locked for security reasons, means of emergency access, by schemes such as break glass cupboard, shall be incorporated.
b) Main switch board shall be installed in rooms or fire safe cupboards so as to safeguard against operation by unauthorized personnel. Otherwise the main switch board shall have lock and key facility for small installations in residences or other occupancies having sanctioned loads less than 5 kW.
c) Switchboards shall be placed only in dry situations and in ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes.
d) In damp situation or where inflammable or explosive dust, gas or vapour is likely to be present, the switchboard shall be totally enclosed and shall have adequate degree of ingress protection (IP). In some cases flameproof enclosure may be necessitated by particular circumstances [*see* 8-2(23)].

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e) Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms or laundries, or in bathrooms, lavatories or toilets, or kitchens.

f) In case of switchboards unavoidably fixed in places likely to be located outdoors, exposed to weather, to drip, or to abnormal moist temperature, the outer casing shall be weatherproof and shall be provided with glands or bushings or adopted to receive screwed conduit, according to the manner in which the cables are run. The casing as well as cable entries shall have suitable IP ratings according to the installation.

g) Adequate illumination shall be provided for all working spaces around the switchboards.

h) Easy access to the enclosure around switchgear is essential to enable easy and safe operation and maintenance. The provisions as given in **5.3.6.8** including requirements for sufficient clearances shall be complied with.

5.4.2.3 Metal-clad switchgear shall be mounted on any of the following types of boards:

a) *Hinged-type metal boards* — These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back. The board shall be securely fixed to the wall by means of proper nuts and bolts designed to take weight of the switch board and shall be provided with a locking arrangement and an earthing and neutral stud or bus. All wires passing through the metal board shall be protected by cable termination glands at the entry hole. The earth stud should commensurate with the size of earth lead/ leads. Alternatively, metal boards may be made of suitable size iron angle section of minimum size 35 mm × 35 mm × 6 mm or iron channel section of minimum size 35 mm x 25 mm x 6 mm frame work suitably mounted on front with a 3 mm thick mild steel plate and on back with 1.5 mm thick mild steel sheet. No apparatus shall project beyond any edge of panel. No fuse body shall be mounted within 25 mm of any edge of the panel.

   NOTE — Such type of boards are particularly suitable for small switchboard for mounting metal-clad switchgear connected to supply at low voltages.

b) *Fixed-type metal boards* — These shall consist of an angle or channel iron frame fixed on the wall or on floor and supported on the wall at the top, if necessary.

   NOTE — Such type of boards are suitable for both small and large switchboards. They are particularly suitable for large switchboards for mounting number of switchgears or high capacity metal-clad switchgear or both in an arrangement which do not require rear access.

c) *Protected-type switchboard* — A protected switchboard is one where all of the switchgear and conductors are protected by metal or halogen free plastic enclosures. They may consist of a metal/plastic cubicle panel, or an iron frame upon which metal-clad switchgears are mounted. They usually consist of a main switch, bus bars and circuit breakers or fuses controlling outgoing circuits.

d) *Outdoor-type switchboard* — An outdoor-type switchboard is one which is totally enclosed and UV ray protected and having high ingress protection against dust and moisture and vermin-proof and high impact resistance (IP 55 or higher and IK 10). Such switchboards are of cubicle type and also provide high impact resistance. Cubicle type boards shall be with hinged doors interlocked with switch-operating mechanisms. The doors of these switchboards shall have facility to ensure that it is always in closed conditions. All such switches shall bear labels indicating their functions.

   NOTE — Such switchboards shall be located away from areas likely to be crowded by the public.

Open type switchboards wherever existing in old buildings shall be phased out and replaced with protected-type switchboards with suitable circuit breakers.

5.4.2.4 *Recessing of boards*

Where so specified, the switchboards shall be recessed in the wall. Ample room shall be provided at the back for connection and at the front between the switchgear mountings (*see* **5.3.6.8**).

5.4.2.5 *Marking of apparatus* {*see also* good practices [8-2(24)]}

Where a board is connected to voltage higher than 250 V, all the apparatus mounted on it shall be marked with the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected:

a) *Alternating current (three-phase) system:*
   Phase 1 – red, Phase 2 – yellow and Phase 3 – blue; and 1 Neutral – black

b) *Direct current (three-wire system)*:
   2 outer wire, Positive – red and Negative – blue; and 1 Mid wire (Neutral) – black

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Where four-wire three-phase wiring is done, the neutral shall be in one colour and the other three phase conductors in another colour (preferably brown) or shall be suitably tagged or sleeved to ensure fool proof identification.

NOTE — Generally brown colour identification is adopted for the phase conductors and black for neutral with additional tags or sleeves or coloured tapes at terminations.

Earth continuity conductor shall be marked with green colour or green with yellow line.

Where a board has more than one switchgear, each such switchgear shall be marked to indicate the section of the installation it controls. The main switchgear shall be marked as such. Where there is more than one main switchboard in the building, each such switchboard shall be marked to indicate the section of the installation and/or building it controls.

All markings shall be clear and permanent.

5.4.2.6 *Drawings*

Before proceeding with the actual construction, a proper drawing showing the detailed dimensions and design including the disposition of the mountings of the boards, which shall be symmetrically and neatly arranged for arriving at the overall dimensions, shall be prepared along the building drawing. Such drawings will show the mandatory clearance spaces if any, and clear height below the soffit of the beam required to satisfy regulations and safety considerations, so that other designers or installers do not get into such areas or spaces for their equipment.

5.4.3 *Distribution Boards*

A distribution board comprises one or more protective devices against over current and ensuring the distribution of electrical energy to the circuits. Distribution board shall provide plenty of wiring space, to allow working as well as to allow keeping the extra length of connecting cables, likely to be required for maintenance.

5.4.3.1 Main distribution board shall be provided with a circuit breaker on each pole of each circuit, or a switch with a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

All incomers should be provided with surge protection devices depending upon the current carrying capacity and fault level (*see* **11**). Surge protecting devices should be provided with backup circuit breaker/fuses, wherever required.

5.4.4 *Branch Distribution Boards*

5.4.4.1 Branch MCB distribution boards shall be provided, along with earth leakage protective device (RCCB/RCD) in the incoming, with a fuse or a miniature circuit breaker or both of adequate rating/ setting chosen on the live conductor of each sub-circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. At least one spare circuit of the same capacity shall be provided on each branch distribution board. Further, the individual branching circuits (outgoing) shall be protected against over-current with miniature circuit breaker of adequate rating. In residential/industrial lighting installations, the various circuits shall be separated and each circuit shall be individually protected so that in the event of fault, only the particular circuit gets disconnected. In order to provide protection against electric shock due to leakage current for human being, a 30 mA RCCB/ RCD shall be installed at distribution board incomer of buildings, such as residential, schools and hospitals. For all other buildings, a 100 mA RCCB/RCD will suffice for protection against leakage current.

In case of phase segregated distribution boards, earth leakage protective device shall be provided in the sub-incomer to provide phase wise earth fault protection. The provision of sub-incomer in distribution board shall be as per consumer requirement.

5.4.4.2 Common circuit shall be provided for installations at higher level (those in the ceiling and at higher levels, above 1 m, on the walls) and for installations at lower level but with separate switch control (sockets for portable or stationery plug in equipment). For devices consuming high power and which are to be supplied through supply cord and plug, separate wiring shall be done. For plug-in equipment provisions shall be made for providing RCCB/RCD protection in the distribution board.

5.4.4.3 It is preferable to have additional circuit for kitchen and bathrooms. Such sub-circuit shall not have more than a total of ten points of light, fans and 6 A socket outlets. The load of such circuit shall be restricted to 800 W and the wiring with 1.5 mm^2 copper conductor cable is recommended. If a dedicated circuit is planned for light fixtures, the load of such circuit shall be restricted to 400 W and the wiring with 1.5 mm^2 copper conductor cable is recommended. If a dedicated circuit is planned for 6A sockets the load of such a circuit shall be restricted to 800 W or a maximum of 8 numbers, whichever is lesser, controlling MCB should be sized accordingly. The wiring shall be with 1.5 mm^2 copper conductor cable. If a separate fan circuit is provided, the number of fans in the circuit shall not exceed ten. Power sub-circuit shall be designed according to the load but in no case shall there be more than two 16 A outlets on each sub-circuit which can be wired with 4 mm^2 for miscellaneous socket loads and shall be with 4 mm^2 copper conductor cable for equipment consuming more than 1 kW. Power sockets

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complying with the accepted standards [8-2(25)] with current rated according to their starting load, wiring, MCB, etc, shall be designed for special equipment space heaters, air conditioners, heat pumps, VRF, etc.

For feeding final single phase domestic type of loads or general office loads it is advisable to introduce additional cables if required to allow lowering of short circuit rating of the switchgear required at user end. Use of hand held equipment fed through flexible cords is safe.

5.4.4.4 The circuits for lighting of common area shall be separate. For large halls 3-wire control with individual control and master control installed near the entrance shall be provided for effective conservation of energy. Occupancy sensors, movement sensors, lux level sensors, etc, may also be considered as switching options for lights, fans, TV, etc, for different closed spaces (*see also* Part 11 'Approach to Sustainability' of the Code).

5.4.4.5 Where daylight is abundantly available, particularly in large halls, lighting in the area near the windows likely to receive daylight shall have separate controls for lights, so that they can be switched off/ automatically reduce intensity selectively when daylight is adequate, while keeping the lights in the areas remote from the windows on (*see also* Part 11 'Approach to Sustainability' of the Code).

5.4.4.6 Circuits for socket outlets may be kept separate from circuits feeding fans and lights. Normally, fans and lights may be wired on a common circuit. In large spaces, circuits for fans and lights may also be segregated. Lights may have group control in large halls and industrial areas. While providing group control, consideration may be given for the nature of use of the area lit by a group. Consideration has to be given for the daylight utilization, while grouping, so that a group feeding areas near windows receiving daylight can be selectively switched off during daylight period.

5.4.4.7 The load on any low voltage sub-circuit shall not exceed 3 000 W. In case of a new installation, all circuits and sub-circuits shall be designed with an initial load of about 2 500 W, so as to allow a provision of 20 percent increase in load due to any future modification. Power sub-circuits shall be designed according to the load, where the circuit is meant for a specific equipment. Good practice is to limit a circuit to a maximum of three sockets, where it is expected that there will be diversity due to use of very few sockets in large spaces (example sockets for use of vacuum cleaner). General practice is to limit it to two sockets in a circuit, in both residential and non-residential buildings and to provide a single socket on a circuit for a known heavy load appliance such as air conditioner, cooking range, etc.

5.4.4.8 In wiring installations at special places like construction sites, stadia, shipyards, open yards in industrial plants, etc, where a large number of high wattage lamps may be required, there shall be no restriction of load on any circuit but conductors used in such circuits shall be of adequate size for the load and proper circuit protection shall be provided. The distribution boards (DBs) used in these areas shall be of UV resistant, double insulated type with IP 66 or higher degree of protection. Power tools and other temporary equipment connected to these DBs shall be sufficiently protected against electrical faults. Insulated IP 66 sockets complying with the accepted standards [8-2(25)] used in these DBs shall have interlocking facility in addition to protection to ensure safe plugging and unplugging of these equipment.

5.4.5 *Location of Distribution Boards*

a) The distribution boards shall be located as near as possible to the centre of the load they are intended to control.
b) These shall be fixed on suitable stanchion or wall and shall be accessible for replacement/ reset of protective devices, and shall not be more than 1.8 m from floor level.
c) These shall be of either metal-clad type, or polycarbonate enclosure of minimum IP 42. But, if exposed to weather or damp situations, these shall be of the weatherproof type conforming to IP 55 and, if installed where exposed to explosive dust, vapour or gas, these shall be of flameproof type in accordance with accepted standards [8-2(26)]. In corrosive atmospheres, these shall be treated with anti-corrosive preservative or covered with suitable plastic compound.
d) Where two and/or more distribution boards feeding low voltage circuits are fed from a supply of medium voltage, the metal case shall be marked 'Danger 415 Volts' and identified with proper phase marking and danger marks.
e) Each shall be provided with a circuit list giving diagram of each circuit which it controls and the current rating of the circuit and size of fuse element.
f) In wiring branch distribution board, total load of consuming devices shall be divided as far as possible evenly between the number of ways in the board leaving spare circuits for future extension.
g) Distribution board shall not be located at structural expansion joints of the building.
h) Distribution board/other electrical outlets shall have a minimum calculated separation distance from lightning protection down-

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conductors to avoid flash over in case of lightning.

j) Walls with flushed distribution boards shall have adequate support behind and surrounding so that there is no physical weight on the distribution board of the civil structure around. Electrical switch sockets, etc, shall also be avoided to be mounted behind the distribution board to avoid touching the board from behind.

5.4.6 *Protection of Circuits*

a) Appropriate protection shall be provided at switchboards, distribution boards and at all levels of panels for all circuits and sub-circuits against short circuit, over-current and other parameters as required. The protective device shall be capable of interrupting maximum prospective short circuit current that may occur, without danger. The ratings and settings of fuses and the protective devices shall be coordinated so as to afford selectivity in operation and in accordance with accepted standards [8-2(27)].

b) Where circuit-breakers are used for protection of a main circuit and of the sub-circuits derived therefrom, discrimination in operation may be achieved by adjusting the protective devices of the sub-main circuit-breakers to operate at lower current settings and shorter time-lag than the main circuit-breaker.

c) Where HRC type fuses are used for back-up protection of circuit- breakers, or where HRC fuses are used for protection of main circuits, and circuit-breakers for the protection of sub-circuits derived there from, in the event of short-circuits protection exceeding the short-circuits protection exceeding the short-circuits capacity of the circuit-breakers, the HRC fuses shall operate earlier than the circuit-breakers; but for smaller overloads within the short-circuit capacity of the circuit-breakers, the circuit-breakers shall operate earlier than the HRC fuse blows.

d) If rewireable type fuses are used to protect sub-circuits derived from a main circuit protected by HRC type fuses, the main circuit fuse shall normally blow in the event of a short-circuit or earth fault occurring on sub-circuit, although discrimination may be achieved in respect of overload currents. The use of rewireable fuses is restricted to the circuits with short-circuit level of 4 kA; for higher level either cartridge or HRC fuses shall be used. However, use of rewireable fuse is not desirable, even for lower fault level areas. MCB's provide a better and dependable protection, as their current setting is not temperable.

e) A fuse carrier shall not be fitted with a fuse element larger than that for which the carrier is designed.

f) The current rating of a fuse or circuit breaker shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.

g) Every fuse shall have its own case or cover for the protection of the circuit and an indelible indication of its appropriate current rating in an adjacent conspicuous position.

h) All distribution board or panel incomer may be protected by a surge protection device, if found necessary (*see* **11**). Separate HRC fuse/ CB with proper enclosure may be required in series with the surge protection device with main incomer. Back-up fuse/CB shall be of the capacity not lower than that recommended by the SPD manufacturer. Short circuit withstand capability of the SPDs should be coordinated with the HRC fuse/CB and SPD should be selected to be matching the fault power expected/calculated at that point.

5.4.7 *Cascading, Discrimination and Limitation*

Cascading and discrimination in switchgear downstream and upstream shall be designed and maintained such that the continuity of power in case of any abnormal conditions such as overload, short circuit and earth faults, etc is maintained and only faulty circuit is isolated and power is made available to other loads.

Cascading technique allows the designer to select circuit breakers of lower breaking capacities. Utilizing the current limiting effect of the incoming breaker, outgoing breaker can sustain the higher faults than its capacity and even maintain the discrimination.

5.5 Protection Class of Equipment and Accessories

The class of ingress protection (IP) and protection against mechanical impact (IK) {*see also* good practice [8-2(6)] and IEC 62262:2002 'Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)'} shall be specific depending on the requirement at the place of installation.

5.6 Voltage and Frequency of Supply

It should be ensured that all equipment connected to the system including any appliances to be used on it are suitable for the voltage and frequency of supply of the system. The nominal values of low and medium voltage systems in India are 240 V and 415 V a.c., respectively, and the frequency is 50 Hz.

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NOTE — The design of the wiring system and the sizes of the cables should be decided taking into account following factors:

a) *Voltage drop* — This should be kept below 6 percent to ensure proper functioning of all electrical appliances and equipment including motors;

b) Thermal limit based current carrying capacity of the cable with appropriate derating factors applicable to the installation conditions;

c) Capacity to withstand the let through fault current based on the fault level and the controlling switchgear disconnection characteristics.

5.7 Rating of Cables and Equipment

5.7.1 The current-carrying capacity of different types of cables shall be chosen in accordance with good practice [8-2(28].

5.7.2 The current ratings of switches for domestic and similar purposes are 6 A, 16 A, 20 A and 25 A.

5.7.3 The current ratings of isolators and normal duty switches and composite units of switches and fuses shall be selected from one of the following values:

16, 25, 32, 63, 100, 160, 200, 320, 400, 500, 630, 800, 1 000 and 1 250 A.

5.7.4 The ratings of rewireable and HRC fuses shall be in accordance with good practice [8-2(29)].

5.7.5 The current ratings of miniature circuit-breakers shall be chosen from the values given below:

6, 10, 16, 20, 25, 32, 40, 50, 63, 80, 100 and 125 A.

5.7.6 The current ratings of moulded case circuit breakers shall be chosen from the values given below:

100, 125, 160, 200, 250, 315, 400, 630, 800, 1 000, 1 250 and 1 600A.

5.7.7 The current ratings of air circuit-breakers shall be chosen from the values given below:

630, 800, 1 000, 1 250, 1 600, 2 000, 2 500, 3 200, 4 000A and 6 300 A.

5.7.8 The current ratings of the distribution fuse board shall be selected from one of the following values:

6, 16, 25, 32, 63 and 100 A.

5.8 Installation Circuits

5.8.1 The nominal cross-sectional area of copper phase conductors in a.c. circuits and of live conductors in d.c. circuits shall be not less than the values specified below:

Sl No.	*Type of Circuit*	*Minimum Copper Wire Size*	*Number of Circuits*
(1)	(2)	(3)	(4)
i)	Lighting	1.5 mm^2	2 or more
ii)	Socket-outlets, 6 A	2.5 mm^2	Any number Areas such as kitchens and laundries 3 × double socket-outlets per circuit. Other areas up to 12 double socket-outlets
iii)	Signaling and control circuits	0.5 mm^2 (*see* Note 1)	—
iv)	Socket-outlets, 16 A	2.5 mm^2	1
v)	Water heater < 3 kW	2.5 mm^2	1
vi)	Heaters or electric equipment more than or equal to 3 kW	4.0 mm^2	1
vii)	Free standing electric range Separate oven and/or cook top	4.0 mm^2	1
viii)	Air conditioner > 1.5 t	4.0 mm^2	1
ix)	Permanently connected appliances including dishwashers, heaters, etc	2.5 mm^2	1 above 10 A. Up to 10 A can be wired as part of a socket-outlet circuit
x)	Appliance rated >3 kW<6 kW	6.0 mm^2	—
xi)	Submains to garage or out-building	2.5 mm^2	1 for each
xii)	Mains cable	—	It should be based on demand load/peaking loads and future loading.

NOTE — In multi-core flexible cables containing 7 or more cores and in signalling control circuits intended for electronic equipment a minimum nominal cross -sectional area of 0.1 mm^2 is permitted.

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5.8.2 Aluminum conductor cables in sizes less than 16 mm^2 cause termination problems leading to heating at the terminals and enhance the possibility of a fire. For conductor sizes less than or equal to 16 mm^2, only copper conductor cables should be used.

5.8.3 Switch or isolator controlling a water heater or geyser should not be located within 1 m from the location of a shower or bath tub, to avoid a person in wet condition reaching the switch or isolator. It is preferable to provide the control switch outside the bath room near the entrance and provide an indication at the water heater. A socket or a connector block with suitable protection against water spray should be provided to connect the water heater. The above considerations apply to switches for outdoor lights and other appliances, with the objective of avoidance of operation of a switch when a person is wet.

5.8.4 Sockets in kitchen, bathroom, toilet, garage, etc, should not be provided within a height of 1 m from the ground level. Similar care has to be taken for installations involving fountains, swimming pools, etc. Light fittings in such areas should be fed at low voltage, preferably through an isolating transformer with a proper earth leakage protection. Where possibility of a person in contact with a wet surface has to operate or touch an electrical switch or an appliance the circuit should be protected by a 100/30 mA RCCB/RCD, as applicable.

5.8.5 *Selecting and Installing Cables*

5.8.5.1 *Cable insulation types*

For the purpose of this Code, cables above 1 mm^2 shall have stranded conductors. All cables when installed, shall be adequately protected against mechanical damage. This can be carried out by either having additional protection, such as being enclosed in PVC conduit or metal pipes, or placing the cables in a suitable location that requires no additional protection. The cables for wiring circuits in electrical installation shall have the appropriate wire size matching the requirement of the loads and the following table gives the recommendations for different types of loads:

For the mains cable	Tough plastic sheathed (TPS) cable
For installation wiring	Tough plastic sheathed (TPS) cables
For main earth or main equipotential wire	Poly vinyl chloride (PVC) insulated conduit wire
Underground installation and installation in cable trench, feeders between buildings, etc	PVC insulated, PVC sheathed armored cables or XLPE insulated, PVC sheathed cables armoured cables
Installation in plant rooms, switch rooms etc, on cable tray or ladder or protected trench, where risk of mechanical damage to cable does not exist.	PVC insulated, PVC sheathed or XLPE insulated, PVC sheathed unarmoured cables

5.8.5.2 *Circuit wire sizes*

Recommended minimum wire sizes for various circuits is given below:

Sl No.	*Circuits*	*Minimum Wire Size*	*Wire Colour*
(1)	(2)	(3)	(4)
i)	1-way lighting	2 + E cable wires 1.5 mm^2	Red-Black-Green or Green/Yellow
ii)	2-way lighting control (straps between the 2 switches)	3 wire cable 1.5 mm^2	Red-White-Blue
iii)	Storage water heaters up to 3 kW	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
iv)	Storage water heaters between 3 kW and 6 kW	2 + E cable 4 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
v)	Socket-outlets and permanent connection units	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow
vi)	Submains to garages or out buildings	2 + E cable 2.5 mm^2 (stranded conductors)	Red-Black-Green or Green/Yellow

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Sl No.	*Circuits*	*Minimum Wire Size*	*Wire Colour*
(1)	(2)	(3)	(4)
vii)	Cooking hobs	2 + E cable	Red-Black-Green or
viii)	Separate ovens	1.5 mm^2 2 + E cable 4 mm^2 (stranded conductors)	Green/Yellow
ix)	Electric range	2 + E cable 6 mm^2 (stranded conductors)	Red-Black- Green or Green/Yellow
x)	Mains	2 wire cable 16 mm^2 (stranded conductors)	Red-Black
xi)	Main equipotential bonding wire	Conduit wire 4 mm^2 (stranded conductors)	Green or Green/Yellow
xii)	Main earth wire	Conduit wire 6 mm^2 (stranded conductors)	Green or Green/Yellow

NOTES

1 2 + E is also known as twin and earth.

2 Earth wire can be as per the following:

a) Green/Yellow throughout their length with, in addition, light blue markings at the terminations, or

b) Light blue throughout their length with, in addition, green/yellow markings at the terminations.

3 The above sizes are recommendatory and shall be modified as per voltage drop, starting current, distance from DB, etc.

5.8.6 *Requirements for Physical Protection of Underground Cables*

Sl No.	*Protective Element*	*Specifications*
(1)	(2)	(3)
i)	Bricks	(a) 100 mm minimum width (b) 25 mm thick (c) sand cushioning 100 mm and sand cover 100 mm
ii)	Concrete slabs	At least 50 mm thick
iii)	Plastic slabs (polymeric cover strips) Fibre reinforced plastic	At least 10 mm thick, depending on properties and has to be matched with the protective cushioning and cover
iv)	PVC conduit or PVC pipe or stoneware pipe or hume pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe
v)	Galvanized pipe	The pipe diameter should be such so that the cable is able to easily slip down the pipe

The trench shall be backfilled to cover the cable initially by 200 mm of sand fill; and then a plastic marker strip shall be put over the full length of cable in the trench. The marker signs shall be provided where any cable enters or leaves a building. This will identify that there is a cable located underground near the building. The trench shall then be completely filled. If the cables rise above ground to enter a building or other structure, a mechanical protection such as a GI pipe or PVC pipe for the cable from the trench depth to a height of 2.0 m above ground shall be provided.

5.9 Lighting and Levels of Illumination

5.9.1 *General*

Lighting installation shall take into consideration many factors on which the quality and quantity of artificial lighting depends. Recent practice in illumination is to provide the required illumination with a large number of light sources (not of higher illumination level) instead of fewer number of light sources of higher illumination level, to produce higher uniformity in illumination level.

Now a wide variety of light sources, such as, fluorescent lamps [tubular (TL) and compact (CFL)], light emitting diodes (LED) and induction lighting are available in addition to the incandescent lamps (GLS and halogen), for application in buildings. Most of them are competitive when applied in the segment for which a particular type is well suited.

With the increase in energy costs and awareness of the need to conserve energy for the protection of the

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environment, lighting design is becoming complex. With the developments in the types of light sources and their control systems now available, lighting design goes with the concept of better light with less energy and least impact on environment.

Automatic lighting control schemes may be considered to have efficient utilization of lights. Automatic controls can take care of the switching off when the space served has no activity or is illuminated by daylight.

5.9.2 *Electrical Installations for Lighting*

The concepts or needs of energy conservation today require more lights to be provided so that different sets of lights are used to light up the area of activity to the required higher level of lighting needed for the activity and provide a general minimum background level of lighting. Any space requires two or three different combination of lighting sets associated with the activity and this may require the wiring to be provided to accommodate the lighting groups in different circuits with group controls, automatic controls and remote controls.

Availability of LED lights with a wide range from 1 W to 100 W allows designers to provide spot task lighting of a high illumination level combined with a general space lighting of low illumination. As light follows the inverse square law, provision of the light source close to the task reduces the energy need.

Lighting demand for buildings should be considered as per type of building. Where nothing is specified, for lighting demand of any type of building a maximum of 13 W/m^2 of all built-up areas including balconies. Covered parking areas may be considered at 3.23 W/m^2 including balconies, service areas, corridors, etc, may be considered with very basic diversity of 80 percent to 100 percent. Power requirements shall be considered at least 55 W/m^2 with an overall diversity not exceeding 50 percent. These shall be excluding defined loads such as lifts, plumbing system, fire fighting systems, ventilation requirement, etc.

While incandescent lamps (GLS or halogen) does not require any control gear, other light sources such as tubular fluorescent lamps, compact fluorescent lamps, mercury vapour lamps, sodium vapour lamps, metal halide lamps and light emitting diode (LED) lamps have non-linear characteristics and require specifically made control gear for each type of lamp for their proper operation. In some cases the control gear is integral with the lamp and in some it is with light fitting and in some it is external. The electrical installation and wiring has to take this into account and provide appropriate space for such control gear. There will be heat emission, introduction of harmonics etc, and they also consume some energy. The electrical and lighting system design has to keep this aspect in the wiring design and installation. Control gear contributes or influences energy conservation significantly and due care should be taken to ensure a proper choice.

5.9.3 *Principles of Lighting*

When considering the function of artificial lighting, attention shall be given to the following principle characteristics before designing an installation:

a) Illumination and its uniformity;
b) Special distribution of light. This includes a reference to the composition of diffused and directional light, direction of incidence, the distribution of luminances and the degree of glare;
c) Colour of the light and colour rendition;
d) Natural light sources, if possible such as light tubes; and
e) System wattage of the luminaire proposed.

5.9.4 The variety of purposes which have to be kept in mind while planning the lighting installation may be broadly grouped as:

a) Industrial buildings and processes;
b) Offices, schools and public buildings;
c) Surgeries and hospitals; and
d) Hostels, restaurants, shops and residential buildings.

5.9.4.1 It is important that appropriate levels of illumination for these and the types and positions of fittings determined to suit the task and the disposition of the working planes.

5.9.5 For detailed requirements for lighting and lighting design and installations, reference shall be made to National Lighting Code. For specific requirements for lighting of special occupancies, reference shall be made to good practice [8-2(30)] and the National Lighting Code.

5.9.6 *Energy Conservation*

Energy conservation may be achieved by using the following:

a) Energy efficient lamps, chokes, ballast, etc, for lighting equipment.
b) Efficient switching systems such as remote sensors, infrared switches, master switches, occupancy sensors, light sensors, light automation, remote switches, etc for switching 'ON' and 'OFF' of lighting circuits.
c) Properly made/connected joints/contacts to avoid loose joints leading to loss of power.

5.10 In locations where the system voltage exceeds 650 V, as in the case of industrial locations, for details of design and construction of wiring installation,

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reference may be made to good practice [8-2(11)].

5.11 Guideline for Electrical Layout in Residential Buildings

For guidelines for electrical installation in residential buildings, reference may be made to good practice [8-2(31)].

A typical distribution scheme in a residential building with separate circuits for lights and fans and for power appliances is given in Fig. 3.

5.12 For detailed information regarding the installation of different electrical equipment, reference may be made to good practice [8-2(32)].

6 WIRING

6.1 Provision for Maximum Load

All conductors, switches and accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the maximum current which will normally flow through them.

6.1.1 *Estimation of Load Requirements*

In estimating the current to be carried by any conductor the following ratings shall be taken, unless the actual values are known or specified for these elements:

Sl No.	*Element*	*Rating* W
(1)	(2)	(3)
i)	Incandescent lamp	60
ii)	Ceiling fan	60
iii)	Table fan	60
iv)	6 A socket outlet	100, unless the actual value of loads are specified
v)	16 A socket outlet	1 000, unless the actual value of loads are specified
vi)	Fluorescent light: Length :	
	a) 600 mm	25
	b) 1 200 mm	50
	c) 1 500 mm	90
vii)	High pressure mercury vapour (HPMV) lamps, high pressure sodium vapour (HPSV) lamps	According to their capacity, control gear losses shall be also considered as applicable
viii)	Compact fluorescent lamp (CFL)	20
ix)	Light emitting diode (LED)	10
x)	Exhaust fan	50
xi)	Geyser (storage type)	2 000
xii)	Geyser (instant)	3 000
xiii)	Computer point	150
xiv)	Computer (laptop)	50
xv)	Printer, laser	1 500
xvi)	Printer, inkjet	70
xvii)	Kitchen outlet	1 500
xviii)	Air conditioner:	
	1 TR	1 250
	1.5 TR	1 875
	2 TR	2 500
	2.5 TR	3 200

6.1.2 Electrical installation in a new building shall normally begin immediately on the commencement of the main structural building work and before finishing work such as plastering has begun except in the case of surface wiring which can be carried out after the plaster work. Usually, no installation work should start until the building is reasonably weatherproof, but where electric wiring is to be concealed within the structures as may be the case with a reinforced concrete building, the necessary conduits and ducts shall be positioned firmly by tying the conduit to the reinforcement before concreting. Care should be taken to avoid use of damaged conduit or ducts, the conduits end shall be given suitable anti-corrosive treatment and holes blocked off by putties or caps to protect conduits from getting blocked. All conduit openings and junction box openings, etc shall be properly protected against entry of mortar, concrete, etc, during construction.

6.2 Selection of Size of Conductors

The size of conductors of circuits shall be so selected that the drop in voltage from consumer's terminals in a public supply (or from the bus-bars of the main switchboard controlling the various circuits in a private generation plant) to any point on the installation does not exceed three percent of the voltage at the consumer's terminals (or at two bus-bars as these may be) when the conductors are carrying the maximum current under the normal conditions of service. The overall voltage drop from the transformer end to consumer's final distribution board shall not exceed six percent.

6.2.1 If the cable size is increased to reduce voltage drop in the circuit, the rating of the cable shall be sufficient to carry the current which the circuit is designed for. In each circuit or sub-circuit the fuse/ circuit-breaker shall be selected to match the current rating of the circuit to ensure the desired protection.

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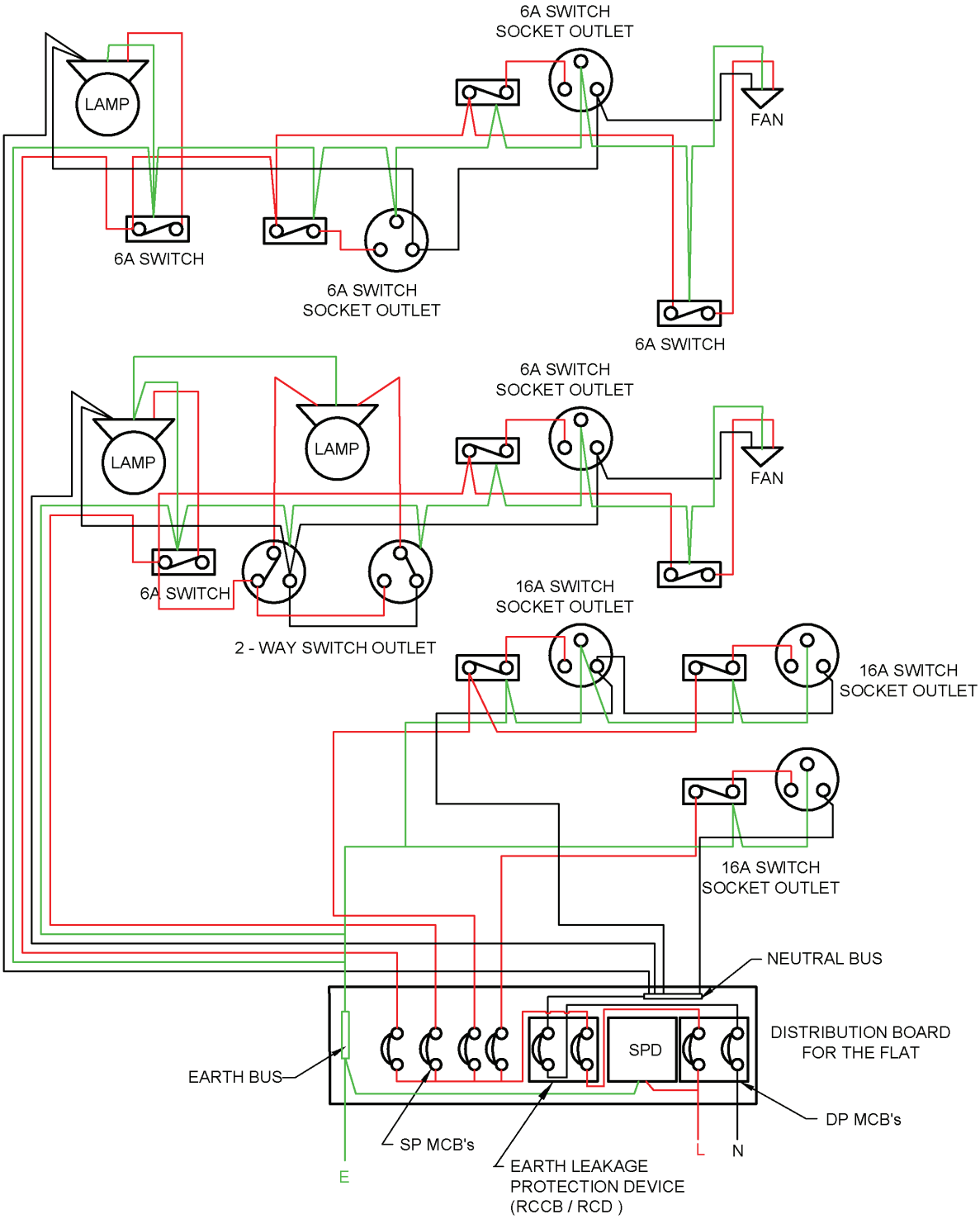


FIG. 3 WIRING DIAGRAM FOR A TYPICAL DISTRIBUTION SCHEME IN A RESIDENTIAL BUILDING FLAT

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6.3 Branch Switches

Where the supply is derived from a three-wire or four-wire source, and distribution is done on the two-wire system, all branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or protective device shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit. Single-pole switches (other than for multiple control) carrying not more than 16 A may be of tumbler type or flush type which shall be on when the handle or knob is down.

6.4 Layout and Installation Drawing

6.4.1 The electrical layout should be drawn indicating properly the locations of all outlets, such as, lamps, fans, appliances (both fixed and movable) and motors and best suit for wiring.

6.4.2 All runs of wiring and the exact positions of all points of switch-boxes and other outlets shall be first marked on the plans of the building and approved by the Engineer-in-Charge or the owner before actual commencement of the work.

6.4.3 Industrial layout drawings should indicate the relative civil and mechanical details.

6.4.4 *Layout of Wiring*

The layout of wiring should be designed keeping in view disposition of the lighting system to meet the illumination levels. All wirings shall be done on the distribution system with main and branch distribution boards at convenient physical and electrical load centres. All types of wiring, whether concealed or unconcealed should be as near the ceiling as possible. In all types of wirings due consideration shall be given for neatness and good appearance.

6.4.5 Balancing of circuits in three-wire or poly-phase installation shall be arranged beforehand. Proper balancing can be done only under actual load conditions. Conductors shall be so enclosed in earthed metal or incombustible insulating material that it is not possible to have ready access to them. Means of access shall be marked to indicate the voltage present.

Where terminals or other fixed live parts between which a voltage exceeding 250 V exists are housed in separate enclosures or items of apparatus which, although separated are within reach of each other, a notice shall be placed in such a position that anyone gaining access to live parts is warned of the magnitude of the voltage that exists between them.

Where loads are single phase, balancing should be for the peak load condition based on equipment usage. Facility for change should be built into the distribution design.

NOTE — The above requirements apply equally to three-phase circuits in which the voltage between lines or to earth exceeds 250 V and to groups of two or more single-phase circuits, between which medium voltage may be present, derived therefrom. They apply also to 3-wire d.c. or 3-wire single-phase a.c. circuits in which the voltage between lines or to earth exceeds 250 V and to groups of 2-wire circuits, between which medium voltage may be present, derived there from.

6.4.6 Medium voltage wiring and associated apparatus shall comply, in all respects, with the requirements of Regulation 35, 36, 37, 40, 41 and 42 of *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010, as amended from time-to-time (*see* Annex B).

6.5 Conductors and Accessories

6.5.1 *Conductors*

Conductors for all the internal wiring shall be of copper. Conductors for power and lighting circuits shall be of adequate size to carry the designed circuit load without exceeding the permissible thermal limits for the insulation. For final section wiring to larger loads, the current carrying capacity will preside. The conductor size shall also be based on the voltage drop in the line so as to provide a terminal voltage not below the prescribed voltage requirement.

The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area not less than 1.50 mm^2 copper. The cross-sectional area of conductor for power wiring shall be not less than 2.5 mm^2 copper. The minimum cross-sectional area of conductor of flexible cord shall be 1.50 mm^2 copper.

In existing buildings where aluminum wiring has been used for internal electrification, changeover from aluminum conductor cables to copper conductor cables is recommended as it has been found that aluminum conductors below 10 mm^2 size pose a number of hazards.

NOTE — It is advisable to replace wiring, which is more than 30 years old as the insulation also would have deteriorated, and will be in a state to cause failure on the slightest of mechanical or electrical disturbance.

6.5.2 *Flexible Cables and Flexible Cords*

Flexible cables and cords shall be of copper and stranded and protected by flexible conduits or tough rubber or PVC sheath to prevent mechanical damage.

6.5.3 *Cable Ends*

When a stranded conductor having a nominal sectional area less than 6 mm^2 is not provided with cable sockets, all strands at the exposed ends of the cable shall be soldered together or crimped using suitable sleeve or ferrules.

6.5.4 *Special Risk*

Special forms of construction, such as flameproof

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enclosures, shall be adopted where there is risk of fire or explosion.

6.5.5 *Connection to Ancillary Buildings*

Unless otherwise specified, electric connections to ancillary buildings, such as out-houses, garages, etc, adjacent to the main building and when no roadway intervenes shall be taken in an earthed GI pipe or heavy duty PVC or HDPE pipe of suitable size. This pipe can be taken either underground or over ground, however, in latter case, its height from the ground shall not be less than 5.8 m. This applies to both runs of mains or sub-mains or final sub-circuit wiring between the buildings.

6.5.6 *Expansion Joints*

Distribution boards shall be so located that the conduits shall not normally be required to cross expansion joints in a building. Where such crossing is found to be unavoidable, special care shall be taken to ensure that the conduit runs and wiring are not in any way put to strain or damaged due to expansion of building structure. Anyone of the following standard methods of connection at a structural expansion joint shall be followed:

a) Flexible conduit shall be inserted at place of expansion joint.
b) Oversized conduit overlapping the conduit.
c) Expansion box.

Supports and flexible joints shall be of same requirement as the rising main/bus duct in so far as resistance to seismic forces is concerned. This is further important when rising mains and bus-ducts cross expansion joints.

6.5.7 *Low Voltage* (*Types of Wires/Cables)*

Low voltage services utilizes various categories of cables/wires, such as fibre optic cable, co-axial, category cable, etc. These shall be laid at least at a distance of 300 mm from any power wire or cable. The distance may be reduced only by using completely closed earthed metal trunking with metal separations for various kind of cable. Special care shall be taken to ensure that the conduit runs and wiring are laid properly for low voltage signal to flow through it.

The power cable and the signal or data cable may run together under floor and near the equipment. However, separation may be required from the insulation aspect, if the signal cable is running close to an un-insulated conductor carrying power at high voltage. All types of signal cables are required to have insulation level for withstanding 2 kV impulse voltage even if they are meant for service at low voltage.

6.6 Joints and Looping Back

6.6.1 Where looping back system of wiring is specified, the wiring shall be done without any junction or connector boxes on the line. Where joint box system is specified, all joints in conductors shall be made by means of suitable mechanical connectors in suitable joint boxes. Whenever practicable, only one system shall be adopted for a building, preferably a looping back system.

6.6.2 In any system of wiring, no bare or twist joints shall be made at intermediate points in the through run of cables unless the length of a final sub-circuit, sub-main or main is more than the length of the standard coil as given by the manufacturer of the cable. If any jointing becomes unavoidable such joint shall be made through proper cutouts or through proper junction boxes open to easy inspection, but in looping back system no such junction boxes shall be allowed.

6.6.3 Joints are a source of problems in reliability and are also vulnerable to fire. They should be avoided or at least minimized. They should under no circumstance exceed more than one to two in total length and distance between two shall not be less than 5 m. Joint should not be used as tap-off for multiple feeders. Where joints in cable conductors or bare conductors are necessary, they shall be mechanically and electrically sound. Joints in non-flexible cables shall be accessible for inspection; provided that this requirement shall not apply to joints in cables buried underground, or joints buried or enclosed in non-combustible building materials. Joints in non-flexible cables shall be made by soldering, brazing, welding or mechanical clamps, or be of the compression type; provided that mechanical clamps shall not be used for inaccessible joints buried or enclosed in the building structure. All mechanical clamps and compression type sockets shall securely retain all the wires of the conductors. Any joint in a flexible cable or flexible cord shall be effected by means of a cable coupler.

For flexible cables for small loads less than 1 kW, while it is desirable to avoid joints, if unavoidable, joints may be made either by splicing by a recognized method or by using a connector and protecting the joint by suitable insulating tape or sleeve or straight joint. For application of flexible cable for loads of 1 kW or more, if joint is unavoidable, crimped joint is preferred. Spliced joint should not be used for large loads.

There are different standard joints, such as epoxy resin based joint, heat shrinkable plastic sleeve joint, etc, and each one has its advantage and disadvantage. Selection has to be made on the basis of application, site conditions and availability of skilled licensed workmen trained in the application of the particular type of joint.

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6.6.4 Every joint in a cable shall be provided with insulation not less effective than that of the cable cores and shall be protected against moisture and mechanical damage. Soldering fluxes which remain acidic or corrosive at the completion of the soldering operation shall not be used.

For joints in paper-insulated metal-sheathed cables, a wiped metal sleeve or joint box, filled with insulating compound, shall be provided.

Where an aluminum conductor and a copper conductor are joined together, precautions shall be taken against corrosion and mechanical damage to the conductors.

6.6.5 *Pull at Joints and Terminals*

Every connection at a cable termination shall be made by means of a terminal, soldering socket, or compression type socket and shall securely contain and anchor all the wires of the conductor, and shall not impose any appreciable mechanical strain on the terminal or socket.

Flexible cords shall be so connected to devices and to fittings that tension is not transmitted to joints or terminal screws. This shall be accomplished by a knot in the cord, by winding with tape, by a special fitting designed for that purpose, or by other approved means which can prevent a pull on the cord from being directly transmitted to joints or terminal screws.

6.7 Passing Through Walls and Floors

6.7.1 Where wires/cables are required to pass through walls, care shall be taken to see that wires/cables pass freely through protective pipe or box and that the wires pass through in a straight line without any twist or cross in wires.

One of the following methods shall be employed for laying wires/cables:

a) *Conduit wiring system* (*see* **6.10**) — The conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit conforming to accepted standards [8-2(33)].

The conduits shall be colour coded as per the purpose of wire carried in the same. The recommended colour coding may be in form of bands of colour (100 mm thick, with centre to centre distance of 300 mm) or coloured throughout. The colour scheme may be as follows:

Conduit Type	*Colour Scheme*
Power conduit	Black
Security conduit	Blue
Fire alarm conduit	Red
Low voltage conduit	Brown
UPS conduit	Green

Conduit wiring system shall comply with accepted standards [8-2(34)]. The number of insulated conductors that can be drawn into rigid conduit is given in Tables 1 (*see* Table 1A for rigid steel conduits and Table 1B for rigid non-metallic conduits).

b) *Cable trunking/cable ways* (*see* **6.11**) — Cable trunking/cable ways system should be used when number of wires/small cable sizes to be laid is more than the conduit capacity. Care should be taken to have space in the trunking system to minimize heating of wires and to provide identification of the different circuits.

Cable trunking or ducting system shall comply with accepted standards [8-2(35)].

c) *Tray and ladder rack* — As tray provides continuous support, unless mounted on edge or in vertical runs (when adequate strapping or clipping is essential), the mechanical strength of supported cable is not as important as with ladder-racking or structural support methods. Consequently, tray is eminently suitable for the smaller unarmoured cabling while ladder racks call for armoured cables or larger unarmoured cables as they provide the necessary strength to avoid sagging between supports. Both tray and ladder racks are provided with accessories to facilitate changes of route, and they provide no difficulty in this respect on vertical runs.

Cable tray/ladder racks and support systems shall be installed in such a way that the deflection between the spans shall be less than 1 percent of the span.

Power cables running in cable ladders both horizontal and vertical shall be fixed with proper clamps which can withstand the mechanical force created on the cable in case of short circuit current. The complete installation consisting of cables, ladders, clamps, ladder supports and fixtures shall also withstand the mechanical force of short circuit current. Only one layer of power cable shall be laid in a ladder. The minimum space between two cables shall be equal to the diameter of the biggest cable.

Cable tray and ladder system shall comply with IEC 61537:2006 'Cable management — Cable tray systems and cable ladder systems' (*under publication as an adopted Indian Standard*).

6.7.2 Insulated conductors while passing through floors shall be protected from mechanical injury by means of rigid steel/non-metal conduit or by mechanical protection up to a height not less than 1.5 m above the

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floor and flush with the ceiling below. These steel conduits shall be earthed and securely bushed.

Power outlets and wiring in the floor shall be generally avoided. If not avoidable, false floor trunking or metal floor trunking should be used. Power sockets of adequate IP/IK rating shall be used.

False floor shall be provided where density of equipment and interconnection between different pieces of equipment is high. Examples are, mainframe computer station, telecommunication switch rooms, etc. Floor trunking shall be used in large halls, convention centres, open plan offices, laboratory, etc.

In case of floor trunking, drain points/weep holes shall be provided within the trunking for installation for conventional centres, exhibition areas or any other place where water may spill into the trunking, as there might be possibility of water seepage in the case of wiring passing through the floors. Proper care should be taken for providing suitable means of draining of water. Possibility of water entry exists from floor washing, condensation in some particular weather and indoor temperature conditions. At the design stage, these aspects shall be assessed and an appropriate means of avoiding, or reducing, and draining method shall be built in. Floor trunking outlets shall be suitably IP rated for protection against dust and water.

Floor outlet boxes are generally provided for the use of appliances, which require a signal, or communication connection. The floor box and trunking system should cater to serve both power distribution and the signal distribution, with appropriate safety and non-interference.

6.7.3 Where a wall tube passes outside a building so as to be exposed to weather, the outer end shall be bell-mouthed and turned downwards and properly bushed on the open end.

6.8 Wiring of Distribution Boards

6.8.1 All connections between pieces of apparatus or between apparatus and terminals on a board shall be neatly arranged in a definite sequence, following the arrangements of the apparatus mounted thereon, avoiding unnecessary crossings.

6.8.2 Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve, lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without the cutting away of cables stands. Cables in each circuit shall be bunched together.

6.8.3 All bare conductors shall be rigidly fixed in such a manner that a clearance of at least 25 mm is maintained between conductors or opposite polarity or phase and between the conductors and any material other than insulation material.

6.8.4 If required, a pilot lamp shall be fixed and connected through an independent single pole switch and fuse to the bus-bars of the board. Leads connecting bus-bars to any instrument or indicating lamp or an outgoing connection switch or breaker face the same fault current that is applicable to the bus-bar and as such should be provided with a fuse capable of handling the prospective fault current.

6.8.5 In a hinged type board, the incoming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board leaving suitable space in between cables, and shall also, if possible, be fixed at the corresponding points on the switchboard panel. The cables between these points shall be of such length as to allow the switchboard panel to swing through an angle of not less than 90° and cables arranged and clamped in such a manner that the cables do not face bending, but only face a twist, when the hinged door is opened. The circuit breakers in such cases shall be accessible without opening the door of distribution board. Also, circuit breakers or any other equipment (having cable size more than 1.5 mm^2 multi-strand wire) shall not be mounted on the door.

NOTE — Use of hinged type boards is discouraged, as these boards lead to deterioration of the cables in the hinged portion, leading to failures or even fire.

6.8.6 Wires terminating and originating from the protective devices shall be properly lugged and taped.

6.9 PVC-Sheathed Wiring System

6.9.1 *General*

Wiring with PVC-sheathed cables may be used for temporary installations for medium voltage installation and may be installed directly under exposed conditions of sun and rain or damp places.

6.9.2 *PVC Clamps/PVC Channel*

The clamps shall be used for temporary installations of 1-3 sheathed wires only. The clamps shall be fixed on wall at intervals of 100 mm in the case of horizontal runs and 150 mm in the case of vertical runs.

PVC channel shall be used for temporary installations in case more than 3 wires or wires or unsheathed wires. The channel shall be clamped on wall at intervals not exceeding 300 mm. PVC clamps/PVC channel shall conform to accepted standards.

6.9.3 *Protection of PVC-Sheathed Wiring from Mechanical Damage*

a) In cases where there are chances of any damage to the wirings, such wirings shall be

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covered with sheet metal protective covering, the base of which is made flush with the plaster or brickwork, as the case may be, or the wiring shall be drawn through a conduit complying with all requirements of conduit wiring system (*see* **6.10**).

b) Such protective coverings shall in all cases be fitted on all down-drops within 1.5 m from the floor.

6.9.4 *Bends in Wiring*

The wiring shall not in any circumstances be bent so as to form a right angle but shall be rounded off at the corners to a radius not less than six times the overall diameter of the cable.

6.9.5 *Passing Through Floors*

All cables taken through floors shall be enclosed in an insulated heavy gauge steel conduit extending 1.5 m above the floor and flush with the ceiling below, or by means of any other approved type of metallic covering. The ends of all conduits or pipes shall be neatly bushed with porcelain, wood or other approved material.

6.9.6 *Passing Through Walls*

The method to be adopted shall be according to good practice. There shall be one or more conduits of adequate size to carry the conductors [*see* **6.10.1**(a)]. The conduits shall be neatly arranged so that the cables enter them straight without bending.

6.9.7 *Stripping of Outer Covering*

While cutting and stripping of the outer covering of the cables, care shall be taken that the sharp edge of the cutting instrument does not touch the rubber or PVC-sheathed insulation of conductors. The protective outer covering of the cables shall be stripped off near connecting terminals, and this protective covering shall be maintained up to the close proximity of connecting terminals as far as practicable. Care shall be taken to avoid hammering on link clips with any metal instruments, after the cables are laid. Where junction boxes are provided, they shall be made moisture-proof with an approved plastic compound.

6.9.8 *Painting*

If so required, the tough rubber-sheathed wiring shall, after erection, be painted with one coat of oil-less paint or distemper of suitable colour over a coat of oil-less primer, and the PVC-sheathed wiring shall be painted with a synthetic enamel paint of quick drying type.

6.10 Conduit Wiring System

Conduit wiring system shall comply with accepted standards [8-2(34)]. Requirements relating to conduit wiring system with rigid steel and non-metallic conduits shall be as per **6.10.1** to **6.10.3**.

6.10.1 *Surface Conduit Wiring System with Rigid Steel Conduits*

a) *Type and size of conduit* — All conduit pipes shall conform to accepted standards [8-2(36)], finished with galvanized or enamelled surface. All conduit accessories shall be of threaded type and under no circumstance pin grip type or clamp type accessories be used. No steel conduit less than 16 mm in diameter shall be used. The number of insulated conductors that can be drawn into rigid steel conduit is given in Tables 1A.

b) *Bunching of cables* — Unless otherwise specified, insulated conductors of a.c. supply and d.c. supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate conduits is recommended.

c) *Conduit joints* — Conduit pipes shall be joined by means of screwed couplers and screwed accessories only [*see* 8-2(37)]. In long distance straight runs of conduit, inspection type couplers at reasonable intervals shall be provided or running threads with couplers and jam-nuts (in the latter case the bare threaded portion shall be treated with anti-corrosive preservative) shall be provided. Threaded on conduit pipes in all cases shall be between 11 mm and 27 mm long sufficient to accommodate pipes to full threaded portion of couplers or accessories. Cut ends of conduit pipes shall have no sharp edges or any burrs left to avoid damage to the insulation of conductors while pulling them through such pipes.

d) *Protection against dampness* — In order to minimize condensation or sweating inside the tube, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects as far as possible.

e) *Protection of conduit against rust* — The outer surface of the conduit pipes, including all bends, unions, tees, conduit system shall be adequately protected against rust particularly when such system is exposed to weather. In all cases, no bare threaded portion of conduit pipe shall be allowed unless such bare threaded portion is treated with anti-corrosive preservative or covered with suitable plastic compound.

f) *Fixing of conduit* — Conduit pipes shall be fixed by heavy gauge saddles, secured to

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Table 1A Maximum Permissible Number of Single-Core Cables up to and including 1 100 V that can be Drawn into Rigid Steel Conduits

[*Clauses* 6.7.1(a) *and* 6.10.1(a)]

Sl No.	Size of Cable		Size of Conduit mm													
	Nominal Cross-Sectional Area mm^2	Number and Diameter (in mm) of Wires	16		20		25		32		40		50		63	
			Number of Cables, *Max*													
			S	B	S	B	S	B	S	B	S	B	S	B	S	B
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i)	1.0	1/1.12[1)]	5	4	7	5	13	10	20	14	—	—	—	—	—	—
ii)	1.5	1/1.40	4	3	7	5	12	10	20	14	—	—	—	—	—	—
iii)	2.5	1/1.80 3/1.06[1)]	3	2	6	5	10	8	18	12	—	—	—	—	—	—
iv)	4	1/2.24 7/0.85[1)]	3	2	4	3	7	5	12	10	—	—	—	—	—	—
v)	6	1/2.80 7/1.06[1)]	2	—	3	2	6	5	10	8	—	—	—	—	—	—
vi)	10	1/3.55[2)]	—	—	2	—	5	4	8	7	—	—	—	—	—	—
		7/1.40[1)]	—	—	2	—	4	3	6	5	8	6	—	—	—	—
vii)	16	7/1.70	—	—	—	—	2	—	4	3	7	6	—	—	—	—
viii)	25	7/2.24	—	—	—	—	—	—	3	2	5	4	8	6	9	7
ix)	35	7/2.50	—	—	—	—	—	—	2	—	4	3	7	5	8	6
x)	50	19/1.80 7/3.007[2)]	—	—	—	—	—	—	—	—	2	—	5	4	6	5

NOTES

1 The table shows the maximum capacity of conduits for the simultaneously drawing of cables. The columns headed S apply to runs of conduit which have distance not exceeding 4.25 m between draw-in boxes, and which do not deflect from the straight by an angle of more than 15°. The columns headed B apply to runs of conduit which deflect from the straight by an angle of more than 15°.

2 In case an inspection type draw-in box has been provided and if the cable is first drawn through one straight conduit, then through the draw-in box, and then through the second straight conduit, such systems may be considered as that of a straight conduit even if the conduit deflects through the straight by more than 15°.

3 Conductor sizes for cables and wires above and including 2.5 mm^2 core size shall be multi-stranded.

[1)] For copper conductors only.
[2)] For aluminium conductors only.

suitable wood plugs or other plugs with screws in an approved manner at an interval of not more than 1 m, but on either side of couplers or bends or similar fittings, saddles shall be fixed at a distance of 300 mm from the centre of such fittings. Conduit fittings shall be avoided as far as possible on conduit system exposed to weather; where necessary, solid type fittings shall be used.

g) *Bends in conduit* — All necessary bends in the system including diversion shall be done by bending pipes; or by inserting suitable solid or inspection type normal bends, elbows or similar fittings; or fixing cast iron, thermoplastic or thermosetting plastic material inspection boxes, whichever is more suitable. Radius of such bends in conduit pipes shall be not less than 75 mm. No length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

h) *Outlets* — All outlets for fittings, switches, etc, shall be boxes of suitable metal or any other approved outlet boxes for either surface mounting or flush mounting system.

j) *Conductors* — All conductors used in conduit wiring shall preferably be stranded. No single-core cable of nominal cross-sectional area greater than 130 mm^2 enclosed along in a conduit and used for alternating current.

k) *Erection and earthing of conduit* — The conduit of each circuit or section shall be completed before conductors are drawn in. The entire system of conduit after erection shall be tested for mechanical and electrical continuity throughout and permanently connected to earth conforming to the requirements as already specified by means of suitable earthing clamp efficiently fastened to conduit pipe in a workman like manner for a perfect continuity between each wire and conduit. Gas or water pipes shall not be used

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as earth medium. If conduit pipes are liable to mechanical damage they shall be adequately protected.

m) Inspection type conduit fittings, such as inspection boxes, draw boxes, bends, elbows and tees shall be so installed that they can remain accessible for such purposes as to withdrawal of existing cables or the installing of traditional cables.

6.10.2 *Recessed Conduit Wiring System with Rigid Steel Conduit*

Recessed conduit wiring system shall comply with all the requirements for surface conduit wiring system specified in **6.10.1** (a) to **6.10.1** (k) and in addition, conform to the requirements specified below:

a) *Making of chase* — The chase in the wall shall be neatly made and be of ample dimensions to permit the conduit to be fixed in the manner desired. In the case of buildings under construction, chases shall be provided in the wall, ceiling, etc, at the time of their construction and shall be filled up neatly after erection of conduit and brought to the original finish of the wall. In case of exposed brick/ rubble masonry work, special care shall be taken to fix the conduit and accessories in position along with the building work.

b) *Fixing of conduit in chase* — The conduit pipe shall be fixed by means of staples or by means of saddles not more than 600 mm apart. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves maintained by bending the conduit pipe itself with a long radius which will permit easy drawing-in of conductors. All threaded joints of rigid steel conduit shall be treated with preservative compound to secure protection against rust.

c) *Inspection boxes* — Suitable inspection boxes shall be provided to permit periodical inspection and to facilitate removal of wires, if necessary. These shall be mounted flush with the wall. Suitable ventilating holes shall be provided in the inspection box covers. The minimum sizes of inspection boxes shall be 75 mm × 75 mm.

d) *Types of accessories to be used* — All outlet, such as switches and wall sockets, may be either of flush mounting type or of surface mounting type, as given below:

1) *Flush mounting type* — All flush mounting outlets shall be of cast-iron or mild steel boxes with a cover of insulating material or shall be a box made of a suitable insulating material. The switches and other outlets shall be mounted on such boxes. The metal box shall be efficiently earthed with conduit by a suitable means of earth attachment.

2) *Surface mounting type* — If surface mounting type outlet box is specified, it shall be of any suitable insulating material and outlets mounted in an approved manner.

The switches/socket outlets shall have adequate IP rating for various utilizations.

6.10.3 *Conduit Wiring System with Rigid Non-Metallic Conduits*

Rigid non-metallic conduits are used for concealed conduit wiring.

6.10.3.1 *Type and size*

All non-metallic conduits used shall conform to accepted standards [8-2(38)] and shall be used with the corresponding accessories {see accepted standards [8-2(39)]}. The conduits shall be circular or rectangular cross-sections.

6.10.3.2 *Bunching of cables*

Conductors of a.c. supply and d.c. supply shall be bunched in separate conduits. For lighting and small power outlet circuits phase segregation in separate circuits is recommended. The number of insulated cables that may be drawn into the conduits are given in Table 1 B. In Table 1B, the space factor does not exceed 40 percent.

6.10.3.3 *Conduit Joints*

Conduits shall be joined by means of couplers. Where there are long runs of straight conduit, inspection type couplers shall be provided at intervals. For conduit fittings and accessories reference may be made to the good practice [8-2(39)].

6.10.3.4 *Fixing of conduit in chase*

The conduit pipe shall be fixed by means of stapples or by means of non-metallic saddles placed at not more than 800 mm apart or by any other approved means of fixing. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves shall be maintained by sending the conduit pipe itself with a long radius which will permit easy drawing in of conductors. At either side of bends, saddles/stapples shall be fixed at a distance of 150 mm from the centre of bends.

6.10.3.5 *Inspection boxes*

Suitable inspection boxes to the nearest minimum requirements shall be provided to permit periodical inspection and to facilitate replacement of wires, if

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Table 1B Maximum Permissible Number of 250 V Grade Single-Core Cables that may be Drawn into Rigid Non-Metallic Conduits

[*Clauses* 6.7.1(a) *and* 6.10.3.2]

Sl No.	Sizes of Cable		Size of Conduit mm					
	Nominal Cross-Sectional Area mm^2	Number and Diameter (in mm) of Wires	16	20	25	32	40	50
			Number of Cables, *Max*					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	1.0	1/1.12[1)]	5	7	13	20	—	—
ii)	1.5	1/1.40	4	6	10	14	—	—
iii)	2.5	(1/1.80) [3/1.06[1)]]	3	5	10	14	—	—
iv)	4	(1/2.24) [7/0.85[1)]]	2	3	6	10	14	—
v)	6	(1/2.80) [7/1.40[1)]]	—	2	5	9	11	—
vi)	10	[1/3.55[2)]] [7/1.40[1)]]	—	—	4	7	9	—
vii)	16	7/1.70	—	—	2	4	5	12
viii)	25	7/2.24	—	—	—	2	2	6
ix)	35	7/2.50	—	—	—	—	2	5
x)	50	7/3.00[2)]	—	—	—	—	2	5
		19/1.80	—	—	—	—	2	3

[1)] For copper conductors only.
[2)] For aluminium conductors only.

necessary. The inspection/junction boxes shall be mounted flush with the wall or ceiling concrete. Where necessary deeper boxes of suitable dimensions shall be used. Suitable ventilating holes shall be provided in the inspection box covers, where required.

6.10.3.6 The outlet boxes such as switch boxes, regulator boxes and their phenolic laminated sheet covers shall be as per requirements of **6.10.1** (h). They shall be mounted flush with the wall.

6.10.3.7 *Types of accessories to be used*

All accessories such as switches, wall sockets, etc, may be either flush mounting type or of surface mounting type.

6.10.3.8 *Bends in conduits*

Wherever necessary, bends or diversions may be achieved by bending the conduits or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings. Heat may be used to soften the conduit for bending and forming joints in case of plain conduits.

6.10.3.9 *Outlets*

In order to minimize condensation or sweating inside the conduit, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects.

6.11 Cable Trunking/Cable Ways

Cable trunking and ducting system of insulating material are used for surface wiring. The number of insulated conductors that can be drawn into cable trunking and ducting system are given in Table 2.

7 FITTINGS AND ACCESSORIES

7.1 Ceiling Roses and Similar Attachments

7.1.1 A ceiling rose or any other similar attachment shall not be used on a circuit the voltage of which normally exceeds 250 V.

7.1.2 Normally, only one flexible cord shall be attached to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.

7.1.3 A ceiling rose shall not embody fuse terminal as an integral part of it.

7.2 Socket-Outlets and Plugs

Each 16 A socket-outlet provided in buildings for the use of domestic appliances, such as, air conditioner and water cooler shall be provided with its own individual fuse, with suitable discrimination with back-up fuse or miniature circuit-breaker provided in the distribution/ sub-distribution board. The socket-outlet shall not necessarily embody the fuse as an integral part of it.

7.2.1 Each socket-outlet shall also be controlled by a switch which shall preferably be located immediately adjacent thereto or combined therewith.

7.2.2 The switch controlling the socket-outlet shall be on the live side of the line.

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Table 2 Maximum Permissible Number of PVC Insulated 650/1 100 V Grade Aluminium/Copper Cable Conforming to Accepted Standard [8-2(3)] that can be Drawn into Cable Trunking/Cable Ways
(*Clause* 6.11)

Sl No.	Nominal Cross-Sectional Area of Conductor mm^2	10/15 mm × 10 mm	20/15 mm × 10 mm	25/15 mm × 16 mm	32 mm × 16 mm	40 mm × 25 mm	40 mm × 40 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	1.5	3	5	6	8	12	18
ii)	2.5	2	4	5	6	9	15
iii)	4	2	3	4	5	8	12
iv)	6	—	2	3	4	6	9
v)	10	—	1	2	3	5	8
vi)	16	—	—	1	2	4	6
vii)	25	—	—	—	1	3	5
viii)	35	—	—	—	—	2	4
ix)	50	—	—	—	—	1	3
x)	70	—	—	—	—	1	2

7.2.3 Ordinary socket-outlet may be fixed at any convenient place at a height above 200 mm from the floor level and shall be away from danger of mechanical injury.

NOTE — In situations where a socket-outlet is accessible to children, it is necessary to install an interlocked plug and socket or alternatively a socket-outlet which automatically gets screened by the withdrawal of plug. In industrial premises socket-outlet of rating 20 A and above shall preferably be provided with interlocked type switch.

In case of public buildings, to facilitate operation of switches/socket-outlets by persons with disabilities and the elderly, these shall be installed at an accessible height for reaching and operating, between 800 mm and 1 100 mm above floor level and shall be located at a minimum of 600 mm with a preference of minimum 700 mm, from any internal corner (*see also* **B-7** of Part 3 'Development Control Rules and General Building Requirements' of the Code). They shall be so fixed so as to be away from danger of mechanical injury.

NOTE — As an exception, electrical wall socket outlets, telephone points and TV sockets can be located at a minimum height of 400 mm above floor level.

7.2.4 In an earthed system of supply, a socket-outlet with plug shall be of three-pin or five-pin type with the third or fifth terminal connected to the earth. When such socket-outlets with plugs are connected to any current consuming device of metal or any non-insulating material or both, conductors connecting such current-consuming devices shall be of flexible cord with an earthing core and the earthing core shall be secured by connecting between the earth terminal of plug and the body of current-consuming devices.

In industrial premises three-phase and neutral socket-outlets shall be provided with a earth terminal either of pin type or scrapping type in addition to the main pins required for the purpose.

7.2.5 In wiring installations for residential buildings, metal clad switch, socket-outlet and plugs shall be used for power wiring. For industrial and commercial application socket outlets conforming to accepted standards [8-2(25)] with suitable circuit breakers shall be used.

NOTE — A recommended schedule of socket-outlets in a residential building is given below:

Sl No.	*Location*	*Number of 6 A Socket-Outlets*	*Number of 16 A Socket-Outlets*
(1)	(2)	(3)	(4)
i)	Bed room	2 to 6	2
ii)	Living room	2 to 4	2
iii)	Kitchen	2 to 8	2
iv)	Dining room	2 to 4	2
v)	Garage	1	1
vi)	For refrigerator	—	1
vii)	For air conditioner	—	1 for each
viii)	*Verandah*	1 per 10 m^2	1
ix)	Bathroom	1	1

7.3 Lighting Fittings

7.3.1 A switch shall be provided for control of every lighting fitting or a group of lighting fittings. Where control at more than one point is necessary as many two way or intermediate switches may be provided as there are control points. *See also* **7.2.3**.

7.3.2 In industrial premises, lighting fittings shall be supported by suitable pipe/conduits, brackets fabricated from structural steel, steel chains or similar materials depending upon the type and weight of the fittings.

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Where a lighting fitting is supported by one or more flexible cords, the maximum weight to which the twin flexible cords may be subjected shall be as follows:

Sl No.	*Nominal Cross-Sectional Area of Twin Cord* mm^2	*Maximum Permissible Weight* kg
(1)	(2)	(3)
i)	0.5	2
ii)	0.75	3
iii)	1.0	5
iv)	1.5	5.3
v)	2.5	8.8
vi)	4	14.0

7.3.3 No flammable shade shall form a part of lighting fittings unless such shade is well protected against all risks of fire. Celluloid shade or lighting fittings shall not be used under any circumstances.

7.3.4 General and safety requirements for electrical lighting fittings shall be in accordance with good practice [8-2(40)].

7.3.5 The lighting fittings shall conform to accepted standards [8-2(26)].

7.4 Fitting-Wire

The use of fitting-wire shall be restricted to the internal wiring of the lighting fittings. Where fitting-wire is used for wiring fittings, the sub-circuit loads shall terminate in a ceiling rose or box with connectors from which they shall be carried into the fittings.

7.5 Lampholders

Lampholders for use on brackets and the like shall be in accordance with accepted standards [8-2(41)] and all those for use with flexible pendants shall be provided with cord grips. All lampholders shall be provided with shade carriers. Where centre-contact Edison screw lampholders are used, the outer or screw contacts shall be connected to the 'middle wire', the neutral, the earthed conductor of the circuit.

7.6 Outdoor Lamps

External and road lamps shall have weatherproof fittings of approved design so as to effectively prevent the ingress of moisture and dust. Flexible cord and cord grip lampholders shall not be used where exposed to weather. In verandahs and similar exposed situations where pendants are used, these shall be of fixed rod type.

7.7 Lamps

All lamps unless otherwise required and suitably protected, shall be hung at a height of not less than 2.5 m above the floor level. All electric lamps and accessories shall conform to accepted standards [8-2(42)]. Following shall also be ensured:

a) Portable lamps shall be wired with flexible cord. Hand lamps shall be equipped with a handle of moulded composition or other material approved for the purpose. Hand lamps shall be equipped with a substantial guard attached to the lampholder or handle. Metallic guards shall be earthed suitably.

b) A bushing or the equivalent shall be provided where flexible cord enters the base or stem of portable lamp. The bushing shall be of insulating material unless a jacketted type of cord is used.

c) All wiring shall be free from short circuits and shall be tested for these defects prior to being connected to the circuit.

d) Exposed live parts within porcelain fixtures shall be suitably recessed and so located as to make it improbable that wires will come in contact with them. There shall be a spacing of at least 125 mm between live parts and the mounting plane of the fixture.

7.8 Fans, Regulators and Clamps

7.8.1 *Ceiling Fans*

Ceiling fans including their suspension shall conform to accepted standards [8-2(43)] and to the following requirements:

a) Control of a ceiling fan shall be through its own regulator as well as a switch in series. *See also* **7.2.3**.

b) All ceiling fans shall be wired with normal wiring to ceiling roses or to special connector boxes to which fan rod wires shall be connected and suspended from hooks or shackles with insulators between hooks and suspension rods. There shall be no joint in the suspension rod, but if joints are unavoidable then such joints shall be screwed to special couplers of 50 mm minimum length and both ends of the pipes shall touch together within the couplers, and shall in addition be secured by means of split pins; alternatively, the two pipes may be welded. The suspension rod shall be of adequate strength to withstand the dead and impact forces imposed on it. Suspension rods should preferably be procured along with the fan.

c) Fan clamps shall be of suitable design according to the nature of construction of ceiling on which these clamps are to be fitted. In all cases fan clamps shall be fabricated from new metal of suitable sizes and they shall be

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as close fitting as possible. Fan clamps for reinforced concrete roofs shall be buried with the casting and due care shall be taken that they shall serve the purpose. Fan clamps for wooden beams, shall be of suitable flat iron fixed on two sides of the beam and according to the size and section of the beam one or two mild steel bolts passing through the beam shall hold both flat irons together. Fan clamps for steel joist shall be fabricated from flat iron to fit rigidly to the bottom flange of the beam. Care shall be taken during fabrication that the metal does not crack while hammer to shape. Other fan clamps shall be made to suit the position, but in all cases care shall be taken to see that they are rigid and safe.

d) Canopies on top and bottom of suspension rods shall effectively conceal suspensions and connections to fan motors, respectively.

e) The lead-in-wire shall be of nominal cross-sectional area not less than 1.5 mm^2 copper and shall be protected from abrasion.

f) Unless otherwise specified, the clearance between the bottom most point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades shall be not less than 300 mm.

A typical arrangement of a fan clamp is given in Fig. 4.

NOTE — All fan clamps shall be so fabricated that fans revolve steadily.

7.8.2 *Exhaust Fans*

For fixing of an exhaust fan, a circular hole shall be provided in the wall to suit the size of the frame which shall be fixed by means of rag-bolts embedded in the wall. The hole shall be nearly plastered with cement and brought to the original finish of the wall. The exhaust fan shall be connected to exhaust fan point which shall be wired as near to the hole as possible by means of a flexible cord, care being taken that the blades rotate in the proper direction.

7.8.3 *Fannage*

7.8.3.1 Where ceiling fans are provided, the bay sizes of a building, which control fan point locations, play an important part. Fans of 1 200/1 400 mm sweep normally cover an area of 9 m^2 to 10 m^2 and therefore in general purpose office buildings, for every part of a bay to be served by the ceiling fans, it is necessary that the bays shall be so designed that full number of fans can be suitably located for the bay, otherwise it will result in ill-ventilated pockets. In general, fans in long halls may be spaced at 3 m in both the directions. If building modules do not lend themselves for proper positioning of the required number of ceiling fans, other fans such as, air circulators or bracket fans will have to be employed for the areas uncovered by the ceiling fans. For this, suitable electrical outlets shall be provided although result will be disproportionate to cost on account of fans.

7.8.3.2 Proper air circulation may be achieved either by larger number of smaller fans or smaller number of larger fans. The economics of the system as a whole should be a guiding factor in choosing the number and type of fans and their locations. For design guidelines in this regard, reference shall be made to Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code.

7.8.3.3 Exhaust fans are necessary for spaces, such as community toilets, kitchens and canteens, and godowns to provide the required number of air changes (*see* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code). Since the exhaust fans are located generally on the outer walls of a room, appropriate openings in such walls shall be provided for, in the planning stage.

NOTE — Exhaust fan requirement is based on the recommended air changes (*see* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code). Reference shall also be made to Part 4 'Fire and Life Safety' of the Code for exhaust fan requirements for smoke extraction.

7.9 Attachment of Fittings and Accessories

7.9.1 In wiring other than conduit wiring, all ceiling roses, brackets, pendants and accessories attached to walls or ceilings shall be mounted on substantial teak wood blocks twice varnished after all fixing holes are made in them. Blocks shall not be less than 40 mm deep. Brass screws shall only be used for attaching fittings and accessories to their base blocks.

7.9.2 Where teak or hardwood boards are used for mounting switches, regulators, etc, these boards shall be well varnished with pure shellac on all four sides (both inside and outside), irrespective of being painted to match the surroundings. The size of such boards shall depend on the number of accessories that can be conveniently and neatly be arranged. Where there is danger of attack by white ants, the boards shall be treated with suitable anti-termite compound and painted on both sides.

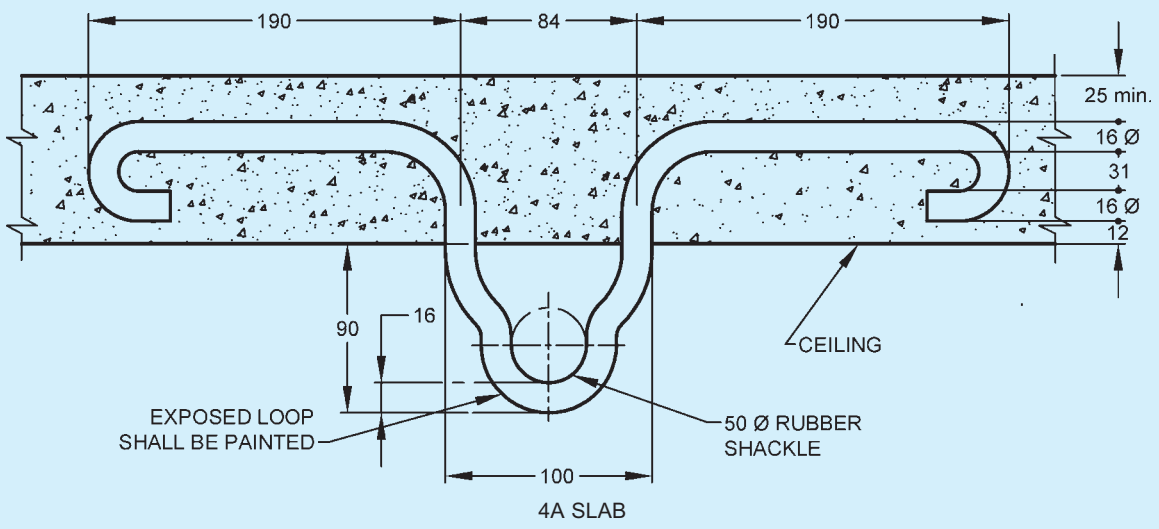
7.10 Interchangeability

Similar parts of all switches, lamp holders, distribution fuse-boards, ceiling roses, brackets, pendants, fans and all other fittings shall be so chosen that they are of the same type and interchangeable in each installation.

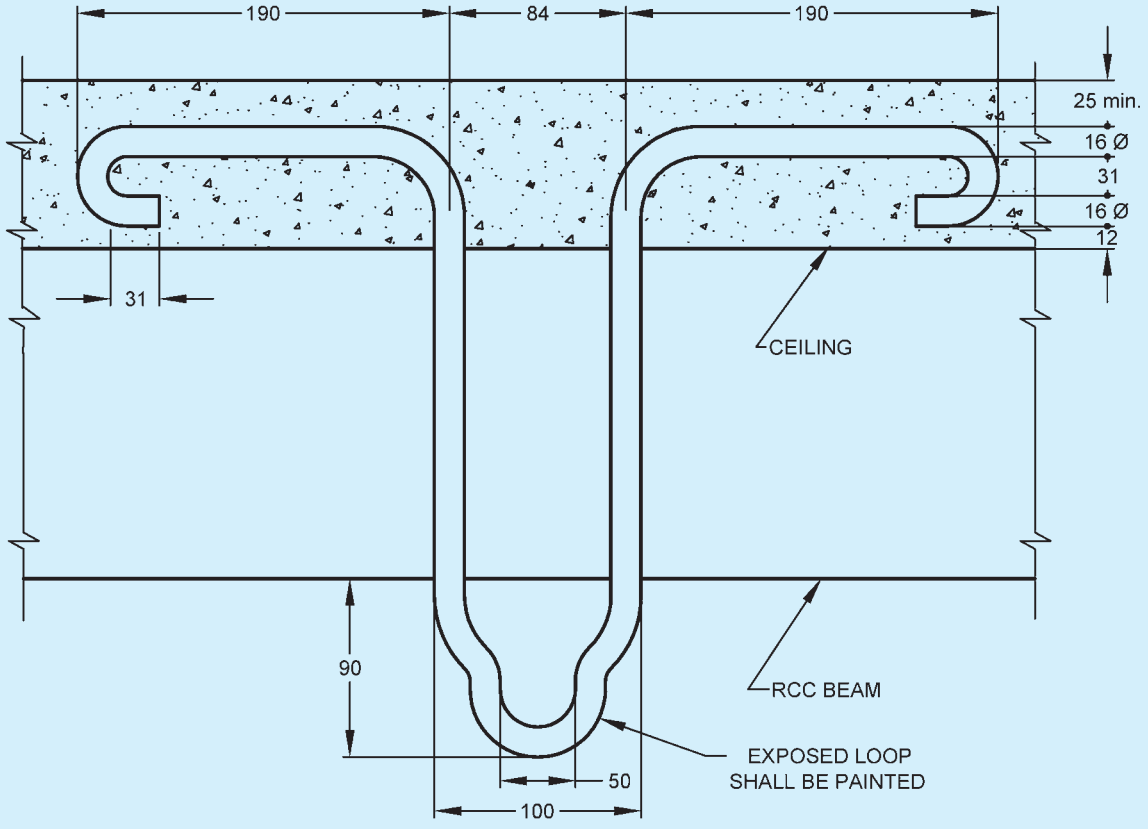
7.11 Equipment

Electrical equipment which form integral part of wiring

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4A SLAB



4B SLAB WITH BEAM

All dimensions in millimetres.

NOTES

1 RCC slab steel reinforcement not shown.

2 Fan clamp shall be placed in position such that its projecting arms are in the line of length of beam.

FIG. 4 TYPICAL DESIGN OF FAN CLAMPS

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intended for switching or control or protection of wiring installations shall conform to the relevant Indian Standards, wherever they exist.

7.12 Positioning of fans and light fittings shall be chosen to make these effective without causing shadows and stroboscopic effect on the working planes.

8 EARTHING

8.1 General

8.1.1 Earthing is an essential part of any electrical installation, essential for the safety from electrical shock, and fire and for operation of most of the protective systems of the electrical installation. The earthing provides the necessary reference of zero potential and helps in activating the operation of the circuit breaker provided for the safe disconnection of power in the event of an abnormality in the flow of current. Earthing systems, apart from addressing safety from shock and fire, help in limiting the interference between one appliance and the other. This is of particular importance in the case of voice and data communication devices. With the proliferation in electrical/electronic gadgets and greater dependence on voice and data communication systems, proper and effective earthing or grounding is very important. Earthing is also necessary for diverting the effects of lightning strikes from the buildings and its contents, including from sensitive equipment.

8.1.2 Different types of earth electrodes and different types of earthing systems available. For low voltage and medium voltage systems which apply to almost all electrical systems of buildings, the common earthing system followed is with the neutral solidly earthed at the source. This system requires that there is always a protective earth continuity conductor running all through the system and all metal parts of electrical appliances connected to an electrical system are connected to the earth continuity conductor. The exception to this system is the double insulated appliances which are connected to the line and neutral and operate on low voltage (single phase) and are also of low power consumption. All appliances (other than double insulated devices) use the earthing through the earth continuity conductor. Single phase appliances use a 3-wire connection with line (live wire), neutral (return path wire) and the earth-wire at zero potential. Three phase appliances use a connection with 4-wires for a load which does not require a neutral connection or use a 5-wire connection if the appliance requires a neutral connection. Care should be taken to ensure that the earthing system, the earth continuity conductor and in case of sockets plugs the earthing pin are not disconnected.

8.1.3 Different earthing systems have features which are suitable for different applications. Earthing system adopted should be so selected so as to match with the type of load, protection device, application, degree of reliability, etc. For classification of electrical systems based on the relationship of the source, and of exposed-conductive parts of the installation, to earth, *see* **2.1.75**.

8.2 Selection and Design of Earthing System

8.2.1 Earthing shall generally be carried out in accordance with the requirements of Regulation 16, 41 and 48 of *Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations*, 2010 as amended from time-to-time (*see* Annex B) and good practice [8-2(44)] and the relevant regulations of the Electricity Supply Authority concerned.

8.2.2 Conductors and earth electrodes in an earthing system shall be so designed and constructed that in normal use their performance is reliable and without danger to persons and surrounding equipment. Earthing system shall be designed such as to have touch potential and step potential as specified in good practice [8-2(44)]. The choice of a material depends on its ability to match the particular application requirement. The requirements for earthing arrangements are intended to provide a connection to earth which,

a) is reliable and suitable for the protective requirements of the installation;
b) can carry earth fault currents and protective conductor currents to earth without danger from thermal, thermo-mechanical and electromechanical stresses and from electric shock arising from these currents;
c) if relevant, is also suitable for functional requirements; and
d) is suitable for the foreseeable external influences {*see* good practice [8-2(44)] and IEC 60364-5-51:2005 'Electrical installations of buildings — Part 5-51: Selection and erection of electrical equipment — Common rules'}, for example, mechanical stresses and corrosion.

8.2.3 The main earthing system of an electrical installation shall consist of,

a) an earth electrode, (electrode can be one vertical rod/pipe/buried plate or an earth mat with several vertical installations or a ring earthing with vertical installations.
b) a main earthing wire;
c) an earth bar (located on the main switchboard for small installation and installed in the wall/ room in case of large industrial electronic installations) for the connection of the main earthing wire, protective earthing wires and/ or bonding wires within the installation; and

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d) a removable link, which effectively disconnects the neutral bar from the earth bar.

NOTE — The requirements of (c) and (d) shall be carried out by a licensed electrician as part of the switchboard installation.

8.2.4 The main earthing wire connection shall,

a) be mechanically and electrically sound;
b) be protected against damage, corrosion, and vibration;
c) not place any strain on various parts of the connection;
d) not damage the wire or fittings; and
e) be secured at the earth electrode.

8.2.4.1 The main earthing wire termination shall be readily accessible at the earth electrode except for **8.2.20**. As far as possible, all earth connections, except exothermically welded, shall be visible for inspection.

8.2.5 Consideration shall be given to the earthing arrangements where currents with high frequencies are expected to flow (*see* **444** of IEC 60364-4-44:2007 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances').

8.2.6 Protection against electric shock (*see* IEC 60364-4-41 'Low-voltage electrical installations — Part 4-41: Protection for safety — Protection against electric shock'), shall not be adversely affected by any foreseeable change of the earth electrode resistance (for example, due to corrosion, drying or freezing).

8.2.7 Where the supply to an installation is at high or extra high voltage, requirements concerning the earthing arrangements of the high or extra high voltage supply and of the low-voltage installation shall also comply with **442** of IEC 60364-4-44:2007 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances'.

8.2.8 A permanent fitting (like a screwed-down plastic label or copper label, or one that can be threaded onto the cable) shall be used at the connection point that is clearly marked with the words: 'EARTHING LEAD — DO NOT DISCONNECT' or 'EARTHING CONDUCTOR — DO NOT DISCONNECT'.

8.2.9 All medium voltage equipment shall be earthed by two separate and distinct connections with earth. The contact area of earth conductor/plate shall be determined in accordance with good practice [8-2(44)].

8.2.9.1 The 415/240 V, 4-wire, 3-phase systems are normally operated with the neutral solidly earthed at source. At medium voltage, Central Electricity Authority regulations require that the neutral be earthed by two separate and distinct connections with earth. Source in the case of a substation (such as 11 kV/415 V) will be the neutral(s) of the transformer(s). Neutral conductor shall be of the same size as the phase conductor.

NOTE — Neutral conductor of half the size of the phase conductor was permitted in earlier installations. But with the proliferation of equipment using non-linear devices and consequent increase in harmonics, the neutral will carry a current more than the notional out-of-balance current and therefore neutral conductor shall be of the same size as the phase conductor.

8.2.10 In the case of high and extra high voltages, the neutral points shall be earthed by not less than two separate and distinct connections to earth, each having its own electrode at the generating station or substation and may be earthed at any other point provided no interference is caused by such earthing. The neutral may be earthed through suitable impedance. Neutral earthing conductor shall be sized as to have a current carrying capacity not less than the phase current.

8.2.11 For industrial/commercial installations having a transformer within the facility, soil resistivity of the place of installation shall be measured as per good practice [8-2(44)] and recorded. For the adopted type of earth electrode configuration, earth resistance of each electrode configuration shall be calculated and recorded based on good practice [8-2(44)].

8.2.12 It is recommended that a drawing showing the main earth connection and earth electrodes be prepared for each installation.

8.2.13 Conductors, other than live conductors, and any other parts intended to carry a fault current shall be capable of carrying that current without attaining an excessive temperature.

8.2.14 Earth system shall be so devised that the testing of individual earth electrode is possible {except for installations according to **5.3.6** of good practice [8-2(45)]}. It is recommended that the value of any earth system resistance shall be such as to conform to the degree of shock protection desired. For measuring purposes, the joint shall be capable of being opened with the aid of a tool. In normal use it shall remain closed.

8.2.15 No addition to the current-carrying system, either temporary or permanent, shall be made which will increase the maximum available earth fault current or its duration until it has been ascertained that the existing arrangement of earth electrodes, earth bus-bar, etc, are capable of carrying the new value of earth fault current which may be obtained by this addition.

8.2.16 No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the

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earthed or earthed neutral conductor and the live conductors, shall be inserted on any supply system. This, however, does not include the case of a switch for use in controlling a generator or a transformer or a link for test purposes.

8.2.17 All materials, fittings, etc, used in earthing shall conform to relevant Indian Standard specification, wherever these exist.

8.2.18 Earthing associated with current-carrying conductor is normally essential for the function of the system and is generally known as system earthing or functional earthing, while earthing of non-current carrying metal work and conductor is essential for the safety of human life, of animals and of property and it is generally known as equipment earthing or protective earthing. The earthing arrangements may be used jointly or separately for protective and functional purposes according to the requirements of the electrical installation. The requirements for protective purposes shall always take precedence.

8.2.19 For selection of electrodes for use in corrosive environments, reference shall be made to good practice [8-2(44)].

8.2.20 Test joints are not required in the case of natural down-conductors combined with foundation earth electrodes (*see* Fig. 5).

8.2.21 For computer and other sensitive electronic equipment system in industrial and commercial application, special bonding techniques with isolation transformer should be employed (*see* Fig. 6).

8.2.22 Isolated earthing is unsafe during a transient condition. In unavoidable conditions if isolated earthing is used, to reduce potential difference between isolated earthing, earth couplers or isolating spark gaps shall be installed. This will reduce potential difference during a transient condition such as lightning.

8.3 Earth Electrodes

The efficacy of any earth electrode depends on its configuration and upon local soil conditions. Number of earth electrodes suitable for the soil conditions and the value of resistance to earth required shall be considered. Examples of earth electrodes which may be used are,

a) concrete-embedded foundation earth electrode;
b) soil-embedded foundation earth electrode;
c) metallic electrode embedded directly in soil vertically or horizontally (for example rods, wires, tapes, pipes or plates);
d) metal sheath and other metal coverings of cables according to local conditions or requirements;
e) other suitable underground metalwork (for example, pipes) according to local conditions or requirements; and
f) welded metal reinforcement of concrete (except pre-stressed concrete) embedded in the earth.

The type, materials and dimensions of earth electrodes shall be selected to withstand corrosion and to have adequate mechanical strength for the intended lifetime. For materials commonly used for earth electrodes, the minimum sizes, from the point of view of corrosion and mechanical strength, when embedded in the soil or in concrete, may be as specified in Table 3. If a lightning protection system is required, **11.5.3** applies {*see* **5.4** of good practice [8-2(45)]}.

NOTES

1 For corrosion, the parameters to be considered are: the soil *p*H at the site, soil resistivity, soil moisture, stray and leakage a.c. and d.c. current, chemical contamination, and proximity of dissimilar materials.

2 The minimum thickness of protective coating is greater for vertical earth electrodes than for horizontal earth electrodes because of their greater exposure to mechanical stresses while being embedded.

Earth electrode either in the form of solid rod, pipe, plate or earth grid should be provided at all premises for providing an earth system. Details of typical pipe, rod and plate earth electrodes are given in Fig. 7 and Fig. 8. Other electrode configurations can be as in Fig. 9 {*see also* **9.2** of good practice [8-2(44)]}.

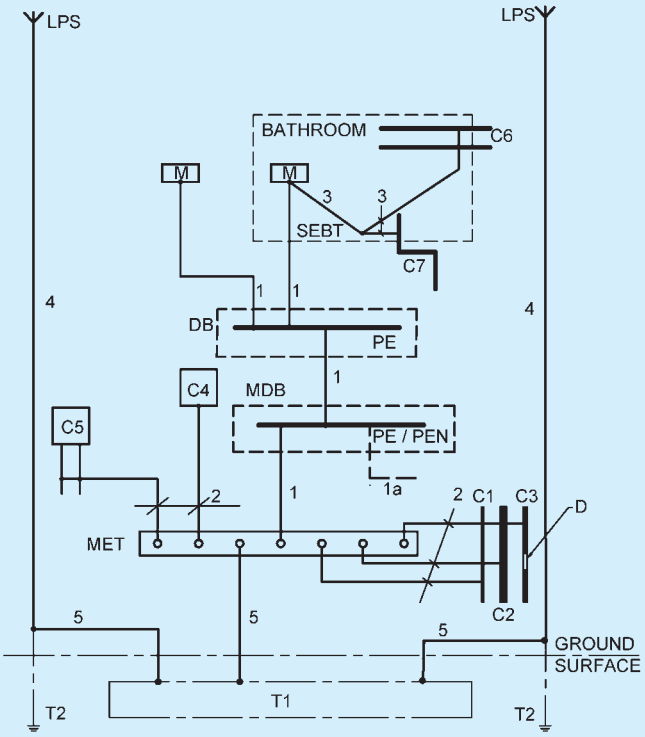
Although electrode material does not affect initial earth resistance, care should be taken to select a material which is resistant to corrosion in the type of soil in which it is used. In case where soil condition leads to excessive corrosion of the electrode, and the connections, it is recommended to use either copper/stainless steel or copper coated steel electrode and copper/stainless steel connections. Exothermic welding may also be adopted to have enhanced life and strength to the connection (*see* Fig. 7B and Fig. 8B). It is recommended to use similar material for earth electrodes and earth conductors or otherwise precautions should be taken to avoid corrosion.

8.4 Earth Enhancing Compound

Multiple rods, even in large numbers, may sometime fail to produce an adequately low resistance to earth. This condition arises in installations involving soils of high resistivity. The alternative is to reduce the resistivity of the soil immediately surrounding the earth electrode. To reduce the soil resistivity, artificial soil treatment shall be adopted.

8.4.1 Earthing enhancing compound is a conductive

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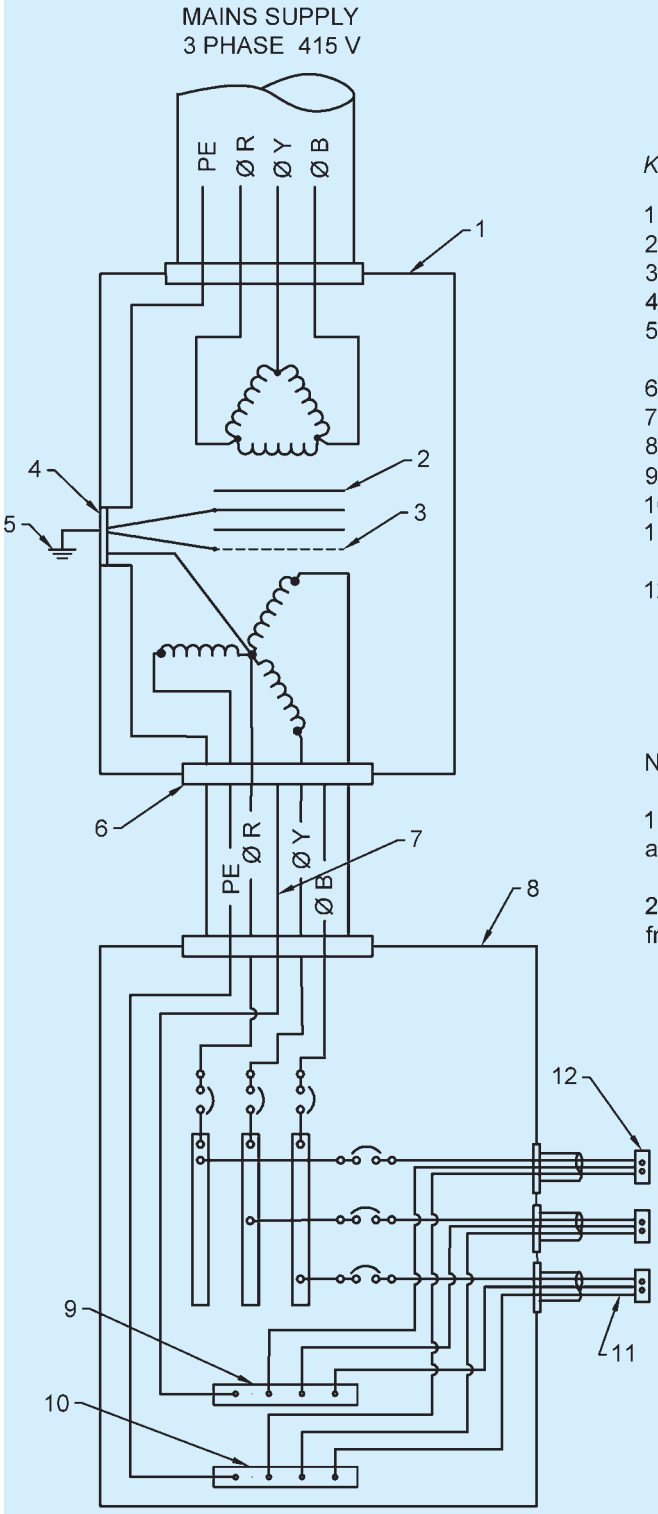
NOTES

1 Functional earthing conductors are not shown in figure.
2 Where a lightning protection system is installed, the additional requirements are given in **11.**

Key	
C	Extraneous-conductive-part
C1	Water pipe, metal from outside
C2	Waste water pipe, metal from outside
C3	Gas pipe with insulating insert, metal from outside
C4	Air conditioning
C5	Heating system
C6	Water pipe, metal for example in a bathroom
C7	Waste water pipe, metal for example in a bathroom
D	Insulating insert
MDB	Main distribution board
DB	Distribution board
MET	Main earthing terminal
SEBT	Supplementary equipotential bonding terminal
T1	Concrete-embedded foundation earth electrode or soil-embedded foundation earth electrode
T2	Earth electrode for LPS, if necessary
LPS	Lightning protection system (if any)
PE	PE terminal(s) in the distribution board
PE/PEN	PE/PEN terminal(s) in the main distribution board
M	Exposed-conductive-part
1	Protective earthing conductor (PE)
1A	Protective conductor, or PEN conductor, if any, from supplying network
2	Protective bonding conductor for connection to the main earthing terminal
3	Protective bonding conductor for supplementary bonding
4	Down conductor of a lightning protection system (LPS), if any
5	Earthing conductor

FIG. 5 EXAMPLE OF AN EARTHING ARRANGEMENT FOR FOUNDATION EARTH ELECTRODE, PROTECTIVE CONDUCTORS AND PROTECTIVE BONDING CONDUCTORS

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Key

1 Isolation transformer
2 Core
3 Shield
4 All earthing connections made at a point
5 Connection to building steel/earth pits/ring earthing
6 Conduit earthing
7 Neutral
8 240/415 Volt power panel
9 Neutral bus[1)]
10 Earth bus[1)]
11 Earth connection for socket/work station/computers
12 3-pin sockets with isolated earth pin

[1)] Both busbars isolated from panel enclosure. No bonding connection between neutral and earth.

NOTES

1 Each branch circuit shall have a separate neutral and earth wire. No daisy chaining permitted.

2 Only computer or control system should be served from this panel.

FIG. 6 RECOMMENDED POWER DISTRIBUTION FOR A COMPUTER AND CONTROL SYSTEM WITH A DELTA/STAR ISOLATION TRANSFORMER

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Table 3 Recommended Minimum Size of Commonly Used Earth Electrodes, Embedded in Soil or Concrete Used to Prevent Corrosion and Provide Mechanical Strength[1)]

(*Clause* 8.3)

Sl No.	Material and Surface	Shape	Diameter	Cross-Sectional Area	Thickness	Weight of Coating	Thickness of Coating/ Sheathing
			mm	mm^2	mm	g/m^2	µm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Steel embedded in concrete (bare, hot galvanized or stainless)	Round wire	10	—	—	—	—
		Solid tape or strip	—	75	3	—	—
ii)	Steel hot-dip galvanized[2)]	Strip[3)] or shaped strip/plate — solid plate — lattice plate	—	90	3	500	63
		Round rod installed vertically	16	—	—	350	45
		Round wire installed horizontally	10	—	—	350	45
		Pipe	25	—	2	350	45
		Stranded (embedded in concrete)	—	70	—	—	—
		Cross profile installed vertically	—	(290)	3	—	—
iii)	Steel copper sheathed	Round rod installed vertically	(15)	—	—	—	2 000
iv)	Steel with electro-deposited copper coating	Round rod installed vertically	14	—	—	—	250[6)]
		Round wire installed horizontally	(8)	—	—	—	70
		Strip installed horizontally	—	90	3	—	70
v)	Stainless steel [4)]	Strip[3)] or shaped strip/plate	—	90	3	—	—
		Round rod installed vertically	16	—	—	—	—
		Round wire installed horizontally	10	—	—	—	—
		Pipe	25	—	2	—	—
vi)	Copper	Strip		50	2	—	—
		Round wire installed horizontally	—	(25)[5)] 50	—	—	—
		Round rod installed vertically	(12) 15	—	—	—	—
		Stranded wire	1.7 for individual strands of wire	(25)[5)] 50	—	—	—
		Pipe[6)]	20	—	2	—	—
		Solid plate	—	—	(1.5) 2	—	—
		Lattice plate	—	—	2	—	—

[1)] See IEC 60364-5-54:2011 'Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors'.

[2)] The coating shall be smooth, continuous and free from flux stains.

[3)] As rolled strip or slit strip with round edges.

[4)] Chromium ≥ 16 percent, Nickel ≥ 5 percent, Molybdenum ≥ 2 percent, carbon ≤ 0.08 percent.

[5)] Where experience shows that the risk of corrosion and mechanical damage is extremely low, 16 mm^2 can be used.

[6)] This thickness is provided to withstand mechanical damage of copper coating during the installation process. It may be reduced to not less than 100 µm where special precautions to avoid mechanical damage of copper during the installation process (for example, drilling holes or special protective tips) are taken according to the manufacturer's instruction.

NOTES

1 Values in bracket are applicable for protection against electric shock only, while values not in brackets are applicable for lightning protection and for protection against electric shock.

2 Metals inserted inside pipe will not influence in the final earth resistance value.

3 Unprotected ferrous materials are not recommended due to high corrosion (*see* IEC 60364-4-43:2008 'Low-voltage electrical installations — Part 4-43: Protection for safety – Protection against overcurrent').

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compound producing low resistance of an earth-termination system. These compounds used for artificial treatment of soil {*see* good practice [8-2 (44)]} shall satisfy the requirements as per IEC 62561-7:2011 'Lightning protection system components (LPSC) — Part 7: Requirements for earthing enhancing compounds'.

8.4.2 The material of the earthing enhancing compound shall be chemically inert to subsoil. It shall not pollute the environment. It shall provide a stable environment in terms of physical and chemical properties and exhibit low resistivity. The earthing enhancing compound shall not be corrosive to the earth electrodes being used.

8.4.3 The materials used for artificial treatment should also fulfil toxicity characteristic leaching procedure (TCLP) requirements.

8.4.4 Use of salt [sodium chloride (NaCl)] for artificial treatment of soil should be avoided as it accelerates corrosion of ferrous materials.

8.5 Earth Electrode Inspection Housings and Earth Electrode Seals

8.5.1 *Earth Electrode Inspection Housing*

Earth electrode inspection housing is the metallic or non-metallic enclosure that houses the down-conductor/ earth-termination connection for inspection and testing purposes and consists of a housing and a removable lid. The design of the earth electrode inspection housing shall be such that it carries out its function of enclosing the down-conductor/earth rod termination in an acceptable and safe manner, and has sufficient internal dimensions to permit the assembly/disassembly of the earth rod clamp. The housing body shall be deep enough to permit the lid to sit flush on the body without fouling on the rod/conductor/clamp assembly. The material of the earth electrode inspection housing shall be compatible with its surrounding environment and shall comply with the tests given in IEC 62561-5: 2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

8.5.2 *Earth Electrode Seal*

Water pressure seal used in conjunction with an earth rod electrode that passes through the foundation of the building. The design of the earth electrode seal shall be such that it carries out its function of preventing ground water bypassing the earth rod and entering the basement of a building, in an acceptable and safe manner. The material of the earth electrode seal shall be compatible with its surrounding environment and comply with the tests given in IEC 62561-5: 2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

8.6 Bonding and Inter connection

All connections made in an earthing system above or below ground should meet electrical conductivity, corrosion resistance, current carrying capacity, and mechanical strength of the conductor. These connections should be strong enough to maintain a temperature rise below that of the conductor and to withstand the effect of heating and the mechanical forces caused by fault currents. Consideration shall be given to electrolytic corrosion when using different materials in an earthing arrangement. The complete connections shall be able to resist corrosion for the intended life of the installation

8.6.1 For external conductors (for example earthing conductor) connected to a concrete-embedded foundation earth electrode, the connection made from hot-dip galvanized steel shall not be embedded in the soil

8.6.2 Where an earth electrode consists of parts that must be connected together, the connection shall be by exothermic welding, pressure connectors, clamps or other suitable mechanical connectors.

8.6.3 All connection components shall meet the requirements according to IEC 62561-1:2012 'Lightning protection system components (LPSC) — Part 1: Requirements for connection components'.

8.7 Equipment and Portions of Installations which shall be Earthed

8.7.1 *Equipment to be Earthed*

Except for equipment provided with double insulation, all the non-current carrying metal parts of electrical installations are to be earthed properly. All metal conduits, trunking, cable sheaths, switchgear, distribution fuse boards, lighting fittings and all other parts made of metal shall be bonded together and connected by means of two separate and distinct conductors to an efficient earth electrode.

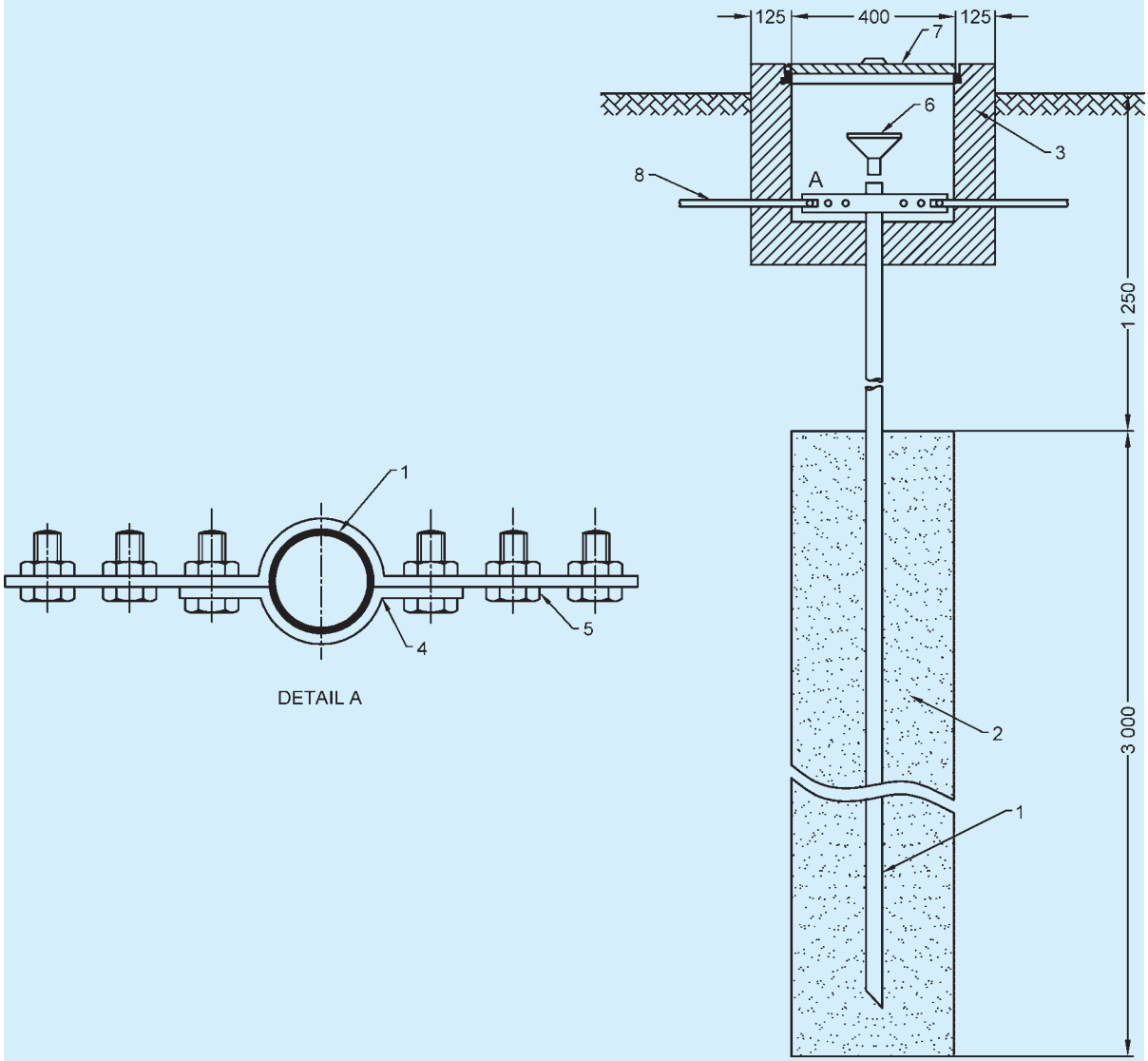
8.7.2 *Structural Metal Work*

Earthing of metallic parts of the structure shall be done according to good practices [8-2(44)] and [8-2(45)].

8.8 Neutral Earthing

To comply with relevant Central Electricity Authority regulations, no fuses or circuit breakers other than a linked circuit breaker shall inserted in an earthed neutral conductor, a linked switch or linked circuit breaker shall be arranged to break or the neutral either with or after breaking all the related phase conductors and. Shall positively make (or close) the neutral before making (or closing) the phases.

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Key

1 a) CI pipe 100 mm ID (*Min*), 13 mm thick (*Min*)
b) GI pipe (class B)/MS Rod, 40 mm ID (*Min)*
2 Earth enhancement material [confirming to IEC 62561-7:2011 'Lightning protection system components (LPSC) — Part 7: Requirements for earthing enhancing compounds'],
or sand, salt and charcoal
3 Inspection chamber
4 Universal stainless steel clamp,
or 50 × 3 mm GI strip
5 M10 bolts and nuts
6 Funnel (for maintenance/watering)
7 CI lid/cover
8 50 × 6 mm GI strip

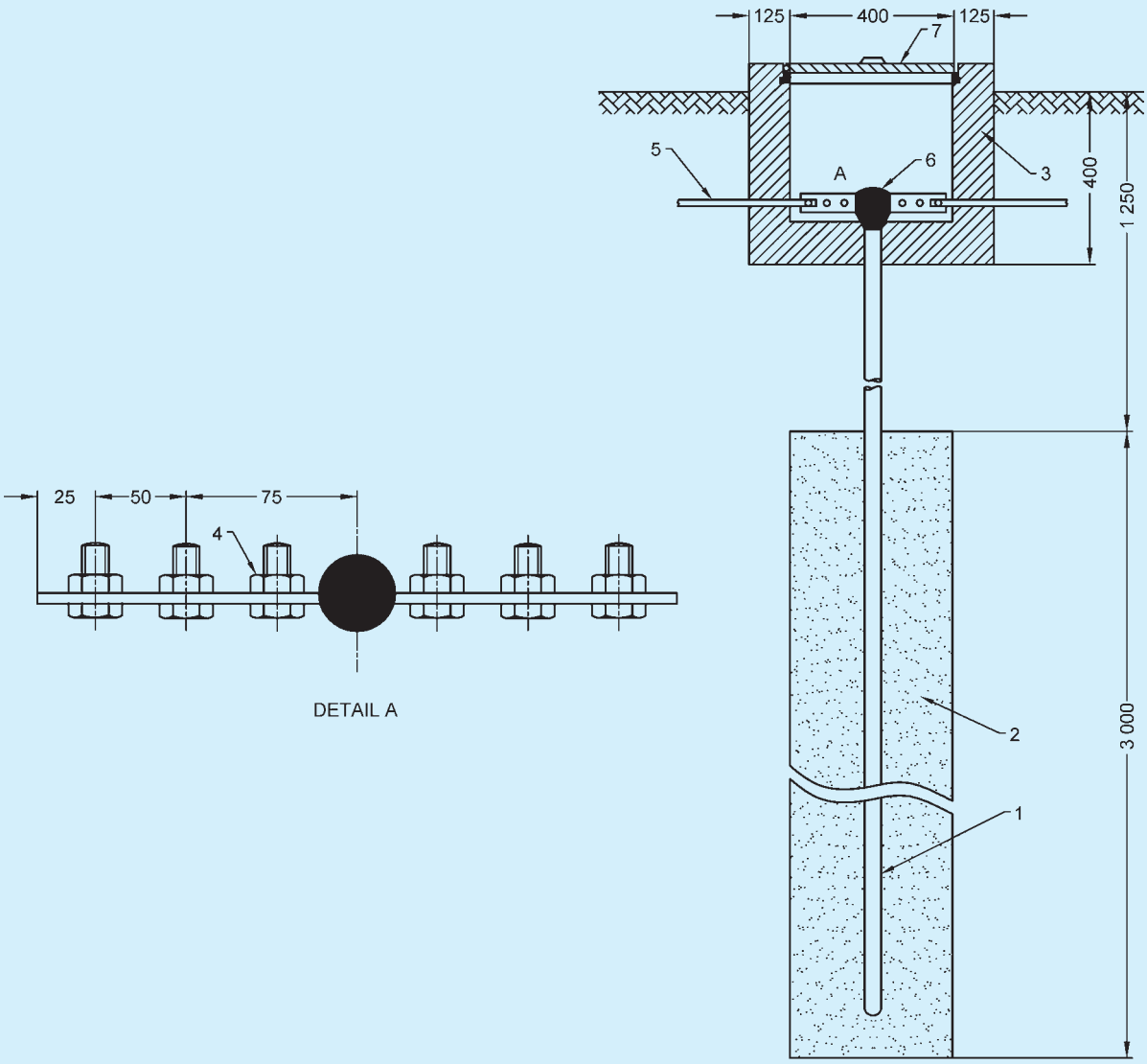
All dimensions in millimetres.

NOTE — Inspection housing can also be of FRP materials with CI cover tested according to IEC 62561-5:2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

7A TYPICAL ARRANGEMENT OF EARTHING WITH PIPE ELECTRODE
(WITH MAINTENANCE ARRANGEMENT)

FIG. 7 — (*Continued*)

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Key

1 Copper/copper bonded steel rod (*see* Table 3 for sizes)
2 Earth enhancement material [conforming to IEC 62561-7:2011 'Lightning protection system components (LPSC) — Part 7: Requirements for earthing enhancing compounds']
3 Inspection chamber
4 M10 bolts and nuts
5 Copper strip — 25 x 6 mm or higher
6 Exothermic welding
7 CI lid/cover

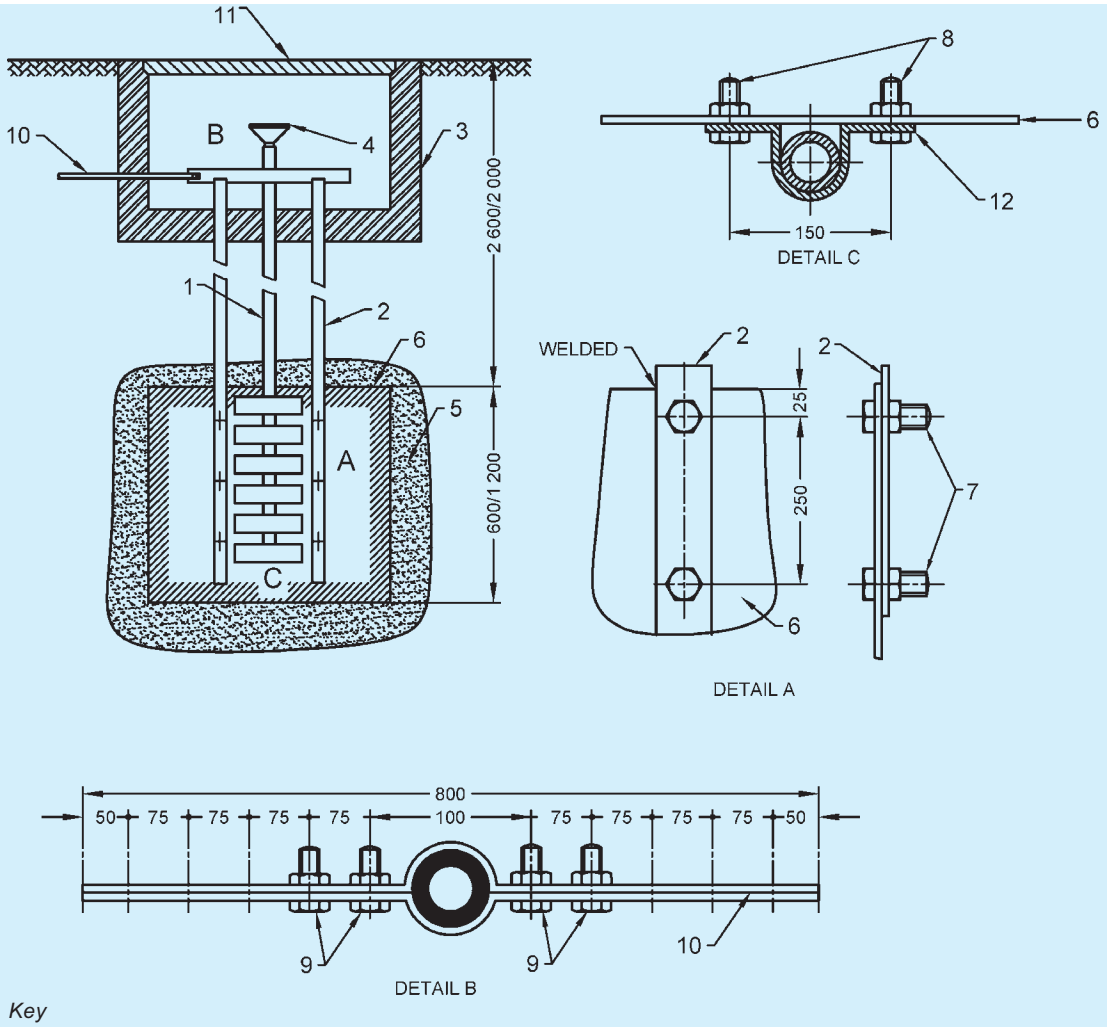
All dimensions in millimetres.

NOTE — Inspection housing can also be of FRP materials with CI cover tested according to IEC 62561-5:2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

7B TYPICAL ARRANGEMENT OF EARTHING WITH COPPER/COPPER BONDED ELECTRODE WITH EXOTHERMIC WELDING (MAINTENANCE FREE ARRANGEMENT)

FIG. 7 TYPICAL ARRANGEMENT OF ELECTRODE EARTHING

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Key

1 50 mm dia GI pipe for watering (maintenance)
2 a) 35 × 6 mm copper strip
b) 50 x 12 mm GI Strip
3 Inspection chamber
4 Funnel (for watering/maintenance)
5 Earth enhancement material [conforming to IEC 62561-7:2011 'Lightning protection system components (LPSC) — Part 7: Requirements for earthing enhancing compounds'], or sand, salt and charcoal
6 a) 600 × 600 × 3 mm copper plate
b) 600 × 600 × 6 mm GI plate
c) 1 200 × 1 200 × 12 mm CI plate
7 a) M12 × 40 brass bolts and nuts
b) M12 × 60 GI bolts and nuts
8 a) M10 × 30 brass bolts and nuts
b) M12 × 50 GI bolts and nuts
9 a) M12 × 40 brass bolts and nuts
b) M12 × 60 GI bolts and nuts
10 a) 35 × 6 copper strip
b) 50 × 12 mm GI strip
11 CI lid/cover
12 a) 25 × 4 mm copper strip for clamp
b) 50 × 12 mm GI copper strip for clamp

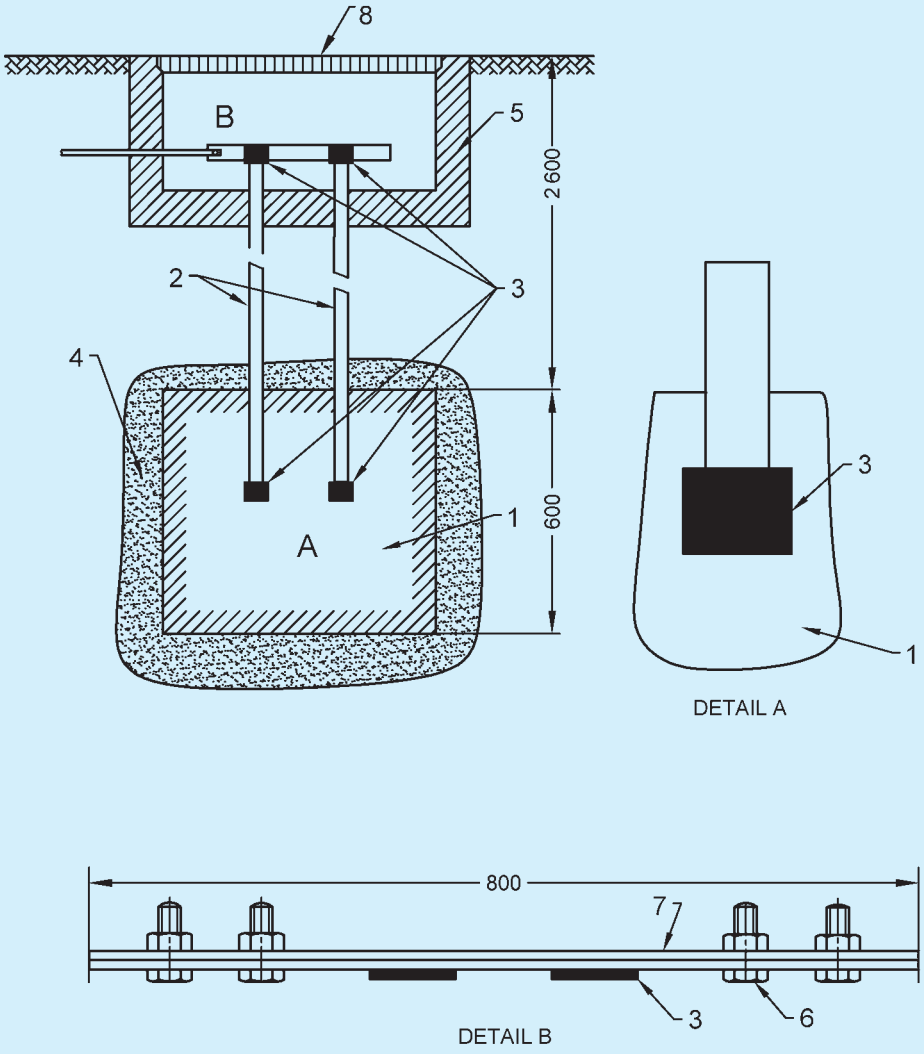
All dimensions in millimetres.

NOTE — Inspection housing can also be of FRP materials with CI cover, tested according to IEC 62561-5: 2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

8A TYPICAL ARRANGEMENT OF CI/GI/COPPER PLATE EARTHING (WITH MAINTENANCE ARRANGEMENT)

FIG. 8 — (*Continued*)

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Key

1 600 × 600 × 3 mm copper plate
2 30 × 6 mm copper strip
3 Exothermic welding
4 Earth enhancement material [conforming to IEC 62561-7:2011 'Lightning protection system components (LPSC) — Part 7: Requirements for earthing enhancing compounds']
5 Inspection chamber
6 M12 × 40 stainless steel bolts and nuts
7 50 × 6 mm copper strip
8 CI lid/cover

All dimensions in millimetres.

NOTE — Inspection housing can also be of FRP materials with CI cover tested according to IEC 62561-5:2011 'Lightning protection system components (LPSC) — Part 5: Requirements for earth electrode inspection housings and earth electrode seals'.

8B TYPICAL ARRANGEMENT OF COPPER PLATE EARTHING WITH EXOTHERMIC WELDING (MAINTENANCE FREE ARRANGEMENT)

FIG. 8 TYPICAL ARRANGEMENT OF PLATE EARTHING

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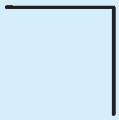
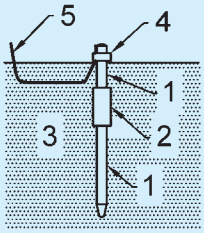
1		Three rods at the vertices of an equilateral triangle
2		Two strips set at right angles to each other, meeting at one corner
3		Vertical electrodes interconnected as a square
4		Three strips set at 120°, meeting at the star point, all of equal length
5		Four strips set in a cruciform
6		Vertical rod 1 Extensible earth rod 2 Rod coupling 3 Soil 4 Conductor to rod clamp 5 Earthing conductor

FIG. 9 MISCELLANEOUS ELECTRODE CONFIGURATIONS

If this neutral point of the supply system is connected permanently to earth, then the above rule applies throughout the installation including 2-wire final circuits. This means that no fuses may be inserted in the neutral or common return wire. And the neutral should consist of a bolted solid link, or part of a linked switch, which completely disconnects the whole system from the supply. This linked switch shall be so arranged that the neutral makes before, and break after the phases.

8.9 System of Earthing

Equipment and portions of installations shall be deemed to be earthed only if earthed in accordance with either the direct earthing system, the multiple earthed neutral system or the earth leakage circuit-breaker system. In all cases, the relevant provisions of Central Electricity Authority regulation shall be complied with.

8.10 The earthing of electrical installations for non-industrial and industrial buildings shall be done in accordance with good practice [8-2(44)].

9 INSPECTION, TESTING AND VERIFICATION OF INSTALLATION

9.1 General Requirements

9.1.1 Before the completed installation, or an addition to the existing installation, is put into service, inspection and testing shall be carried out in accordance with the *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations,* 2010, as amended from time-to-time. In this connection, Regulation 4, 5, 5A, 8, 30, 31, 32, 40 and 46 of the

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regulation shall be complied with (*see* Annex B). In the event of defects being found, these shall be rectified, as soon as practicable and the installation retested.

9.1.2 Periodic inspection and testing shall be carried out in order to maintain the installation in a sound condition after putting into service.

9.1.3 Where an addition is to be made to the fixed wiring of an existing installation, the latter shall be examined for compliance with the recommendations of the Code.

9.1.4 The individual equipment and materials which form part of the installation shall generally conform to the relevant Indian Standard specification, wherever applicable. If there is no relevant Indian Standard specification for any item, these shall be approved by the appropriate authority.

9.1.5 *Completion Drawings*

On completion of the electric work, a wiring diagram shall be prepared and submitted to the Engineer-in-Charge or the owner. All wiring diagrams shall indicate clearly, the main switch board, the runs of various mains and submains and the position of all points and their controls. All circuits shall be clearly indicated and numbered in the wiring diagram and all points shall be given the same number as the circuit in which they are electrically connected. Also the location and number of earth points and the run of each loads should be clearly shown in the completion drawings.

9.2 Inspection of the Installation

9.2.1 *General*

On completion of wiring a general inspection shall be carried out by competent personnel in order to verify that the provisions of this Code and that of *Central Electricity Authority (Measures Relating to Safety and Electric Supply) Regulations*, 2010, have been complied with. This, among other things, shall include checking whether all equipment, fittings, accessories, wires/cables, used in the installation are of adequate rating and quality to meet the requirement of the load. General workmanship of the electrical wiring with regard to the layout and finish shall be examined for neatness that would facilitate easy identification of circuits of the system, adequacy of clearances, soundness, contact pressure and contact area. A complete check shall also be made of all the protective devices, with respect to their ratings, range of settings and coordination between the various protective devices.

9.2.2 *Item to be Inspected*

All equipment in a substation including HV panel, transformer, LV panel, emergency DG sets, battery bank, cables, cable terminations, etc, need inspection. Healthiness of the main distribution boards, metering panels, distribution cables, rising mains, bus ducts, etc, need to be verified along with earthing system.

9.2.2.1 *Substation installations*

In substation installation, it shall be checked whether,

1) the installation has been carried out in accordance with the approved drawings;
2) phase to phase and phase to earth clearances are provided as required;
3) all equipment are efficiently earthed and properly connected to the required number of earth electrodes;
4) HV and MV/LV switchgears are all vermin and damp-proof and all unused openings or holes are blocked properly;
5) the required ground clearance to live-terminals is provided;
6) suitable fencing is provided with gate with lockable arrangements;
7) there is no vegetation in outdoor substation;
8) the required number of caution boards, fire-fighting equipment, operating rods, rubber mats, etc, are kept in the substation;
9) in case of indoor substation sufficient ventilation and draining arrangements are made;
10) all cable trenches are provided with non-inflammable covers;
11) free accessibility is provided for all equipment for normal operation;
12) all name plates are fixed and the equipment are fully painted;
13) all construction materials and temporary connections are removed;
14) oil-level, bus bar tightness, transformer tap position, etc, are in order;
15) earth pipe troughs and cover slabs are provided for earth electrodes/earth pits and the neutral and lightning arrestor earth pits are marked for easy identification;
16) earth electrodes are of GI pipes or CI pipes or copper plates or Cu bonded rods as per Table 3. For earth connections, brass bolts and nuts with lead washers are provided in the pipes/plates;
17) earth pipe troughs and oil sumps/pits are free from rubbish and dirt and stone jelly and the earth connections are visible and easily accessible;
18) earthing system designed are periodically checked for permissible limits of step and touch potential.

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19) the earth bus bars have tight connections and corrosion-free joint surfaces;
20) operating handle of protective device are provided at an accessible height from ground, that is, 300 mm to 1 800 mm;
21) adequate headroom is available in the transformer room for easy topping-up of oil, maintenance, etc;
22) safety devices, horizontal and vertical barriers, bus bar covers/shrouds, automatic safety shutters/doors interlock, handle interlock are safe and in reliable operation in all panels and cubicles;
23) clearances in the front, rear and sides of the main HV and MV and sub-switch boards are adequate;
24) the switches operate freely; the 3 blades make contact at the same time, the arcing horns contact in advance; and the handles are provided with locking arrangements;
25) insulators are free from cracks, and are clean;
26) in transformers, there is any oil leak;
27) connections to bushing in transformers for tightness and good contact;
28) bushings are free from cracks and are clean;
29) accessories of transformers like breathers, vent pipe, buchholz relay, etc, are in order;
30) connections to gas relay in transformers are in order;
31) oil and winding temperature are set for specific requirements in transformers;
32) in case of cable cellars, adequate arrangements to pump out water that has entered due to seepage or other reasons;
33) all incoming and outgoing circuits of HV and MV panels are clearly and indelibly labelled for identifications;
34) no cable is damaged;
35) there is adequate clearance around the equipment installed; and
36) cable terminations are proper.

9.2.2.2 *Medium/low voltage installation*

In medium and low voltage installations, it shall be checked whether,

a) all blocking materials that are used for safe transportation in switchgears, contactors, relays, etc, are removed;
b) all connections to the earthing system are feasible for periodical inspection;
c) sharp cable bends are avoided and cables are taken in a smooth manner in the trenches or alongside the walls and ceilings using suitable support clamps at regular intervals;
d) suitable circuit breaker or lockable push button is provided near the motors/apparatus for controlling supply to the motor/apparatus in an easily accessible location;
e) two separate and distinct earth connections are provided for the motor/apparatus;
f) control switch-fuse is provided at an accessible height from ground for controlling supply to overhead travelling crane, hoists, overhead bus bar trunking;
g) the metal rails on which the crane travels are electrically continuous and earthed and bonding of rails and earthing at both ends are done;
h) four core cables are used for overhead travelling crane and portable equipment, the fourth core being used for earthing, and separate supply for lighting circuit is taken;
j) if flexible metallic hose is used for wiring to motors and other equipment, the wiring is enclosed to the full lengths, and the hose secured properly by approved means;
k) the cables are not taken through areas where they are likely to be damaged or chemically affected;
m) the screens and armours of the cables are earthed properly;
n) the belts of the belt driven equipment are properly guarded;
p) adequate precautions are taken to ensure that no live parts are so exposed as to cause danger;
q) ammeters and voltmeters are tested;
r) the relays are inspected visually by moving covers for deposits of dusts or other foreign matter;
s) wherever bus ducts/rising mains/overhead bus trucking are used, special care being taken for earthing the system. All tap off points are provided with adequately rated protective device like MCB, MCCB, fuses, RCCB/RCD, SPD (*see* **11**), etc;
t) all equipment are weather, dust and vermin proof; and
u) any and all equipment having air insulation as media maintain proper distances between phases; phase to neutral; phase to earth and earth to neutral.

9.2.2.3 *Overhead lines*

For overhead lines, it shall be checked whether,

a) all conductors and apparatus including live

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parts thereof are inaccessible;

b) the types and size of supports are suitable for the overhead lines/conductors used and are in accordance with approved drawing and standards;

c) clearances from ground level to the lowest conductor of overhead lines, sag conditions, etc, are in accordance with **4.7**;

d) where overhead lines cross the roads or cross each other or are in proximity with one another, suitable guarding is provided at road crossings and also to protect against possibility of the lines coming in contact with one another;

e) every guard wire is properly earthed;

f) the type, size and suitability of the guarding arrangement provided is adequate;

g) stays are provided suitably on the overhead lines as required and are efficiently earthed or provided with suitably stay insulators of suitable voltages;

h) anti-climbing devices and danger board/ caution board, notices are provided on all HV supports;

j) clearances along the route are checked and all obstructions, such as, trees/branches and shrubs are cleared on the route to the required distance on either side;

k) clearance between the live conductor and the earthed metal parts are adequate;

m) for the service connections tapped-off from the overhead lines, cut-outs of adequate capacity are provided;

n) all insulators are properly and securely mounted; also they are not damaged.

p) all poles are properly grouted/insulated so as to avoid bending of pole towards tension; and

q) steel poles, if used is properly earthed.

9.2.2.4 *Lighting and convenience power circuits*

For the lighting and convenience power circuits, it shall be checked whether,

a) wooden boxes and panels are avoided in factories for mounting the lighting boards and switch controls, etc;

b) neutral links are provided in double pole switch-fuses which are used for lighting control, and no protective device (such as MCB, MCCB, fuses, RCCB/RCD, etc) is provided in the neutral;

c) the plug points (6 A) in the lighting circuit are all of 3/5-pin type, the third pin being suitably earthed;

d) the plug points (16 A) in the lighting circuit are all of 3/6-pin type, the third pin being suitably earthed;

e) tamper-proof interlocked switch socket and plug are used for locations easily accessible;

f) lighting wiring in factory area is taken enclosed in conduit and conduit properly earthed, or alternatively, armoured cable wiring is used;

g) a separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment;

h) proper connectors and junction boxes are used wherever joints are to be made in conductors or cross-over of conductors takes place;

j) cartridge fuse units are fitted with cartridge fuses only;

k) clear and permanent identification marks are painted in all distribution boards, switchboards, sub-main boards and switches as necessary;

m) the polarity has been checked and all protective devices (such as MCB, MCCB, fuses, RCCB/RCD, etc) and single pole switches are connected on the phase conductor only and wiring is correctly connected to socket-outlets;

n) spare knockouts provided in distribution boards and switch fuses are blocked;

p) the ends of conduits enclosing the wiring leads are provided with ebonite or other suitable bushes;

q) the fittings and fixtures used for outdoor use are all of weather-proof construction and of suitable IP and IK rating, and similarly, fixtures, fittings and switchgears used in the hazardous area, are of flame-proof application;

r) proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals;

s) flat ended screws are used for fixing conductor to the accessories;

t) use of flat washers backed up by spring washers for making end connections is desirable; and

u) all metallic parts of installation, such as conduits, distribution boards, metal boxes, etc, have been properly earthed.

9.3 Testing of Installation

9.3.1 *General*

After inspection, the following tests shall be carried

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out, before an installation or an addition to the existing installation is put into service. Any testing of the electrical installation in an already existing installation shall commence after obtaining permit to work from the Engineer-in-Charge and after ensuring the safety provisions.

Testing of the installations will cover the testing of equipment, connections, cables, switchgear, protective devices, circuit breakers and the associated relays, measuring instruments and earthing. Periodicity of testing should not exceed six months. More frequent testing may be prescribed for complex installations and installations feeding sensitive loads. Due date of next test cycle should be displayed on the equipment.

9.3.2 *Testing*

9.3.2.1 *Switchboards*

HV and MV switchboards shall be tested in the manner indicated below:

a) All high voltage switchboards shall be tested for dielectric test as per good practice [8-2(14)].
b) All earth connections shall be checked for continuity.
c) The operation of the protective devices shall be tested by means of secondary or primary injection tests.
d) The operation of the breakers shall be tested from all control stations.
e) Indication/Signalling lamps shall be checked for proper working.
f) The operation of the breakers shall be tested for all interlocks.
g) The closing and opening timings of the breakers shall be tested, wherever required for auto-transfer schemes.
h) Contact resistance of main and isolator contacts shall be measured.
j) The specific gravity and the voltage of the control battery shall be measured.

9.3.2.2 *Transformers*

Transformers shall be tested in the manner indicated below:

a) All commissioning tests shall be in accordance with good practice [8-2(9)].
b) Insulation resistance on HV and MV windings shall be measured at the end of 1 min as also at the end of 10 min of measuring the polarization index. The absolute value of insulation resistance should not be the sole criterion for determining the state of dryness of the insulation. Polarization index values should form the basis for determining the state of dryness of insulation. For any class of insulation, the polarization index should be greater than 1.5.

9.3.2.3 *Cables*

Cable installations shall be checked as given below:

a) It shall be ensured that the cables conform to the relevant Indian Standards. Tests shall also be done in accordance with good practice [8-2(11)] and [8-2(15)]. The insulation resistance before and after the tests shall be checked.
b) The insulation resistance between each conductor and against earth shall be measured. The insulation resistance varies with the type of insulation used and with the length of cable. The following empirical rule gives reasonable guidance:

$$\text{Insulation resistance in megaohms} = \frac{10 \times \text{Voltage, in kV}}{\text{Length, in km}}$$

c) Physical examination of cables shall be carried out.
d) Cable terminations shall be checked.
e) Continuity test shall be performed before charging the cable with current.

9.3.2.4 *Motors and other equipment*

The following tests shall be made on motor and other equipment.

The insulation resistance of each phase winding against the frame and between the windings shall be measured. Megger of 500 V or 1 000 V rating shall be used. Star points should be disconnected. Minimum acceptable value of the insulation resistance varies with the rated power and the rated voltage of the motor.

The following relation may serve as a reasonable guide:

$$R_I = \frac{20 \times E_n}{1\,000 + 2P}$$

where

R_I = insulation resistance in mega-ohms at 25°C.
E_n = rated phase to phase voltage.
P = rated power, in kW.

If the resistance is measured at a temperature different from 25°C, the value shall be corrected to 25°C.

The insulation resistance as measured at ambient temperature does not always gives a reliable value, since moisture may have been absorbed during shipment and storage. When the temperature of such a motor is raised, the insulation resistance will initially drop considerably, even below the acceptable minimum. If any suspicion

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exists on this score, motor winding shall be dried out.

9.3.2.5 *Wiring installation*

The following tests shall be done:

a) The insulation resistance shall be measured by applying between earth and the whole system of conductor or any section thereof with all fuses in place and all switches closed, and except in earthed concentric wiring, all lamps in position or both poles of installation otherwise electrically connected together, a d.c. voltage of not less than twice the working voltage, provided that it does not exceed 500 V for medium voltage circuits. Where the supply is derived from three-wire (a.c. or d.c.) or a poly-phase system, the neutral pole of which is connected to earth either direct or through added resistance the working voltage shall be deemed to be that which is maintained between the outer or phase conductor and the neutral.

b) The insulation resistance in mega-ohm of an installation measured as in (a) shall be not less than 50 divided by the number of points on the circuit, provided that the whole installation need not be required to have an insulation resistance greater than one mega-ohm.

c) Control rheostats, heating and power appliances and electric signs, may, if desired, be disconnected from the circuit during the test, but in that event the insulation resistance between the case of framework, and all live parts of each rheostat, appliance and sign shall be not less than that specified in the relevant Indian Standard specification or where there is no such specification, shall be not less than half a mega-ohm.

d) The insulation resistance shall also be measured between all conductors connected to one pole or phase conductor of the supply and all the conductors connected to the middle wire or to the neutral on to the other pole of phase conductors of the supply. Such a test shall be made after removing all metallic connections between the two poles of the installation and in these circumstances the insulation resistance between conductors of the installation shall be not less than that specified in (b).

9.3.2.6 *Completion certificate*

On completion of an electrical installation (or an extension to an installation) a certificate shall be furnished by the contractor, counter-signed by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in a prescribed form as required by the local electric supply authority. One such recommended form is given in Annex G. This is a general form giving the minimum basic requirements and the items in the form have to be augmented keeping in view the features of the particular equipment, system or installation and environmental conditions of its operation.

9.3.2.7 *Earthing*

For checking the efficiency of earthing, the following tests shall be done:

a) The earth resistance of each electrode shall be measured.

b) Earth resistance of earthing grid shall be measured.

c) All electrodes shall be connected to the grid and the earth resistance of the entire earthing system shall be measured.

These tests shall preferably be done during the summer months.

9.4 Checklists covering basic minimum set of checks for installation, handing over and commissioning of typical equipment of a substation are given in Annex E for general reference and use. Checklist for handing over of earthing pits is given in Annex F for general reference and use. For any installation, the proper checklist should be developed keeping in view the type of loads, quality of service, environmental conditions and operating requirements of redundancy and reliability.

10 ALLIED/MISCELLANEOUS SERVICES

Requirements relating to various allied services shall be as per **10.1** to **10.9**.

10.1 Telecommunication and Information and Communication Technology Services

10.1.1 *Telephone Services*

10.1.1.1 House wiring of telephone subscribers in small buildings may be on the surface of walls or desirably, in a concealed manner through conduits. In large multi-storeyed buildings intended for commercial, business and office use as well as for residential purposes, wiring for telephone connections should be done in a concealed manner through conduits. The requirements of telecommunication facilities like telephone connections, private branch exchange and intercommunication facilities, should be planned well in advance so that suitable provisions are made in the building plan in such a way that the demand for telecommunication services in any part of the building at any floor are met at any time during the life of the building.

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10.1.1.2 Layout arrangements, methods for internal block wiring and other requirements regarding provisions of space, etc, may be decided depending on the number of phone outlets and other details in consultation with engineer/architect and user. *See also* Part 8 'Building Services, Section 6 Information and Communication Enabled Installations' of the Code.

10.1.2 *Information and Communication Technology Services including Computer Networking* *See* Part 8 'Building Services, Section 6 Information and Communication Enabled Installations' of the Code.

10.2 Public Address System — *See* Part 4 'Fire and Life Safety' of the Code.

10.3 Common Antenna System for TV Receivers

10.3.1 In multi-storeyed apartments, houses and hotels where many TV receivers are located, a common master antenna system may preferably be used to avoid mushrooming of individual antennas.

10.3.2 Master antenna is generally provided at the top most convenient point in any building and a suitable room on the top most floor or terrace for housing the amplifier unit, etc, may also be provided in consultation with the architect/engineer.

10.3.3 From the amplifier rooms, conduits should be laid in recess to facilitate drawing co-axial cable to individual flats. Suitable 'Tap Off' boxes may be provided in every room/flat, as required.

10.4 Emergency and Standby Power Supply Systems

10.4.1 *General*

Use of electricity has grown tremendously and for various activities the dependence on electricity has increased to such an extent as to cause serious problems even with loss of electrical power for a few moments. As a result, a wide variety of alternate sources of electricity are being in our built environment.

The different alternative sources of power are the Uninterrupted Power Supply (UPS) System, inverter, CNG/LPG generator sets, diesel/petrol/kerosene oil generator sets, bio-gas generator sets.

In addition to the above, there is a proliferation of power sources, such as solar photo-voltaic cells, wind generators, bio-mass and waste based power plants etc, primarily oriented towards reduction of the environmentally harmful CO_2 emissions.

These systems give electricity during the periods of the failure of the conventional grid based public energy system and keep our critical systems in continued operation. However, introduction of more than one source of electrical power introduces questions of safety. For safety from electrical shock to human beings or livestock, the hazard is not just dependent on the main high powered source such as the grid, but the hazard is the same from a low powered source also. Shock from a small 20 W inverter can be as dangerous as a shock from the grid with megawatts of power at the back. As such precautions from the angle of safety apply equally to all sources of power. Electric shock hazards are dependent on the system voltage and as such even a low capacity generator or an inverter (of capacity 100 VA) poses the same level of shock hazard as a multi-kilovolt ampere capacity generator and all protection provisions (such as safety earthing, earth leakage and overload breakers) shall be provided as done for a large capacity system.

Power devices contain fuel, batteries which are points of concentrated sources of energy constrained in a small place. Any unintended improper release of this bottled up energy can unleash devastating consequences, such as fire and as such care is required in location which houses any of these sources of electrical power and its associated components.

10.4.2 *Uninterrupted Power Supply (UPS) System*

UPS is an electrical device providing an interface between the mains power supply and sensitive loads (computer systems, instrumentation, etc). The UPS supplies sinusoidal a.c. power free of disturbances and within strict amplitude and frequency tolerances. It is generally made up of a rectifier/charger and an inverter together with a battery for backup power in the event of a mains failure with virtually no time lag.

In general UPS system shall be provided for sensitive electronic equipment like computers, printers, fire alarm panel, public address system equipment, access control panel, EPABX, etc, with the following provisions:

a) Isolation transformers may be provided in many UPS systems to provide higher grade of power supply quality to the loads fed by the UPS.
b) UPS shall have dedicated neutral earth pits. This earth pit shall be interconnected with other earth pits below soil for equipotential bonding.
c) Adequate rating of protective devices such as MCB, MCCB, fuses, RCCB/RCD, etc, shall be provided at both incoming and outgoing sides.
d) UPS room shall be provided with adequate ventilation and/or air conditioning as per requirement.
e) For all 3 phase UPS, 4 pole CB (circuit breaker) shall be used and for all 1 phase UPS, Double Pole CB shall be used.

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10.4.3 *Inverter*

In general inverter system shall be provided for house lighting, shop lighting, etc.

NOTE — While a UPS system is provided to maintain power supply without any break even in the event of a failure of the incoming power supply, an inverter system is provided where a short break is acceptable.

Inverter systems also have a battery bank to supply power during the failure of the main power supply and the battery charged through a rectifier. The following provisions shall apply to inverter systems:

a) Adequate rating of protective devices such as MCB, MCCB, fuses, RCCB/RCD, etc, shall be provided at both incoming and outgoing sides.
b) Earthing shall be done properly.
c) Adequate ventilation space shall be provided around the battery section of the inverter.
d) Care shall be taken in circuit design to keep the connected load in such a manner that the demand at the time of mains failure is within the capability of the inverter.

NOTE — If the inverter fails to take over the load at the time of the mains failure, the purpose of providing the inverter and battery backup is defeated.

10.4.4 The following provisions shall apply to both inverter and UPS systems:

a) Circuits which are fed by the UPS or inverter systems should have suitable marking to ensure that a workman does not assume that the power is off, once he has switched off the mains from the DB for maintenance.
b) Electric shock hazards are dependent on the system voltage and as such even a low capacity generator or an inverter (of capacity 100 VA) poses the same level of shock hazard as a multi-kilovolt ampere capacity generator and all protection provisions (such as safety earthing, earth leakage and overload breakers) shall therefore be provided as done in case of a large capacity system.
c) UPS and inverter systems should be provided with protection to shut the output during abnormal conditions, such as overload or short circuit. Such systems may also have the choice of auto-restoration after a preset time delay and an ultimate lock-out after a number of restoration attempts. Warning should be displayed wherever the possibility of automatic restoration is possible.
d) Batteries that go with UPS and inverter systems are required to be placed in well-ventilated spaces as oxygen and hydrogen gasses are produced in the batteries, which unless ventilated, can cause explosive conditions.
e) The flooring for the battery room should be with acid (or alkali as the case may be) resistant tiles or coating.

10.4.5 *Standby Generating Set (less than 5 kVA)*

In general, small standby generating sets (using either diesel or petrol or kerosene or LPG or CNG) may be provided for small installations, such as offices, shops, small scale industry, hostels, etc, which shall comply the following requirements:

a) These shall be located outside in open areas.
b) There shall be no risk of fire due to presence of such equipment in the premise.
c) They shall be in reach of authorized persons only.
d) Adequate firefighting equipment shall be provided near such installations.
e) Exhaust from these shall be disposed in such a way so as not to cause health hazard.

NOTE — Installation of a set in a closed space poses the hazard of accumulation of the exhaust gasses which contains harmful gases such as carbon monoxide, and also reduction of oxygen in the air in the enclosure.

f) These shall have acoustic enclosure, or shall be placed at a location so as not to cause noise pollution.
g) Adequate ventilation shall be provided around the installation.
h) Protective devices such as MCB, MCCB, fuses, RCCB/RCD, etc, with adequate rating shall be provided.
j) Separate and adequate body and neutral earthing shall be done.
k) Cumulative capacity shall not exceed 10 kVA.

10.5 Building Management System

A building management/automation system may be considered to be provided for controlling of some and monitoring of all parameters of heating, ventilation and air conditioning system (HVAC); electrical; plumbing; fire fighting; low voltage system, such as telephone, TV; etc. This not only leads to reduction of energy consumption, it also generates data leading to better operation practice and systematic maintenance scheduling. The total overview provided by a building automation system, with a capability to oversee a large number of operating and environmental parameters on real time basis leads to introduction of measures which further leads to reduction in energy consumption.

It also helps in reduction in skilled manpower

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requirement for operation and maintenance of large complexes. This system can further be linked to other systems such as fire alarm system, public address system, etc for more effective running of services. This system can be used for analysis and controlling of all services in a particular complex, leading to efficient and optimum utilization of available services.

NOTE — *See* Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' and Part 12 'Asset and Facility Management' of the Code for provisions relating to building management system.

10.6 Security System

Security system may comprise an integrated closed circuit television system, access control system, perimeter protection systems, movement sensors, etc. These have a central control panel, which has a defined history storage capacity. This main control panel may be located near to the fire detection and alarm system.

These may be considered for high security areas or large crowded areas or complexes. High security areas may consider uncorded, high-resolution, black and white cameras in place of coloured cameras. These cameras may be accompanied or automatically controlled with movement sensors. Cameras may be linked to access controls so that proper recording of the movement at the points of access to high security areas is maintained.

Access control may be provided for entry to high security areas. The systems may have proximity card readers, magnetic readers, etc.

NOTE — *See* Part 12 'Asset and Facility Management' of the Code for provisions relating to security system.

10.7 Car Parking Area

10.7.1 *Electrical Vehicle Charging*

Adequate electrical provisioning should be made for electric vehicle charging in designated spaces for electric car parks in enclosed/covered car parking. These electrical outlets should be fed from a separate distribution board located near such outlets for electric car parks. Distribution board and outlets should be protected and metered.

NOTE — Reference may be made to IEC 60364-7-722:2015 'Low-voltage electrical installations — Part 7-722: Requirements for special installations or locations — Supplies for electric vehicles'.

10.7.2 *Car Park Management System*

Wherever car park management system is provided in multi-level parking or other parking lots with features of boom barriers, pay and display machines (manned or unmanned type) and parking guidance system (for displaying number of car spaces vacant on various floors, direction of entry and exit, etc), the electrical provisions for the same shall be adequately backed with UPS for protection of vehicle and for efficient car park management.

10.8 Solar Photovoltaic Power Generating System

10.8.1 *General*

Solar energy, which is available in two forms, heat and light, is a renewable and inexhaustible natural resource and can supplement/augment the depleting fossil fuel resources. Greenhouse gases and pollutant emissions which result from fossil fuel generation can also be offset by solar photovoltaic power generation. Most parts of the country receive good solar radiation of 4 to 7 kWh/m^2 per day and almost 300 sunny days in a year making solar PV system one of the most preferred renewable energy source in the country.

10.8.2 Solar PV power generating system consists of components and subsystems that are used to convert incident solar radiation directly into electrical energy. The energy converter (namely, solar photovoltaic cells which convert solar energy directly into d.c. electric power) does not have moving parts and has a comparatively long lifetime. Also, it can be used in decentralized/distributed mode.

PV cells are made of light-sensitive semiconductor materials that use photons to dislodge electrons to drive an electric current. The available cell technology used in construction of solar PV is single crystal or mono-crystalline silicon/poly-crystalline or multi-crystalline silicon/amorphous thin film. Individual PV cells are interconnected to form a PV module. This takes the form of a panel for easy installation.

The electrical parameters of the input of a subsystem should be compatible with the output electrical parameters of a preceding subsystem(s).

Most solar PV systems can be mounted on a building or installed on ground. For buildings, they are either mounted on the roof or integrated into the building facade (BIPV).

10.8.3 *Types of Solar PV Generating System*

When photovoltaic modules are exposed to sunlight, they generate electricity in d.c. waveform. A d.c./a.c inverter then converts the d.c into a.c. or stabilizes d.c. for further distribution. The PV power generating systems can broadly be classified into two categories, namely, stand-alone (with a.c. output or with d.c. output) and grid connected system (*see* Fig. 10).

10.8.3.1 *Stand alone solar PV system* (*see* Fig. 11)

Stand alone solar PV generating system is an independent power production system that is not connected to the grid and can thus be designed free from grid code requirements. This system is also known

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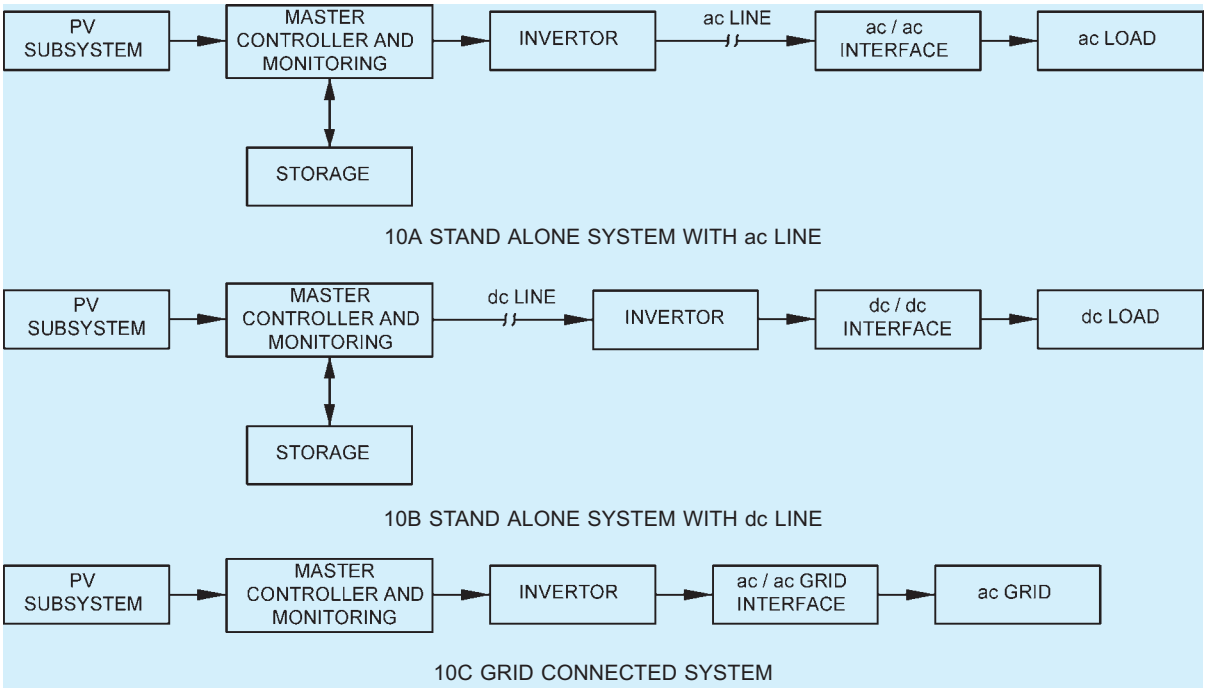


FIG. 10 PV POWER GENERATING SYSTEM AND MAJOR SUBSYSTEMS

as off-grid system. Off-grid solar PV systems are applicable for areas where there is no available power grid, such as remote villages, forests, off-shore islands, ships. But they may also be installed within the city in situations where it is inconvenient or too costly to tap electricity from the power grid.

An off-grid solar PV system needs deep cycle rechargeable batteries, such as lead-acid, nickel-cadmium or lithium-ion batteries to store electricity for use under conditions where there is little or no output from the solar PV system, such as during the night.

10.8.3.2 *Grid connected solar PV system* (*see* Fig. 12)

A grid connected solar PV generating system is interconnected with an existing electric power grid, subject to grid requirements. This system is also known as grid-tied system. A building has two parallel power supplies, one from the PV solar system and the other from the power grid. The combined power supply feeds all the loads connected to the main a.c. distribution board. The ratio of solar PV supply to power grid supply varies, depending on the size of the solar PV system. Whenever the solar PV supply exceeds the building's current demand, excess electricity is exported into the grid. When there is no sunlight to generate PV electricity at night, the power grid will feed all the building's demand. A grid-connected system can be an effective way to reduce dependence on utility power during the day, increase renewable energy production, and improve the environment.

10.8.4 When designing solar PV system, care should be taken to address design aspects relating to earthing, short circuit protection, lightning protection and switching control. This shall be done in accordance with Part 8 'Solar Photovoltaic (PV) Power Supply Systems' of National Electrical Code, 2011. Earthing and lightning protection of solar PV systems shall be done in accordance with the procedure laid down in **8** and **11**, respectively.

10.9 Aviation Obstacle Lights

High-rise buildings and structures such as chimneys and towers are potential hazards to aircraft. The provision of aviation obstacle lights (AOL) on tall buildings/structures is intended to reduce hazards to aircraft by indicating their presence. AOLs, low, medium or high intensity obstacle lights, or a combination of such lights, shall be provided on buildings of different heights as per the requirements of Annex 14 to the Convention on International Civil Aviation, Volume I Aerodrome Design and Operations, International Civil Aviation Organization (ICAO). A general arrangement of AOLs in case of group of buildings is given in Fig. 13.

11 LIGHTNING PROTECTION OF BUILDINGS

11.1 Basic Considerations For Protection

11.1.1 There are no devices or methods capable of modifying the natural weather phenomena to the extent that they can prevent lightning discharges. Lightning

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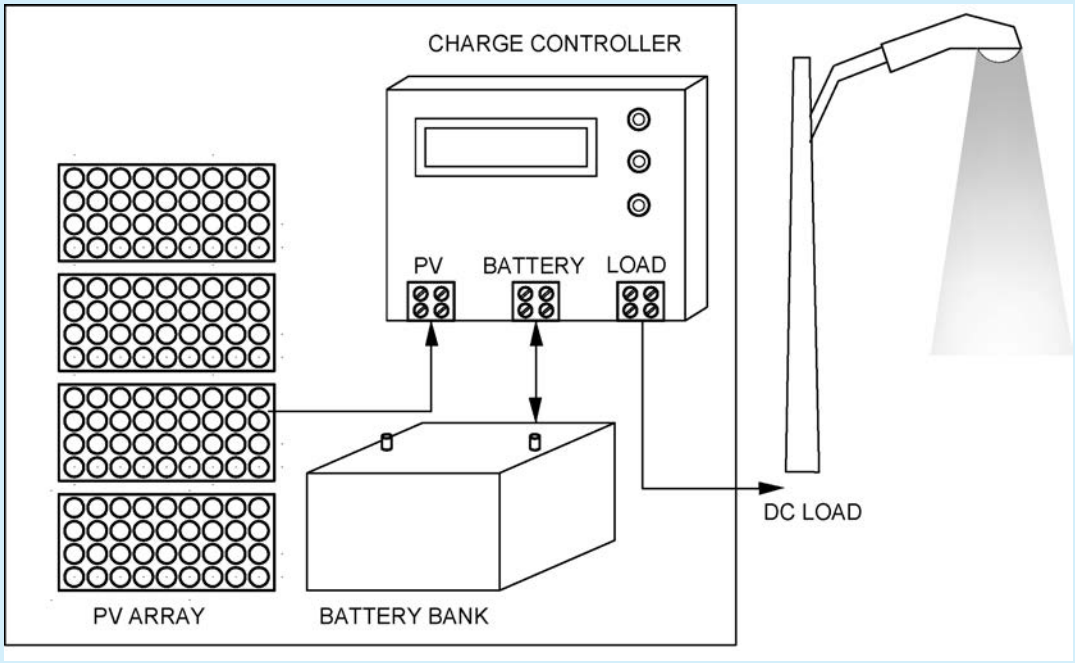


FIG. 11 STAND ALONE SOLAR PV SYSTEM

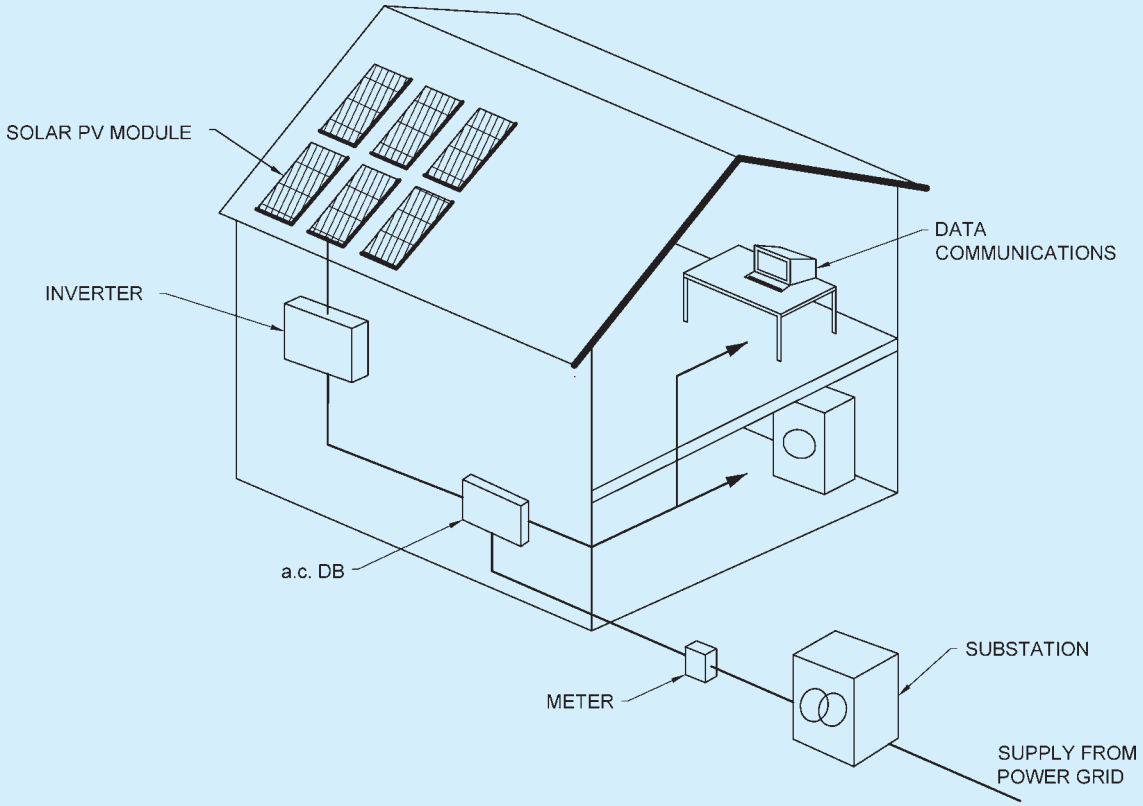
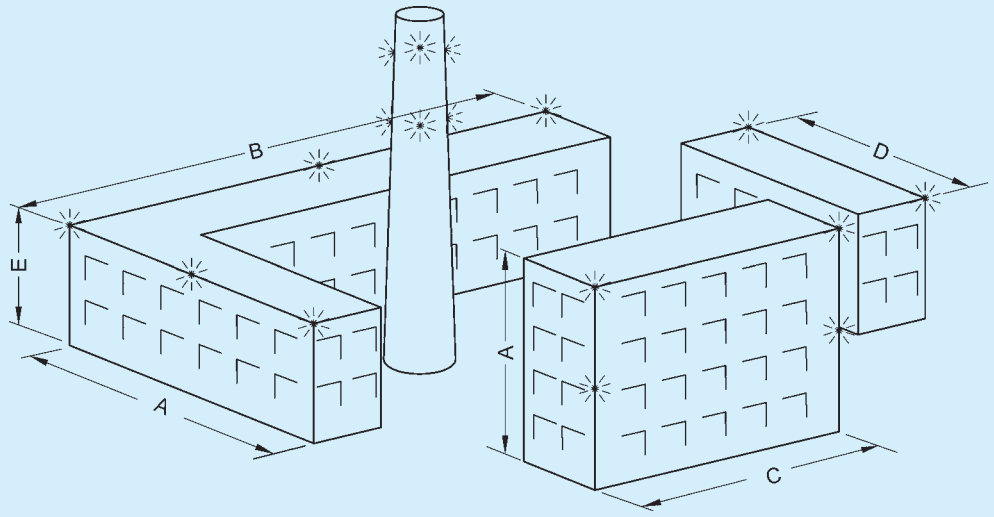


FIG. 12 GRID CONNECTED SOLAR PV SYSTEM

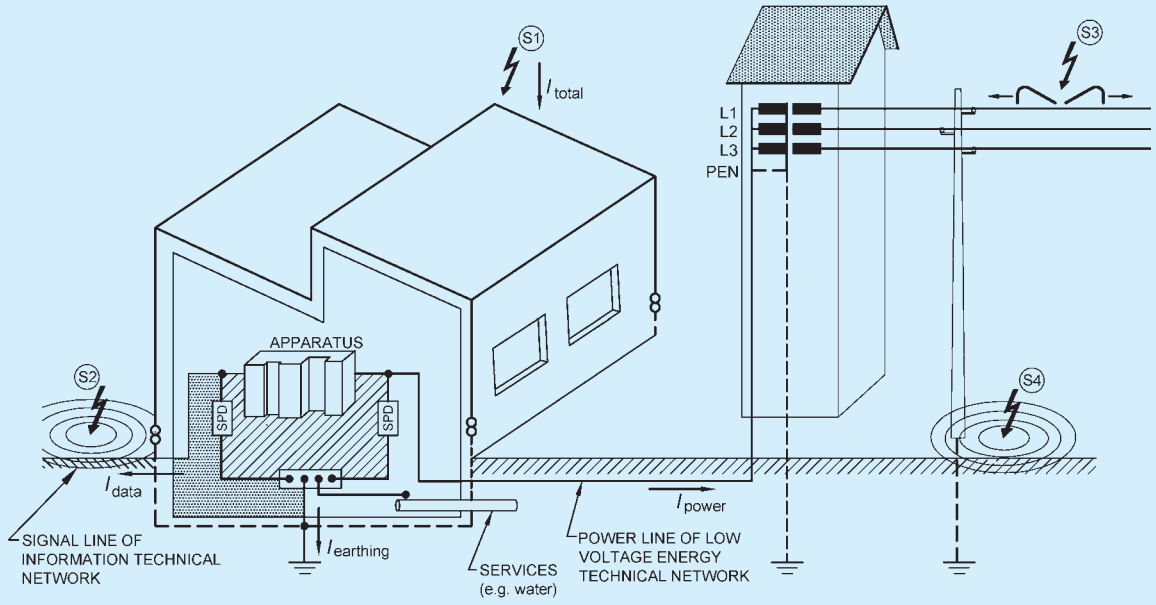
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flashes to, or nearby, structures (or lines connected to the structures) are hazardous to people, to the structures themselves, their contents and installations as well as to lines (*see* Fig. 14). Lightning protection measures therefore become essential. Lightning protection systems are methods to divert the effects of lightning discharges away from the buildings, its occupants and sensitive equipment housed in the building, including from the necessary connections from public systems to the building. Lightning discharges are of very high energy and can have devastating effects depending on the path of its discharge. Lightning strike is not predictable and is a random phenomenon both from the aspect of its occurrence and intensity or the energy discharge. Protection systems have been developed purely on laboratory behaviour of simulated lightning



A, *B* = 45 m - 90 m
C, *D*, *E* < 45 m

FIG. 13 TYPICAL ARRANGEMENT OF AVIATION OBSTACLE LIGHTS IN CASE OF GROUP OF BUILDINGS



Key
S1 Flash to the structure
S2 Flash near the structure
S3 Flash to the service connected to the structure
S4 Flash near the service connected to the structure

FIG. 14 BASIC EXAMPLE OF DIFFERENT SOURCE OF DAMAGE TO A STRUCTURE AND LIGHTNING CURRENT DISTRIBUTION WITHIN A SYSTEM

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strikes and methods of containing them or diverting them to safe paths with least damage. At the same time it is necessary to understand that lightning possibly causes the maximum loss of life to human beings and animals due to its unpredictability, lack of forewarning and protection systems only provide a means of diversion of lightning discharges to safe paths.

Lightning protection systems may be installed to avoid accidents, severe injuries and (may be even) deaths of humans and animals due to direct or indirect lightning. In many cases, the need for protection may be self-evident, for example:

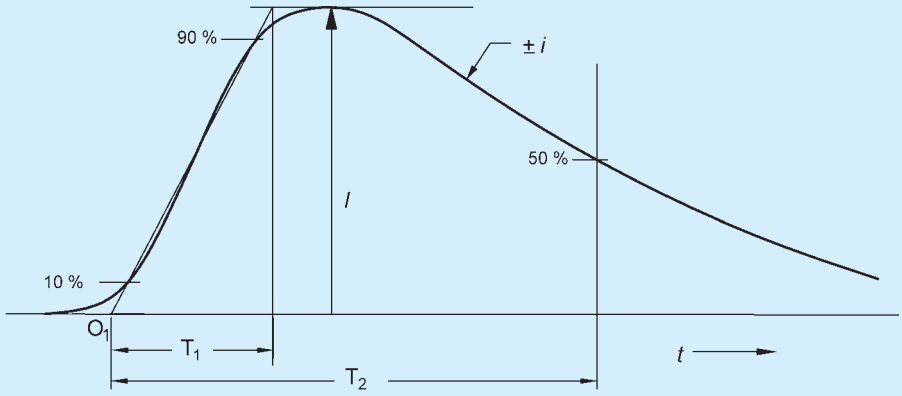
a) where the area is one in which lightning strokes are prevalent;
b) where large numbers of people congregate, such as, sports, cultural, assembly buildings;
c) where there are very tall, complex or isolated structures;
d) where there are structures of historic or cultural importance;
e) structures with inherent explosive risks; for example, explosives factories, stores and dumps and fuel tanks;
f) where essential public services are concerned (as lightning may lead to power outages and unplanned interruptions of production processes); and
g) where there is wide use of electrical and electronic equipment/ components that are sensitive to the effects of lightning (in industry, ICT enabled buildings, transportation and communication).

11.2 The maximum values of lightning current parameters for the different lightning protection levels (LPL) are given below and are used to design lightning protection components (for example, cross-section of conductors, thickness of metal sheets, current capability of SPDs, separation distance against dangerous sparking) and to define test parameters simulating the effects of lightning on such components {*see* good practice [8-2(46)] for details}:

First positive impulse			*LPL*			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	200	150	100	
Impulse charge	Q_{Short}	C	100	75	50	
Specific energy	W/R	MJ/?	10	5.6	2.5	
Time parameters	T_1/T_2	µs/µs	10/350			
First negative impulse [1)]			*LPL*			
Current parameters	Symbol	Unit	I	II	III	
Peak current	I	kA	100	75	50	
Average steepness	dl/dt	kA/µs	100	75	50	
Time parameters	T_1/T_2	µs/µs	1/200			
[1)] The use of this current shape concerns only calculations and not testing.						
Subsequent impulse			*LPL*			
Current parameters	Symbol	Unit	I	II	III	IV
Peak current	I	kA	50	37.5	25	
Average steepness	dl/dt	kA/µs	200	150	100	
Time parameters	T_1/T_2	µs/µs	0.25/100			
Long stroke			*LPL*			
Current parameters	Symbol	Unit	I	II	III	IV
Long stroke charge	Q_{Long}	C	200	150	100	
Time parameter	T_{Long}	s	0.5			
Flash			*LPL*			
Current parameters	Symbol	Unit	I	II	III	IV
Flash charge	Q_{Flash}	C	300	225	150	

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Definitions of impulse current parameters are shown in Fig. 15 {*see also* good practice [8-2(46)]}.



Key
O_1 Virtual origin
I Peak current
T_1 Front time
T_2 Time to half value

FIG. 15 DEFINITIONS OF IMPULSE CURRENT PARAMETERS

11.3 Risk Assessment

The need for protection, the economic benefits of installing protection measures and the selection of adequate protection measures should be determined in terms of risk assessment. The protection measures should ensure that the calculated risk is less than the tolerable risk (*see* **11.3.3**). Tolerable risk is the maximum value of the risk which can be tolerated. Risk assessment and level of lighting protection required shall be assessed as per the procedure laid down in **11.3.1** to **11.3.4**. The good practice [8-2(47)] shall be followed for details.

11.3.1 *Typical Values of Tolerable Risk* (R_T)

The typical values of tolerable risk (R_T) are given below:

Sl No.	*Type of Loss*	*Tolerable Risk*
(1)	(2)	(3)
i)	Loss of human life or permanent injuries	10^{-5} (One injury out of 100 000 strikes)
ii)	Loss of service to the public	10^{-3} (One service loss out of 1 000 strikes)
iii)	Loss of cultural heritage	10^{-4} (One damage out of 10 000 strikes)
iv)	Economic Loss	10^{-3} (One failure out of 1 000 strikes)

11.3.2 *Risk Analysis and Lightning Protection Level (LPL)*

Risk analysis is done considering the following factors and protection is divided in to four protection levels (LPL I to IV) (*see* Tables 4 and 5):

a) *Source of damage* — Such as flashes to a structure, flashes near a structure, flashes to a line, flashes near a line;

b) *Type of damage* — Injury to living beings by electric shock, physical damage, failure of electrical and electronic systems; and

c) *Type of loss* — Loss of human life (including permanent injury), loss of service to the public, loss of cultural heritage, loss of economic value (structure, content, and loss of activity).

11.3.3 *Risk*

Risk (R) is the value of probable average annual loss (humans or goods) due to lightning, relative to the total value (humans or goods) of the structure to be protected. For each type of loss which may appear in a structure or in a service, the relevant risk shall be evaluated for each source and type of damage as given below:

R_1 : risk of loss of human life;
R_2 : risk of loss of service to the public;
R_3 : risk of loss of cultural heritage; and
R_4 : risk of loss of economic value.

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Each risk component, $R_x = N_x \times P_x \times L_x$

where

N_x = number of dangerous events per annum;

P_x = probability of damage to a structure; and

L_x = consequent loss.

NOTE — For annual number of thunderstorm days of various places, **11.8** shall be referred to.

Total risk, R is the sum of various risk components. If $R \leq R_T$, lightning protection is not necessary, where R_T is the tolerable risk.

Besides the need of lightning protection for a structure or for a service, it may be useful to ascertain the economic benefits of installing protection measures in order to reduce the economic loss, L4. The assessment of components of risk R_4 for a structure allows the user to evaluate the cost of the economic loss with and without the adopted protection measures.

11.3.4 *Lightning Protection Level (LPL)*

Based on the risk assessment if protection is necessary, lightning protection is divided into four levels (LPL I to IV) which helps in designing and implementing protection measures for an economical implementation. LPL I provides the maximum protection and is expensive, whereas, LPL IV provides the least protection and is less expensive. Recommended lightning protection level (LPL) for typical buildings is given in Table 5 for guidance.

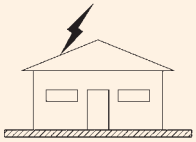
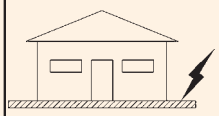
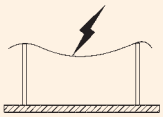
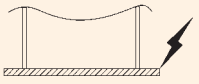
Complete system for protection of structures against lightning, including their internal systems and contents, as well as persons, in general consisting of an LPS and SPM shall be installed to avoid damages to structures, accidents, severe injuries and (may be even) deaths of humans due to direct or indirect lightning. Both protection measures should complement each other.

Before proceeding with the detailed design of a lightning protection, the following essential steps should be taken:

a) Decide whether or not the structure needs protection and, if so, what are the special requirements by making all calculations {*see* good practice [8-2(47)]}.

b) Ensure a close liaison between the architect/ engineer, the builder, the lightning protective system engineer, and the appropriate

Table 4 Source and Type of Damage and Type of Loss
(*Clause* 11.3.2)

Sl No.	Point of Strike	Source of Damage	Structure		Service (Metal Lines such as Power, Telephone, etc)	
			Type of Damage	Type of Loss	Type of Damage	Type of Loss
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1)		S1	D1	L1, L4[2)]		
			D2	L1, L2, L3, L4	D2	L`2, L`4
			D3	L1[1)], L2, L4	D3	L`2, L`4
2)		S2	D3	L1[1)] , L2 , L4		
3)		S3	D1	L1, L4[2)]		
			D2	L1, L2, L3, L4	D2	L`2, L`4
			D3	L1[1)] , L2, L4	D3	L`2, L`4
4)		S4	D3	L1[1)] , L2, L4	D3	L`2, L`4

[1)] Only for structures with risk of explosion, and for hospitals or other structures where failures of internal systems immediately endangers human life.
[2)] Only for properties where animals may be lost.

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authorities throughout the design stages (*see also* Note).

c) Agree the procedures for testing and future maintenance {*see* good practice [8-2(47)]}.

NOTE — Modern buildings with electronic equipment need protection from radiated surges of lightning. To achieve this, structural steel of the building is also sometimes used as a part of lightning protection system {*see* good practice [8-2(47)]}. In such cases, lightning protection measures shall be included in the structural drawing, particularly for foundation.

Table 5 Recommended LPL for Typical Buildings
(*Clause* 11.3.4)

Sl No.	Application	LPL
(1)	(2)	(3)
i)	Computer data centres, military applications, high rise hotels/hospitals, nuclear power stations, airports, essential services such as telecom	I
ii)	Low rise hospitals/hotels, ex-zones in the industry and chemical sector, fuel retail outlets/gas stations/compressor stations and similar installations	II
iii)	Schools, banks, residential buildings, temples, churches, mosques, community halls, etc	III/IV

NOTE — Detailed risk assessment should be done before execution.

11.4 Lightning Protection

11.5 Lightning Protection System (LPS)

The main and most effective measure for protection of structures against physical damage is considered to be the lightning protection system (LPS). It usually consists of both external and internal lightning protection systems.

An external LPS which consists of air-termination system, down-conductor system and earthing system {*see* good practice [8-2(45)] for details} is intended to,

a) intercept a lightning flash to the structure (with an air-termination system),

b) conduct the lightning current safely towards earth (using a down-conductor system), and

c) disperse the lightning current into the earth (using an earth-termination system).

An internal LPS comprises equipotential bonding or a separation distance (and hence electrical insulation) between the external LPS components and other electrically conducting elements internal to the structure.

Both external and internal protection systems should complement each other. Class of LPS denotes the classification of an LPS according to the lightning protection level for which it is designed. Four classes of LPS (I, II, III and IV) are defined as a set of construction rules, based on the corresponding LPL. Each set includes level-dependent (for example, rolling sphere radius, mesh width etc.) and level-independent (for example, cross-sections, materials, etc) construction rules {see good practice [8-2(47)]}.

Main protection measures against injury to living beings due to touch and step voltages are intended to,

1) reduce the dangerous current flowing through bodies by insulating exposed conductive parts, and/or by increasing the surface soil resistivity; and

2) reduce the occurrence of dangerous touch and step voltages by physical restrictions and/or warning notices.

The type and location of an LPS should be carefully considered in the initial design of a new structure, thereby enabling maximum advantage to be taken of the electrically conductive parts of the structure. By doing so, design and construction of an integrated installation is made easier, the overall aesthetic aspects can be improved, and the effectiveness of the LPS can be increased at minimum cost and effort.

Access to the ground and the proper use of foundation steelwork for the purpose of forming an effective earth-termination may well be impossible once construction work on a site has commenced. Therefore, soil resistivity and the nature of the earth should be considered at the earliest possible stage of a project. This information is fundamental to the design of an earth-termination system and may influence the foundation design work for the structure.

Regular consultation between LPS designers and installers, architects/civil engineer and builders is essential in order to achieve the best result at minimum cost. If lightning protection is to be added to an existing structure, every effort should be made to ensure that it conforms to the principles of this Code. The design of the type and location of an LPS should take into account the features of the existing structure.

11.5.1 *Air-Termination System*

11.5.1.1 Air-termination system is a part of an external LPS using metallic elements such as rods, mesh conductors or catenary wires intended to intercept lightning flashes. The probability of penetration by a lightning current on a structure is considerably decreased by the presence of a properly designed air-termination system. Air-termination systems can be composed of any combination of the following elements:

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a) Vertical rods (offers certain angle of protection);
b) Catenary wires; and
c) Meshed/Grid conductors.

All types of air-termination systems shall be positioned in accordance with **11.5.1.2**. The individual air-terminations rods should be connected together at roof level to ensure current division. Radioactive air-terminals shall not be allowed. Any other kind of air-terminal like dissipation system/ESE air-terminal/CSE air-terminal shall not be acceptable.

11.5.1.2 *Positioning*

Air-termination components installed on a structure shall be located at corners, exposed points and edges (especially on the upper level of any facades) in accordance with one or more of the following methods {*see also* Figs. 16 to 20 in conjunction with good practice [8-2(45)]}:

a) Protection angle method;
b) Rolling sphere method; and
c) Mesh method.

The protection angle method is suitable for simple shaped buildings but it is subject to limits of air-termination height indicated in Table 6. The mesh method is a suitable form of protection where plane/pitch roof surfaces are to be protected. The rolling sphere method is suitable in all cases. *See* good practice [8-2(45)] for details.

11.5.1.3 Roof mounted electrical/electronic equipment (for example, chillers, antennas, cameras and bill boards) need vertical air-termination to avoid direct flashover. All parts of lightning protection should maintain separation distance from these electrical/electronic equipment. Power and data connection to these equipment should have proper Class I and Class II SPD's (*see* **11.6.5**) to avoid failures. Overhead cables such as cable TV lines from one building to the other should be avoided.

11.5.1.4 Unearthed metallic roofs should be avoided. Metallic roofs shall be connected either to steel reinforcement or to other earthed steel parts of the building satisfying the requirements of number of down-conductors (*see* **11.5.2**). Small buildings with metallic roofs less than 100 m^2 shall be earthed at least not less than 2 places.

11.5.1.5 *Structures of height less than 60 m and more than 60 m*

On structures lower than 60 m in height, generally flashes to the side may not occur, hence air-termination protection on sides will not be required (*see* Fig. 21A).

On structures taller than 60 m, flashes to the side may occur, especially to points, corners and edges of surfaces. In general, the risk due to these flashes is low, but electrical and electronic equipment on walls or outside structures may be destroyed even by lightning flashes with low current peak values.

An air-termination system shall be installed to protect the upper part of tall structures (that is, typically the topmost 20 percent of the height of the structure as far as this part exceeds 60 m in height) and the equipment installed on it. The rules for positioning the air-termination systems on these upper parts of a structure shall meet at least the requirements for LPL IV with emphasis on the location of air-termination devices on corners, edges, and significant protrusions (such as balconies, viewing platforms, etc (*see* Fig. 21B).

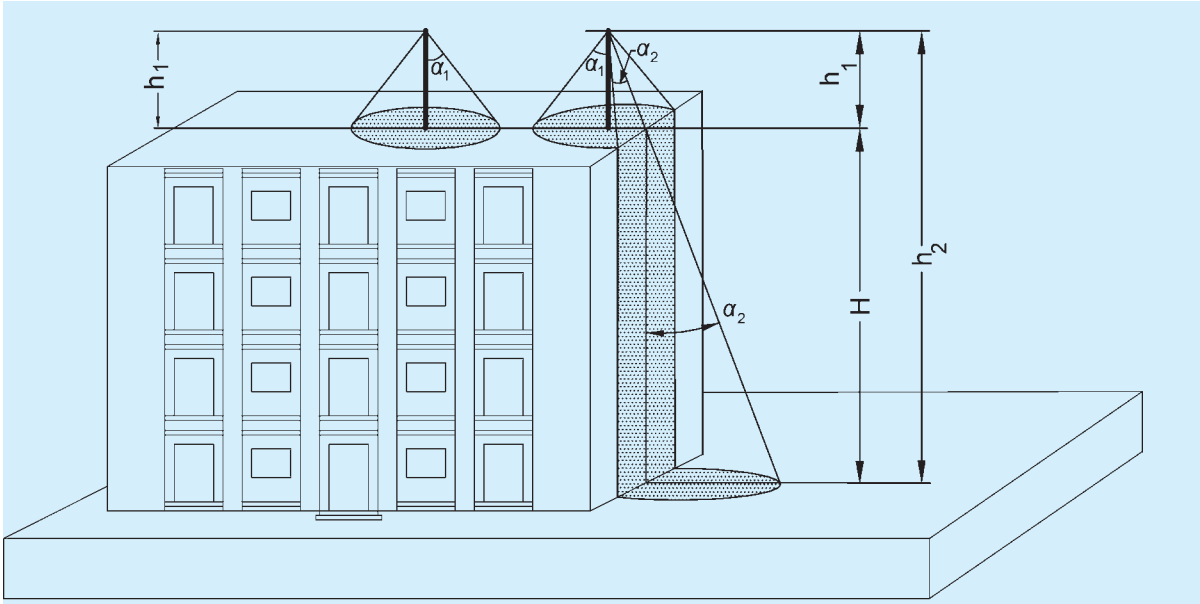
11.5.1.6 *Buildings with roof top solar PV and water heaters*

Vertical air-terminals are required for protecting roof mounted installations such as solar PV, water heaters, chillers as well as water tanks. Protection angle should be considered as per Table 6. Vertical air-terminals need to be connected to the air-termination mesh/down-conductors. Metal support structure of these installations shall be bonded to the air-termination mesh/down-conductors. Class I/Class II surge protection devices (SPDs) (*see* **11.6.5**) should be installed in the electrical lines to protect the installations inside the building (typically d.c. SPD for solar PV output at inverter or junction box level and a.c. SPD

Table 6 Maximum Values of Mesh Size and Protection Angle Corresponding to the Class of LPS
(*Clause* 11.5.1.2)

Sl No.	Class of LPS	Mesh Size	Rolling Sphere Radius	Protection Angle with respect to Height				
			r	10 m	20 m	30 m	45 m	60 m
		m	m					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	I	5 × 5	20	45	23	← Cannot be used →		
ii)	II	10 × 10	30	54	38	23	← Cannot be used →	
iii)	III	15 × 15	45	62	48	36	3	Cannot be used
iv)	IV	20 × 20	60	65	54	45	34	23

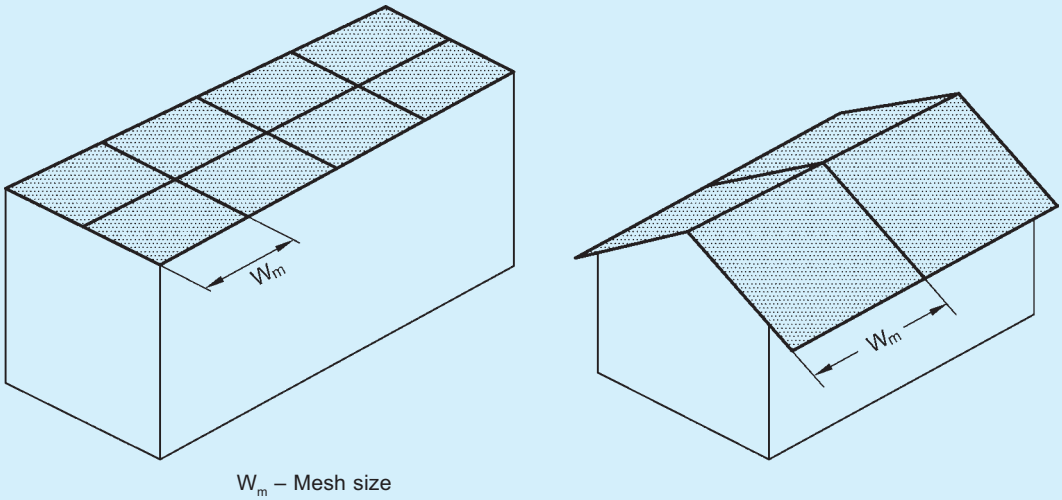
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Key

- H Height of the building over the ground reference plane
- h_1 Physical height of an air-termination rod
- h_2 Height of the air-termination rod over the ground (= h_1 + H)
- α_1 The protection angle corresponding to the air-termination height, $h = h_1$, being the height above the roof surface to be measured (reference plane)
- α_2 The protection angle corresponding to the height, h_2 (= H + h_1)

FIG. 16 PROTECTION ANGLE METHOD OF AIR-TERMINATION DESIGN FOR DIFFERENT HEIGHTS ACCORDING TO TABLE 6

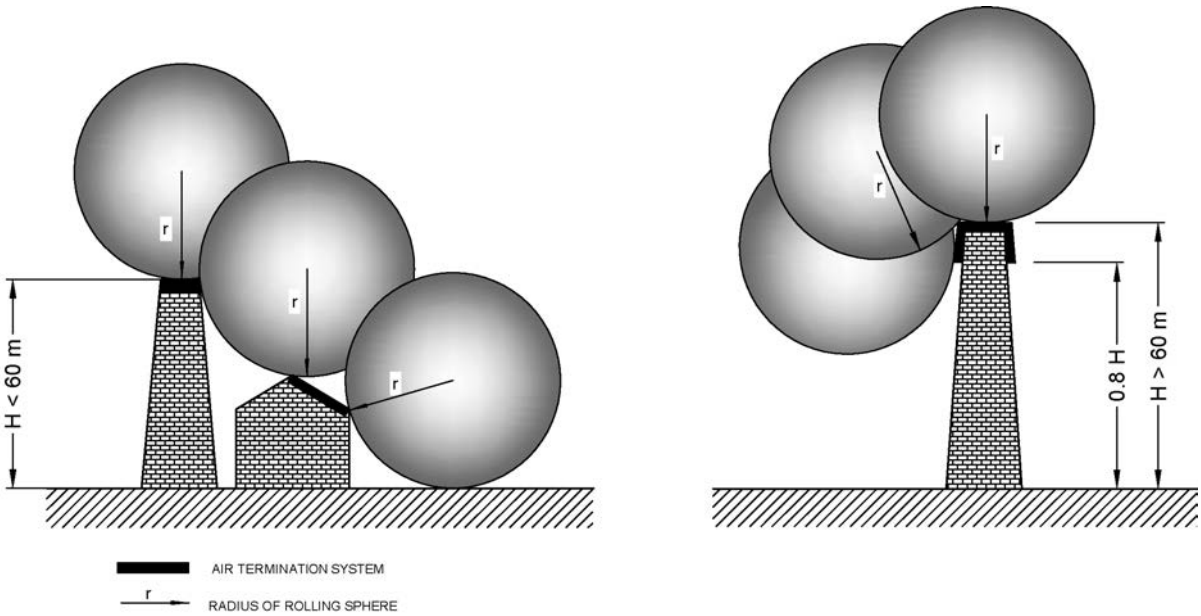


W_m – Mesh size

NOTE — The mesh size should comply with table 6.

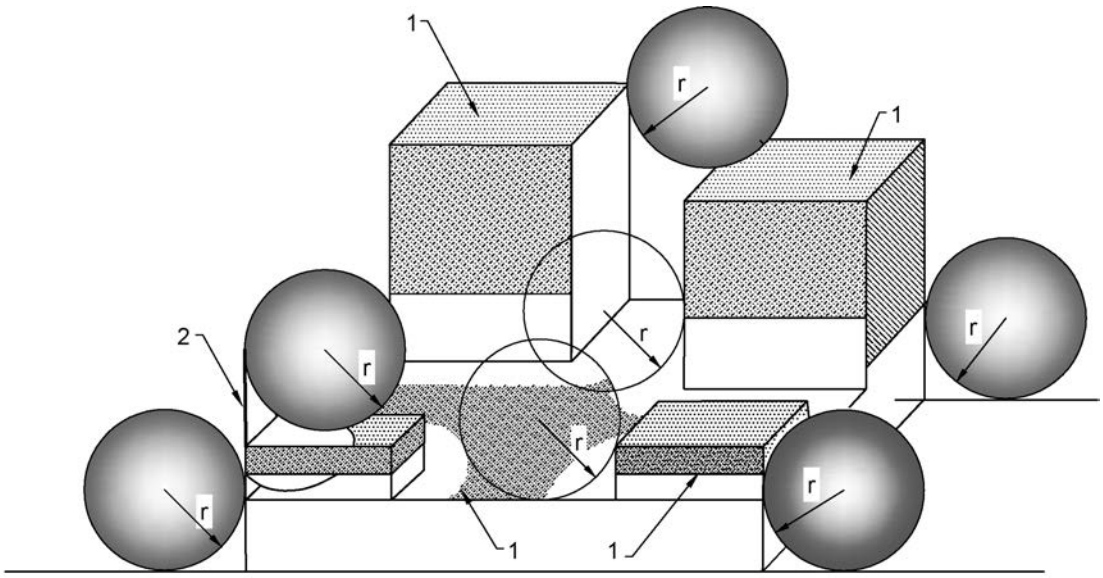
FIG. 17 DESIGN OF AIR-TERMINATION SYSTEM ACCORDING TO MESH METHOD

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NOTE — The rolling sphere, *r* should comply with the selected class of LPS (*see* Table 6).

FIG. 18 DESIGN OF AIR-TERMINATION SYSTEM ACCORDING TO THE ROLLING SPHERE METHOD



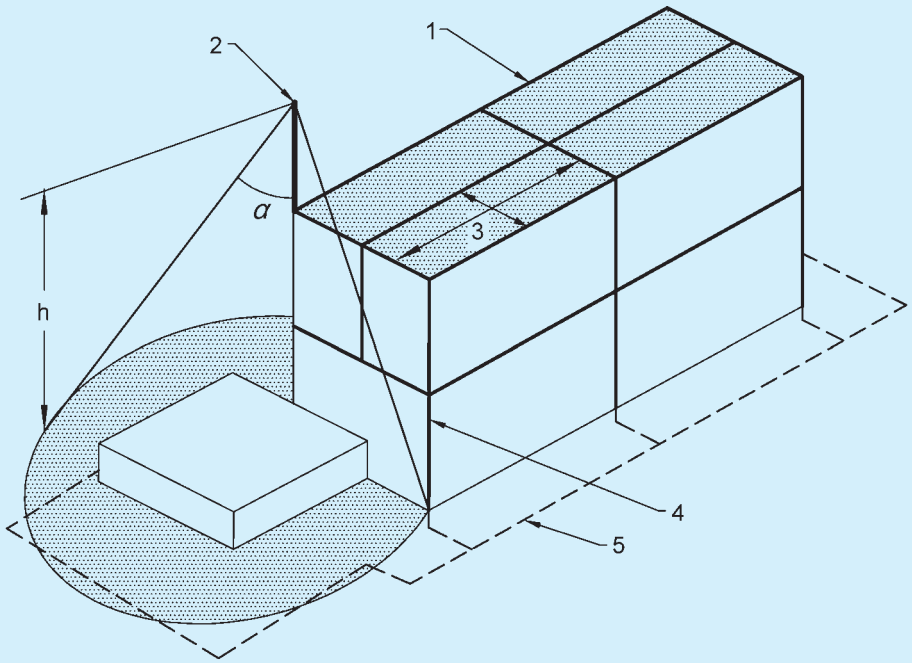
Key

1 Shaded areas are exposed to lightning interception and need protection according to Table 6
2 Mast on the structure
r Radius of rolling sphere according to Table 6

NOTE — Protection against side flashes is required {*see* good practice [8-2(45)] for details}.

FIG. 19 DESIGN OF AIR-TERMINATION CONDUCTOR NETWORK FOR A STRUCTURE WITH COMPLICATED SHAPE

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Key

1 Air-termination conductor (also called as mesh/Faraday cage). *See* Table 6 for mesh size
2 Air-termination rod
3 Mesh size
4 Down-conductor
5 Earthing system with ring conductor
h = Height of the air-terminal above ground level
α = Protection angle

FIG. 20 DESIGN OF AN LPS AIR-TERMINATION ACCORDING TO THE PROTECTION ANGLE METHOD, MESH METHOD AND GENERAL ARRANGEMENT OF AIR-TERMINATION ELEMENTS

for inverter output and mains input). The roof top PV system or 240 V a.c. water heaters or any other equipment should not pose any safety risk related to lightning protection and protection of overall building may be reviewed by the expert after installation of roof top PV system. Necessary measures may then be required to complete the lightning protection arrangement.

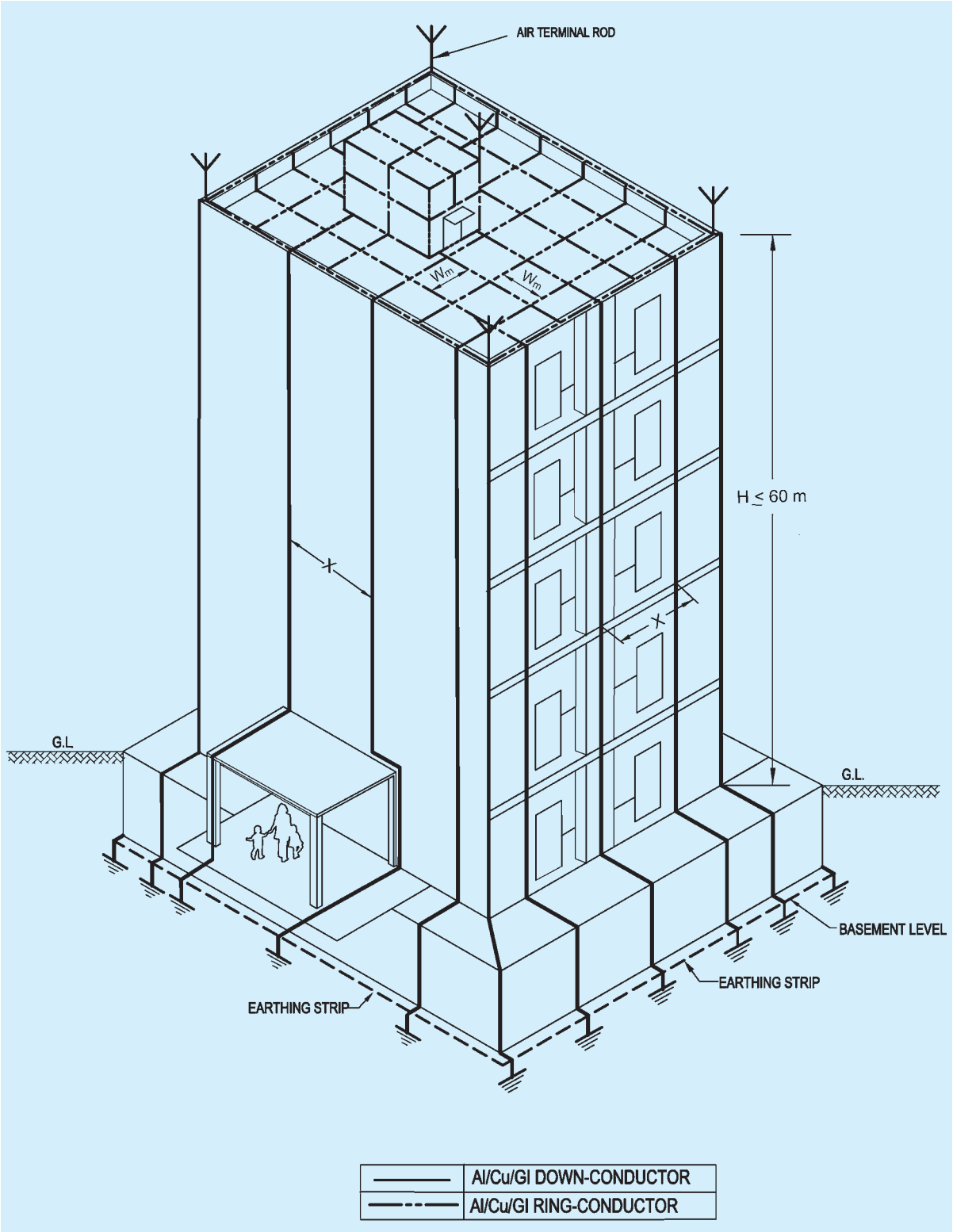
11.5.1.7 *Large solar PV power plants/farms*

Vertical air-terminals for PV modules based on LPL III/IV connected directly to the frame shall protect against direct lightning impact in case of large solar PV power plants/farms. A design according to rolling sphere method should be done for zone of protection (for example, 1 m rod at 0.5 m height from panel at four corners provides protection to approximately 12 m × 9 m area). Maximum height of the air-termination rod above the panel should be restricted to less than 0.5 m considering the influence of shadow of air-terminal in current generation. To reduce step potential, structures should be interconnected with underground earth mats/isolating spark gaps, wherever necessary. The short circuit current/expected fault current should be taken into consideration while designing earthing arrangement or while selection of the suitable SPD so as to withstand the same. The provisions should be made to avoid possible d.c. arcing to avoid fire hazards and for the safety of the working personnel.

11.5.1.8 *Buildings with roof top telecom towers*

The metallic tower itself will act as air-termination. Antennas mounted above these towers (if antenna mounted below to the top of tower by more than 1 m, then no air-terminal is required on top of tower) need air-terminals connected to the main structure. The main structure shall be connected to the air-termination conductors for the balance of the building if available. Two separate down-conductors with a size of minimum 150 mm^2 should be used in addition to regular down-conductors to make the bonding between tower and ring earthing. In order to avoid uncontrolled flash overs and also to protect equipment, which may be mounted

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NOTES

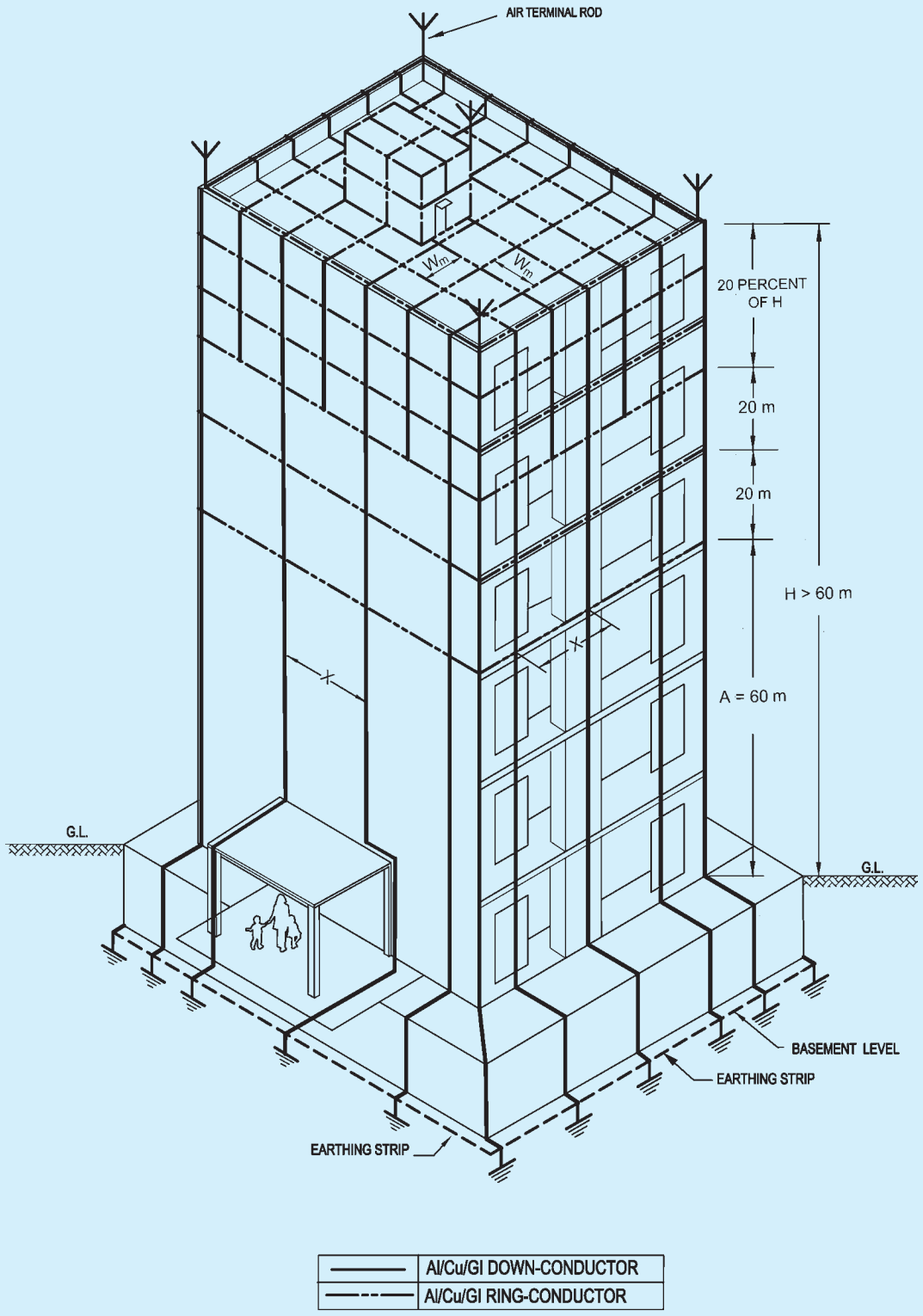
1 Mesh size, W_m shall be as per Table 6.

2 Down-conductor spacing, X, shall be as per Table 7.

21A TYPICAL LIGHTNING PROTECTION SYSTEM FOR BUILDINGS OF HEIGHT, H ≤ 60 m

FIG 21 — (*Continued*)

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NOTES

1 Mesh size, W_m shall be as per Table 6.

2 Down-conductor spacing, X, shall be as per Table 7.

21B TYPICAL LIGHTNING PROTECTION SYSTEM FOR BUILDINGS OF HEIGHT, H > 60 m

FIG. 21 TYPICAL LIGHTNING PROTECTION SYSTEM FOR BUILDINGS

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on the tower itself, special cable with increased dielectric strength as down-conductor should be used. Since these down-conductors are shielded, the area of cross-section will be significantly lower than 50 mm^2 but not less than 16 mm^2, which is sufficient enough to discharge the lightning current.

Every power, coaxial, data and other metallic lines connected between the telecom installation and the other parts of the building shall be protected with Class 1 and Class 2 SPD. It should be ensured that SPDs during their operation do not impede fire safety.

11.5.1.9 *Lightning protection for multi-storeyed car park roofs/helipads*

Air-termination studs (*see* Fig. 22) may be used for lightning protection for multi-storeyed car park roofs/ helipads. Air-termination studs used can be connected to the reinforcement steel of a concrete roof. In the case of roofs where a connection to the reinforcement cannot be made, the roof conductors can be laid in the seams of the carriageway slabs and air-termination studs can be located at the mesh joints. The mesh width shall not exceed the value corresponding to the protection class given in Table 6. The persons and vehicles on this parking area are not protected against direct lightning.

11.5.2 *Down-conductor System*

Down-conductor system is a part of an external LPS intended to conduct lightning current from the air-termination system to the earth-termination system. In order to reduce the probability of damage due to lightning current flowing in the air-termination system, the down-conductors shall be arranged in such a way that from the point of strike to earth,

a) several parallel current paths exist;
b) the length of the current paths is kept to a minimum; and
c) equipotential bonding to conducting parts of the structure is performed.

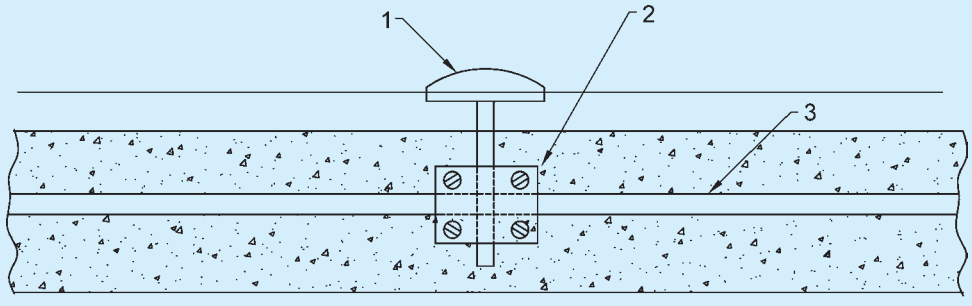
11.5.2.1 Typical values of the distance between down-conductors are given in Table 7. These values can be used for horizontal ring conductors installed for a tall building more than 60 m height. The minimum number of down-conductors shall be 2 (diagonally opposite to each other) for building with an area less than 100 m^2.

Table 7 Minimum Distance Between Down-Conductors
(*Clause* 11.5.2.1)

Sl No.	Class of LPS	Distance m
(1)	(2)	(3)
i)	I	10
ii)	II	10
iii)	III	15
iv)	IV	20

11.5.2.2 Down-conductors shall be installed so that, as far as practicable, they form a direct continuation of the air-termination conductors. It shall be installed straight and vertical such that they provide the shortest and most direct path to earth. The formation of sharp bends and loops shall be avoided. Every down-conductor should be connected to a Type B ring/ foundation earthing. Connection of down-conductor to a Type A earthing is allowed only in case of space constraints or existing buildings, where installation is difficult.

11.5.2.3 While routing the down-conductors, separation distance need to be calculated based on good practice [8-2(45)] and maintained from live parts/services.



Key
1 Air-termination stud
2 Steel conductor connecting to several bars of the reinforcement steel
3 Steel reinforcement to concrete

FIG. 22 TYPICAL AIR-TERMINATION STUDS USED ON CAR PARK ROOFS

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11.5.2.4 Lateral connection of down-conductors at ground level and every 10 m to 20 m of height as a ring conductor as per below table is considered to be good practice. The installation of as many down-conductors as possible, at equal spacing around the perimeter interconnected by ring conductors, reduces the probability of dangerous sparking and facilitates the protection of internal installations {*see* good practice [8-2(45)]}. This condition is fulfilled in metal framework structures and in reinforced concrete structures in which the interconnected steel is electrically continuous.

11.5.2.5 Routing of down-conductors (insulated or uninsulated) through electrical and other service shafts are not allowed as it can create fire and explosion during lightning.

11.5.2.6 Separation distance is the distance required between air-terminals/lightning down-conductor and any conductive/metallic/electrical/ electronic part of a building to avoid uncontrolled flashover. Separation distance (S), in m should be calculated as per the following formula:

$$S = \frac{K_i \times K_c \times l}{K_m}$$

where

K_i = depends on the selected LPL (*see* Table 8);
K_m = depends on the electrical insulation material (*see* Table 9);
K_c = depends on the partial lightning current flowing on the air-termination and the down-conductor (*see* Table 10); and
l = length, in m along the air-termination and the down-conductor from the point where the separation distance is to be considered, to the nearest equipotential bonding point or the earth-termination.

11.5.2.6.1 Cable with increased dielectric strength and tested for lightning current discharge may be used to avoid specific separation distance to live parts of the building {*see* good practice [8-2(45)]}.

11.5.2.7 The down-conductor shall be supported on structure like column at every 1 m using suitable clamps or connectors or exothermic welding. The clamps or connectors or exothermic welding shall be tested for the lightning current as per selected LPL. Reference may be made to table given below and good practice [8-2(45)] for supporting details:

Sl No.	*Arrangement*	*Fixing Centres for Tape, Stranded and Soft Drawn Round Conductors*	*Fixing Centres for Round Solid Conductors*
		mm	mm
(1)	(2)	(3)	(4)
i)	Horizontal conductors on horizontal surfaces	1 000	1 000
ii)	Horizontal conductors on vertical surfaces	500	1 000
iii)	Vertical conductors from the ground to 20 m	1 000	1 000
iv)	Vertical conductors from 20 m and thereafter	500	1 000

NOTES
1 This table does not apply to built -in type fixings, which may require special considerations.
2 Assessment of environmental conditions (that is, expected wind load) should be undertaken and fixing centres different from those recommended may be found to be necessary.

11.5.2.8 At the structures, which cannot be punctured for holding the down-conductors, like tin roofs, glass structures, etc, the down-conductors should be supported with adhesive type clamps tested for weather durability and for withstanding lightning currents as per selected LPL.

11.5.2.9 The wind speed shall be taken into account while mounting the air-termination and down-conductor system {*see* good practice [8-2(45)]}.

11.5.3 *Earth-termination System*

Earth-termination system is a part of an external LPS which is intended to conduct and disperse lightning current into the earth. When dealing with the dispersion of the lightning current (high frequency behaviour) into the ground, whilst minimizing any potentially dangerous over-voltages, the shape and dimensions of the earth-termination system are the important criteria. In general, a low earthing resistance (if possible lower than 10 ohm when measured at low frequency) is recommended. From the viewpoint of lightning protection, a single integrated structure earth-termination system is preferable and is suitable for all purposes (that is, lightning protection, power systems and telecommunication systems).

Type A earth-termination comprising of vertical/ horizontal conductor or Type B earth-termination comprising of ring earthing/foundation earthing shall be used satisfying the requirements of this Code as well as good practice [8-2(45)].

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Table 8 Isolation of External LPS — Approximated Values of Coefficient, K_c
(*Clause* 11.5.2.6)

Sl No.	Number of Down-conductors, *n*	K_c
(1)	(2)	(3)
i)	1 (only in case of an isolated LPS)	1
ii)	2	0.66
iii)	3 and more	0.44

NOTE — Values of Table 8 apply for all Type B earthing arrangements and for Type A earthing arrangements, provided that the earth resistance of neighbouring earth electrodes do not differ by more than a factor of 2. If the earth resistance of single earth electrodes differ by more than a factor of 2, $K_c = 1$ is to be assumed.

Table 9 Isolation of External LPS — Values of Coefficient, K_i
(*Clause* 11.5.2.6)

Sl No.	Class of LPS	K_i
(1)	(2)	(3)
i)	I	0.08
ii)	II	0.06
iii)	III and IV	0.04

Table 10 Isolation of External LPS — Values of coefficient, K_m
(*Clause* 11.5.2.6)

Sl No.	Material	K_m
(1)	(2)	(3)
i)	Air	1
ii)	Concrete, bricks, wood	0.5

NOTES
1 When there are several insulating materials in series, it is a good practice to use the lower value for K_m.
2 In using other insulating materials, construction guidance and the value of K_m should be provided by the manufacturer.

11.5.3.1 *Type A earthing*

Length of the earth electrode depends on the soil resistivity and class of LPS {*see* [8-2(45)] for details and Table 11 for vertical earth electrode}. For Type A, minimum number of earth electrodes should be 2.

11.5.3.2 *Type B earthing*

This type of arrangement comprises either a ring conductor external to the structure to be protected, in contact with the soil for at least 80 percent of its total length, or a foundation earth electrode. Such earth electrodes may also be meshed. For the ring earth electrode (or foundation earth electrode), the area enclosed by the ring earth electrode (or foundation earth electrode) shall be not less than the value of Type A earthing as given in Table 11 {*see also* [8-2(45)]}.

Table 11 Minimum Length of Vertical Earth Electrode
(*Clause* 11.5.3.1)

Sl No.	Class of LPS	Typical Length of Each Vertical Earth Electrode Based on Soil Resistivity m			
		Up to 500 Ω-m	1 000 Ω-m	2 000 Ω-m	3 000 Ω-m
(1)	(2)	(3)	(4)	(5)	(6)
i)	I	2.5	10	25	40
ii)	II	2.5	5	15	25
iii)	III	2.5	2.5	2.5	2.5
iv)	IV	2.5	2.5	2.5	2.5

11.5.3.3 In structures where only electrical systems are provided, a Type A earthing arrangement may be used, but a Type B earthing arrangement is preferable. In structures with electronic systems, a Type B earthing arrangement is recommended.

11.5.3.4 In industrial and commercial structures, the ring earth electrode around the structure or the ring earth electrode in the concrete at the perimeter of the foundation, should be integrated with a meshed network under and around the structure, having a mesh width of typically 5 m. This greatly improves the performance of the earth-termination system. If the basement's reinforced concrete floor forms a well-defined interconnected mesh and is connected to the earth-termination system, typically at every 5 m, the same will also be suitable {*see* good practice [8-2(45)]}.

11.5.3.5 For buildings without steel reinforced foundation (brickwork/stones) a Type B earth-termination (ring earthing) shall be installed.

11.5.3.6 Where large numbers of people frequently assemble in an area adjacent to the structure to be protected, further potential control for such areas should be provided. More ring earth electrodes should be installed at distances of approximately 3 m from the first and subsequent ring conductors. Ring electrodes further from the structure should be installed more deeply below the surface, that is, those at 4 m from the structure at a depth of 1 m, those at 7 m from the structure at a depth of 1.5 m and those at 10 m from the structure at a depth of 2 m. These ring earth electrodes should be connected to the first ring conductor by means of radial conductors.

11.5.3.7 For buildings integrating structural steel as down-conductor and earth-termination, earth resistivity

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measurements are not required. Proper drawings should be made based on the actual installation and submitted to authorities if necessary. *See also* good practice [8-2(45)].

11.5.4 *Use of Natural Components*

Natural components are conductive components installed in a building not specifically for lightning protection which can be used to provide the function of one or more parts of the LPS.

Natural components made of conductive materials, which will always remain in/on the structure (for example, interconnected steel-reinforcement, metal framework of the structure, steel roof, metal facade, handrails, etc) should be used as parts of an LPS such as air-termination, down-conductor and earthing, if it satisfies the requirement according to good practices [8-5(44)] and [8-5(45)]. Bonding of different metallic installations in the building should be done to avoid dangerous potential differences which results in flashover. This integrated method is not only economical but does not influence or spoil the aesthetics of the building. It also reduces the failure of electronic equipment inside the building from radiated lightning effects.

In case of natural down-conductors combined with foundation earth electrodes, test joints are not required and earth resistance measurements are not necessary (*see also* **11.5.3.7**)

11.5.4.1 *Continuity of steelwork in reinforced concrete structures*

Steelwork within reinforced concrete structures is considered to be electrically continuous provided that the major part of interconnections of vertical and horizontal bars are welded or otherwise securely connected. Connections of vertical bars shall be welded, clamped or overlapped a minimum of 20 times their diameters and bound or otherwise securely connected. For new structures, the connections between reinforcement elements shall be specified by the designer or installer, in cooperation with the builder and the civil engineer. *See* [8-2(45)] for details.

For structures utilizing steel reinforced concrete (including pre-cast, pre-stressed reinforced units), the electrical continuity of the reinforcing bars shall be determined by electrical testing between the uppermost part and ground level (*see* Fig. 23). The overall electrical resistance should not be greater than 0.2 Ω, measured using test equipment suitable for this purpose. If this value is not achieved, or it is not practical to conduct such testing, the reinforcing steel shall not be used as a natural down-conductor. In this case it is recommended that an external down-conductor be installed. In the case of structures of pre-cast reinforced concrete, the electrical continuity of the reinforcing steel shall be established between individual adjacent pre-cast concrete units. *See* [8-2(45)] for details.

11.5.4.2 *Bonding network*

A low impedance bonding network is needed to avoid dangerous potential differences between all equipment inside the building. Moreover, such a bonding network also reduces the magnetic field, thereby reduces the radiated surges inside the building and provides more protection for electrical/electronic equipment {*see* good practice [8-5(48)]}.

This can be realized by a meshed bonding network integrating conductive parts of the structure, or parts of the internal systems, and by bonding metal parts or conductive services at the boundary of each LPZ directly or by using suitable SPDs.

The bonding network can be arranged as a three-dimensional meshed structure with a typical mesh width of 5 m (*see* Fig. 24 and Fig. 25). This requires multiple interconnections of metal components in and on the structure (such as concrete reinforcement, elevator rails, cranes, metal roofs, metal facades, metal frames of windows and doors, metal floor frames, service pipes and cable trays). Bonding bars (for example, ring bonding bars, several bonding bars at different levels of the structure) and magnetic shields of the LPZ shall be integrated in the same way.

Conductive parts (for example, cabinets, enclosures, racks) and the protective earth conductor (PE) of the internal systems shall be connected to the bonding network {*see* good practice [8-5(48)]}.

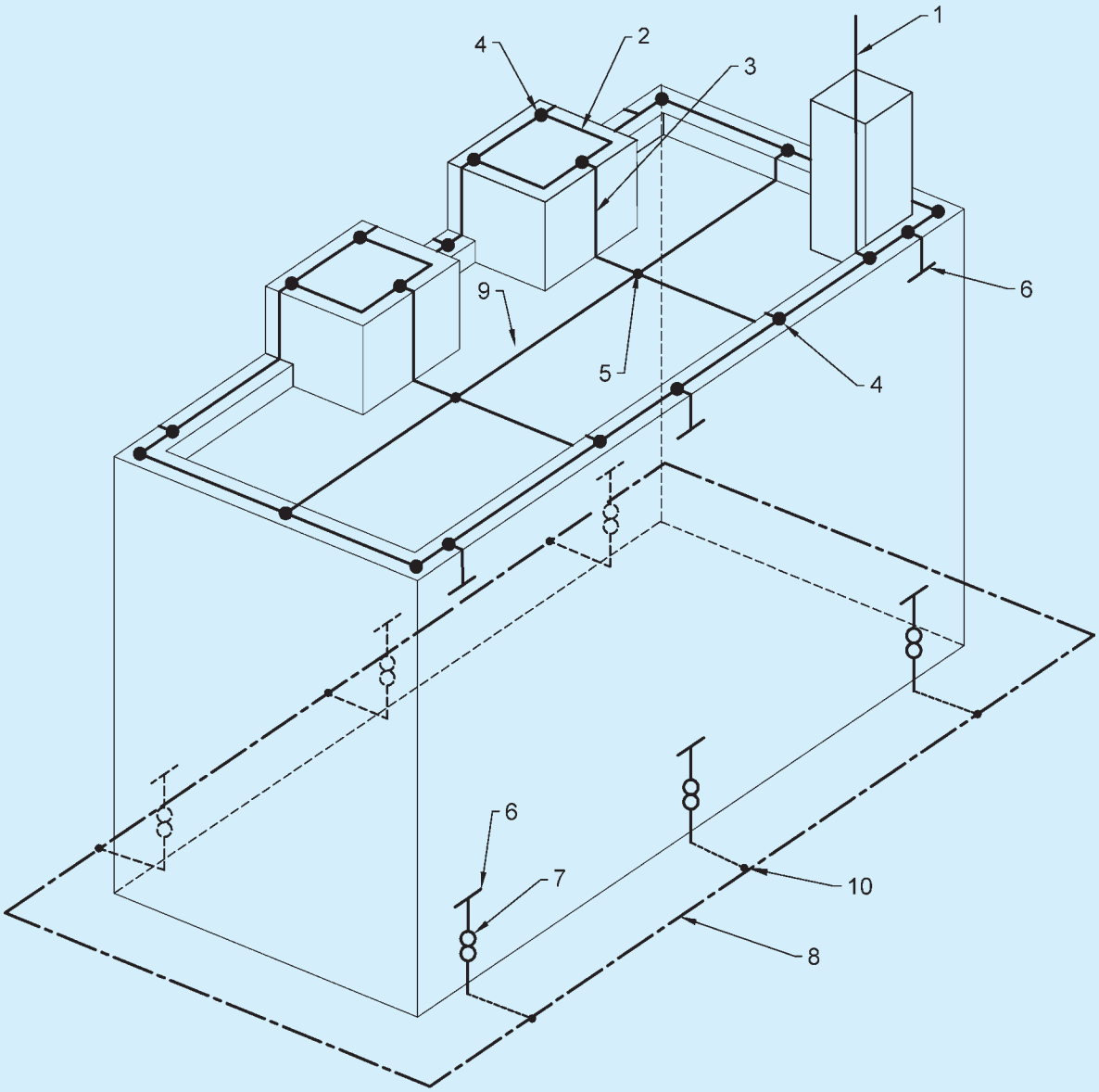
11.5.5 *Materials and Dimensions*

Copper and aluminium are recommended for exposed areas on installations required to have a long life. Galvanized steel may be preferred for temporary installations such as exhibition centres. Although it is a common practice to use material in the form of strip for horizontal air-terminations, down-conductors and bonds, it is more convenient to use round material, particularly as it facilitates the making of bends in any plane. If different materials are used in an installation, care should be taken to avoid galvanic corrosion by the use of bi-metallic connectors. *See* Tables 12 to 14 for details.

11.5.6 Protection measures against injury to living beings due to touch voltage and step voltage shall be provided in accordance with good practice [8-2(45)].

11.5.7 Inspection of the LPS shall be done as per the good practice [8-2(45)].

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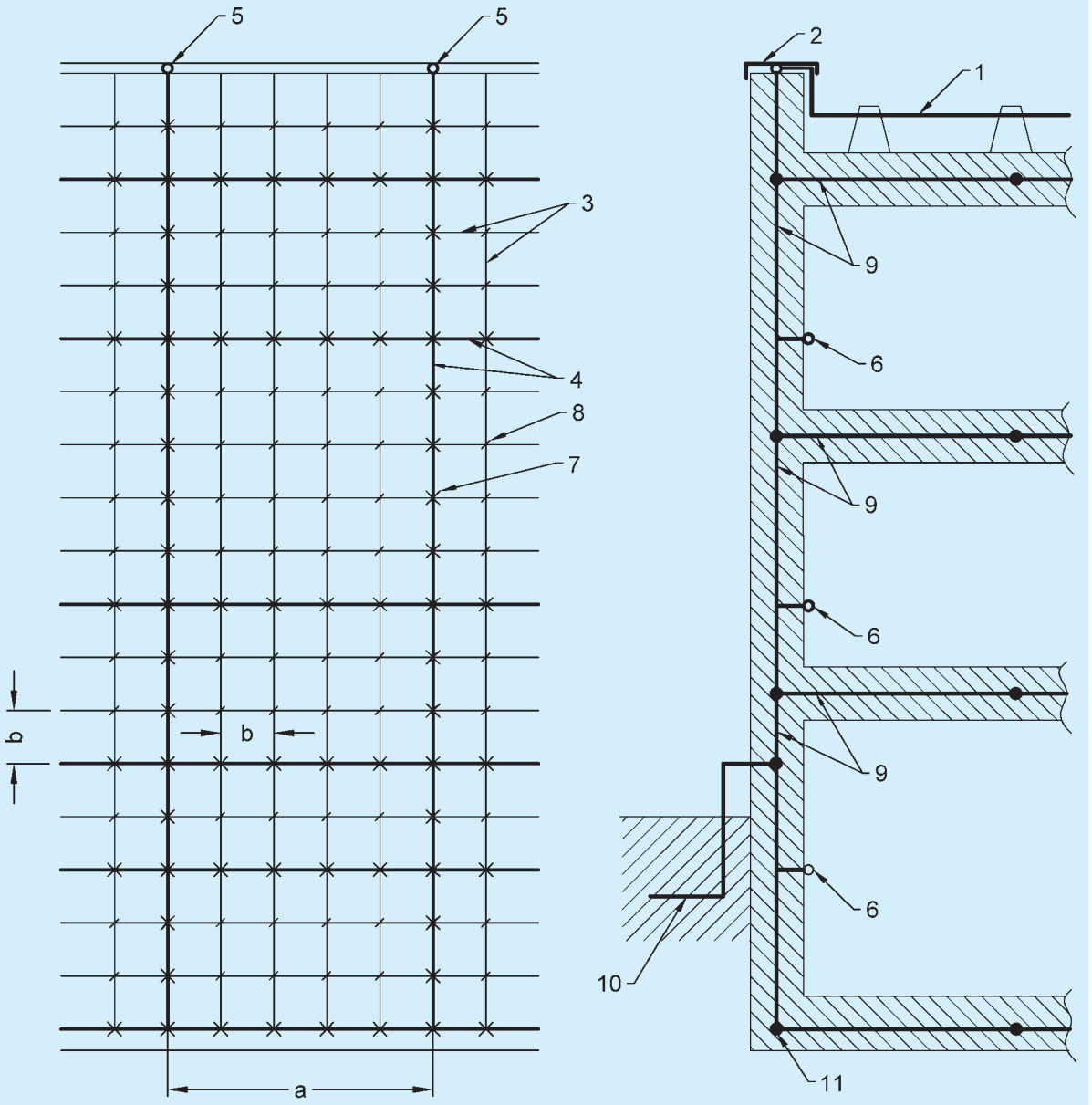
Key

1 Air-termination rod
2 Horizontal air-termination conductor
3 Down-conductor
4 T-type joint
5 Cross type joint
6 Connection to steel reinforcing rods {*see* **E-4.3.3** and **E-4.3.6** of good practice [8-2(45)]}
7 Test joint
8 Type B earthing arrangement, ring electrode
9 Flat roof with roof fixtures
10 T-type joint — corrosion resistant

NOTE — The steel reinforcement of the structure should comply with available Indian Standards. All dimensions of the LPS should comply with the selected protection level.

FIG. 23 CONSTRUCTION OF EXTERNAL LPS ON A STRUCTURE OF STEEL-REINFORCED CONCRETE USING THE REINFORCEMENT OF THE OUTER WALLS AS NATURAL COMPONENTS

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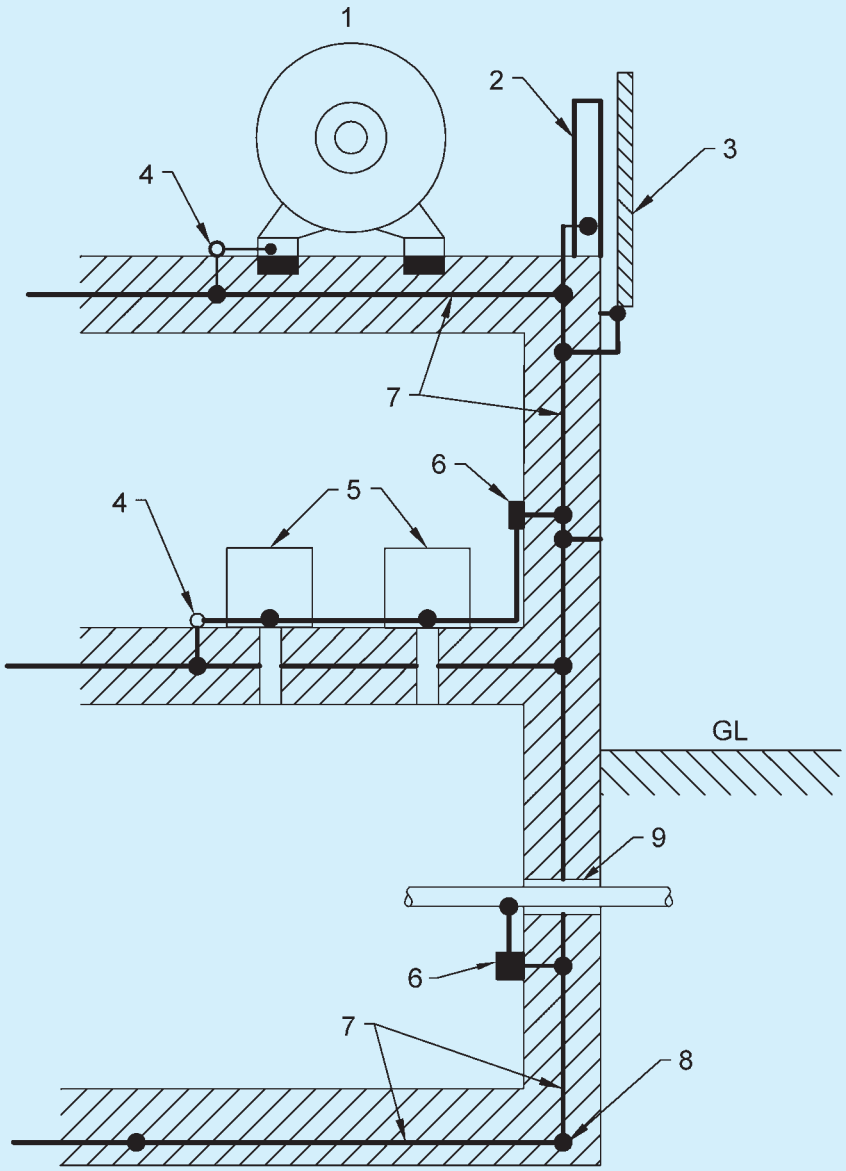


Key

1 Air-termination conductor
2 Metal covering of the roof parapet
3 Steel reinforcing rods
4 Mesh conductors superimposed on the reinforcement
5 Joint of the mesh conductor
6 Joint of the internal bonding bar
7 Connection made by welding or clamping
8 Arbitary connection
9 Steel reinforcement in concrete (with super imposed mesh conductors)
10 Ring earthing electrode (if any)
11 Foundation earthing electrode
a Typical distance of 5 m for superimposed mesh conductor
b Typical distance of 1 m for connecting this mesh with the reinforcement

FIG. 24 UTILIZATION OF REINFORCING RODS OF A STRUCTURE FOR EQUIPOTENTIAL BONDING

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Key

1 Electric power equipment
2 Steel girder
3 Metal covering of the facade
4 Bonding joint
5 Electrical or electronic equipment
6 Bonding bar
7 Steel reinforcement in concrete (with superimposed mesh conductors)
8 Foundation earthing electrode
9 Common inlet for different services

FIG. 25 EQUIPOTENTIAL BONDING IN A STRUCTURE WITH STEEL REINFORCEMENT

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Table 12 LPS Materials and Conditions of Use[1)]
(*Clause* 11.5.5)

Sl No.	Material	Use			Corrosion		
		In Open Air	In Earth	In Concrete	Resistance	Increased by	May be destroyed by galvanic coupling with
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds Organic materials	—
		Stranded	Stranded	Stranded			
		—	As coating	As coating			
ii)	Hot galvanized steel[2), 3) and 4)]	Solid	Solid	Solid	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
		Stranded[5)]		Stranded[5)]			
iii)	Steel with electro-deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	
iv)	Stainless steel	Solid	Solid	Solid	Good in many environments	High chlorides content	—
		Stranded	Stranded	Stranded			
v)	Aluminium	Solid	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
		Stranded					

1) This table gives general guidance only. In special circumstances more careful corrosion immunity considerations are required.
2) Galvanized steel may be corroded in clay soil or moist soil.
3) Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.
4) Galvanized steel in contact with reinforcement steel in concrete may, under certain circumstances, cause damage to the concrete.
5) Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.

11.6 Protection of Electrical/Electronic Systems within Structures

11.6.1 The internal LPS shall avoid the occurrence of dangerous sparking within the structure to be protected due to lightning current flowing in the external LPS or in other conductive parts of the structure. Dangerous sparking between different parts can be avoided by means of equipotential bonding or electrical insulation between the parts.

Permanent failure of electrical and electronic systems can be caused by the lightning electromagnetic impulse (LEMP) *via*:

a) Conducted and induced surges transmitted to equipment *via* connecting wiring; and
b) The effects of radiated electromagnetic fields directly into equipment itself.

Surges to the structure can originate from sources external to the structure or from within the structure itself, and

1) surges which originate externally from the structure are created by lightning flashes striking incoming lines or the nearby ground, and are transmitted to electrical and electronic systems within the structure *via* these lines.
2) surges which originate internally within the structure are created by lightning flashes striking the structure itself or the nearby ground. Surges can also originate internally within the structure from switching effects (for example, switching of inductive loads).

The coupling can arise from different mechanisms such as,

i) resistive coupling (for example, the earth impedance of the earth-termination system or the cable shield resistance); and
ii) magnetic field coupling (for example, caused by wiring loops in the electrical and electronic system or by inductance of bonding conductors).

In general electrical and electronic systems are subject to damage from a lightning electromagnetic impulse (LEMP). The wave shapes of lightning impulse and surges are given in good practices [8-2(46)] and [8-2(48)]. The lightning current parameters given under **11.2** may also be referred. LEMP protection measures (SPM) need to be provided to avoid failure of internal systems. The design of SPM should be carried out by experts in lightning and surge protection who possesses a broad knowledge of installation practices of lightning protection systems.

11.6.2 *Lightning Protection Zone Concept*

Protection against LEMP is based on the lightning

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Table 13 Material, Configuration and Minimum Cross-Sectional Area of Air-Termination Conductors and Rods, Earth Lead-in Rods and Down-Conductors[1)]
(*Clause* 11.5.5)

Sl No.	Material	Configuration	Minimum Cross-Sectional Area mm^2
(1)	(2)	(3)	(4)
i)	Copper, Tin plated Copper	Solid tape	50
		Solid round[2)]	50
		Stranded[2)]	50
		Solid round[3)]	176
ii)	Aluminium	Solid tape	70
		Solid round	50
		Stranded	50
iii)	Aluminium alloy	Solid tape	50
		Solid round	50
		Stranded	50
		Solid round[3)]	176
iv)	Copper coated aluminium alloy	Solid round	50
v)	Hot dipped galvanized steel	Solid tape	50
		Solid round	50
		Stranded	50
		Solid round[3)]	176
vi)	Copper coated steel	Solid round	50
		Solid tape	50
vii)	Stainless steel	Solid tape[4)]	50
		Solid round[4)]	50
		Stranded	50
		Solid round[3)]	176

[1)] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of the IEC 62561 series.
[2)] 50 mm^2 (8 mm diameter) may be reduced to 25 mm^2 in certain application where mechanical strength is not an essential requirement. Consideration should in this case, given to reducing the space between fasteners.
[3)] Applicable for air-termination rods and earth lead-in rods. For air-termination rods where mechanical stress such as wind loading is not critical, a 9.5 mm diameter, 1 m long rod may be used.
[4)] If the thermal and mechanical considerations are important, then these values should be increased to 75 mm^2.

protection zone (LPZ) concept. The zone containing systems to be protected shall be divided into LPZs. These zones are theoretically assigned part of space (or of an internal system) where the LEMP severity is compatible with the withstand level of the internal system. Successive zones are characterized by significant changes in the LEMP severity. The boundary of an LPZ is defined by the protection measures employed.

11.6.3 *Equipment Protection Principles*

11.6.3.1 For protection against the effects of radiated electromagnetic fields impinging directly onto the equipment, SPM consisting of spatial shields and/or shielded lines, combined with shielded equipment enclosures should be used.

11.6.3.2 For protection against the effects of conducted and induced surges being transmitted to the equipment *via* connection wiring, SPM consisting of a coordinated SPD system should be used. SPD to be used according to their installation position are as follows:

a) *At the line entrance into the structure (at the boundary of LPZ 1, for example at the main distribution panel):*
   1) SPD tested with I_{imp} (typical waveform 10/350, for example, SPD tested according to class I); and
   2) SPD tested with I_n (typical waveform 8/20, for example, SPD tested according to class II).

b) *Close to the apparatus to be protected (at the boundary of LPZ 2 and higher, for example, at secondary distribution board, or at a socket outlet):*
   1) SPD tested with I_n (typical waveform 8/20

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Table 14 Material Configuration and Minimum Dimensions of Earth Electrodes[1) and 2)]
(*Clause* 11.5.5)

Sl No.	Material	Configuration	Minimum Dimensions		
			Earth Rod Diameter mm	Earth Conductor mm^2	Earth Plate mm
(1)	(2)	(3)	(4)	(5)	(6)
i)	Copper, Tin plated copper	Stranded		50	
		Solid round	15	50	
		Solid Tape		50	
		Pipe	20		
		Solid plate			500 × 500
		Lattice plate[3)]			600 × 600
ii)	Hot dipped galvanized steel	Solid round	14	78	
		Pipe	25		
		Solid tape		90	
		Solid plate			500 × 500
		Lattice plate			600 × 600
		Profile	[4)]		
iii)	Bare steel[5)]	Stranded		70	
		Sold round		78	
		Solid tape		75	
iv)	Copper coated steel	Solid round	14[6)]	50	
		Solid tape		90	
v)	Stainless steel[7)]	Solid round	15	78	
		Solid tape		100	

[1)] Mechanical and electrical characteristics as well as corrosion resistance properties shall meet the requirements of IEC 62561 'Lightning protection system components (LPSC)' series.
[2)] In case of a type B arrangement foundation earthing system, the earth electrode shall be correctly connected at least every 5 m with the reinforcement steel.
[3)] Lattice plate constructed with a minimum total length of conductor of 4.8 m.
[4)] Different profiles are permitted with a cross-section of 290 mm^2 and a minimum thickness of 3 mm, for example, cross profile.
[5)] Shall be embedded in concrete for a minimum depth of 50 mm.
[6)] 250µm minimum radial copper coating, with 99.9 percent copper content
[7)] Chromium ≥ 16 percent, nickel ≥ 5 percent, molybdenum ≥ 2 percent, carbon ≤ 0.08 percent.

for example, SPD tested according to class II); and

2) SPD tested with a combination wave (typical waveform 8/20 for example, SPD tested according to class II).

11.6.3.3 Failures of equipment due to electromagnetic fields impinging directly onto the equipment can be considered negligible provided the equipment complies with the relevant radio frequency emission and immunity (EMC) product standards. In general, equipment is required to comply with the relevant EMC product standards therefore SPM consisting of a coordinated SPD system is usually considered sufficient to protect such equipment against the effects of LEMP. For equipment not complying with the relevant EMC product standards, SPM consisting of a coordinated SPD system as well as additional magnetic shielding measures shall be considered. Coordinated SPD protection should ensure the voltage impulses due to conducted surges are less than the voltage impulse withstanding capacity of the equipment as well as shielding measures should ensure the radiated surges are within the withstanding capacity of the equipment.

11.6.3.4 *Design of SPM*

SPM can be designed for protection of equipment against surges and electromagnetic fields, as given below. *See* good practice [8-2(48)] for some examples of SPM using protection measures, such as LPS, magnetic shields and coordinated SPD systems (*see* **11.6.5**).

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a) SPM employing spatial shields and a coordinated SPD system will protect against radiated magnetic fields and against conducted surges. Cascaded spatial shields and coordinated SPDs can reduce the magnetic field and surges to a lower threat level.

b) SPM employing a spatial shield of LPZ 1 and an SPD at the entry of LPZ 1 can protect equipment against the radiated magnetic field and against conducted surges.

NOTE — The protection would not be sufficient if the magnetic field remains too high (due to low shielding effectiveness of LPZ 1), or if the surge magnitude remains too high (due to a high voltage protection level of the SPD and due to the induction effects onto wiring downstream of the SPD).

c) SPM using shielded lines, combined with shielded equipment enclosures, will protect against radiated magnetic fields. The SPD at the entry of LPZ 1 will provide protection against conducted surges. To achieve a lower threat level (in one step from LPZ 0 to LPZ 2), a special SPD may be required (for example additional coordinated stages inside) to reach a sufficient low voltage protection level.

d) SPM using a coordinated SPD system is only suitable to protect equipment which is insensitive to radiated magnetic fields, since the SPDs will only provide protection against conducted surges. A lower threat surge level can be achieved using coordinated SPDs.

NOTES

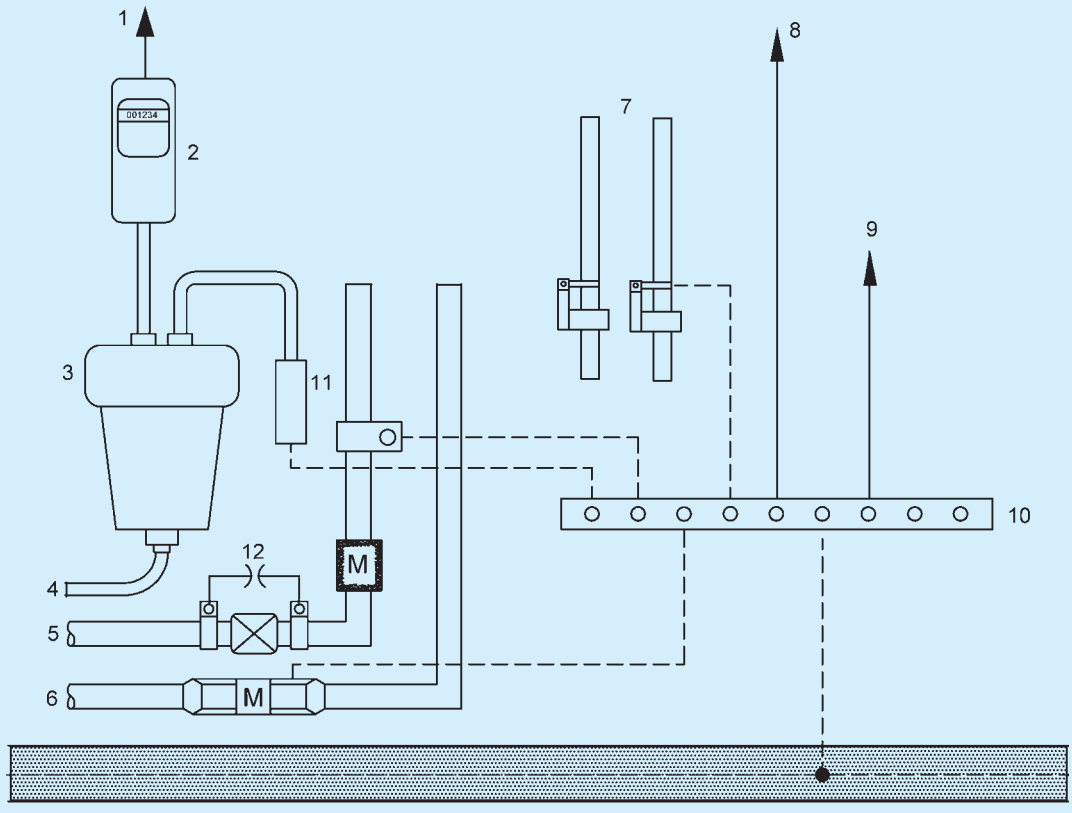
1 Solutions in accordance with (a) to (c) are recommended especially for equipment which does not comply with relevant EMC product standards.

2 An LPS in accordance with good practice [8-2(45)] that employs only equipotential bonding SPDs provides no effective protection against failure of sensitive electrical and electronic systems. The LPS can be improved by reducing the mesh dimensions and selecting suitable SPDs, so as to make it an effective component of the SPM.

11.6.4 *Equipotentialization of Services to LPS*

Equipotentialization is achieved by interconnecting the LPS with structural metal parts, metal installations, internal systems, external conductive parts and lines connected to the structure. *See* Fig. 26.

Interconnection can be done with bonding conductors,



Key

1 Power to user
2 Power meter
3 House connection box
4 Power from utility
5 Gas
6 Water
7 Central heating system
8 Electronic appliances
9 Screen of antenna cable
10 Equipotential bonding bar
11 Surge protection device
12 Isolating spark plug
M Meter

FIG. 26 EXAMPLE OF AN EQUIPOTENTIAL BONDING ARRANGEMENT

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where the electrical continuity is not provided by natural bonding or by using surge protective devices (SPD's), where direct connections with bonding conductors is not feasible (for example, installation of SPD's for power, data, telecom lines, etc). It contains at least one non-linear component to ensure perfect equipotential bonding. All SPD's at the service entrance to an installation should be able to divert 10/350 µS impulse current depending upon selected level of protection. A three phase four wire system should be designed for 50 percent of the I_{imp} of selected LPS and single phase two wire system should be designed for 25 percent of the I_{imp} of selected LPS. The lightning current distribution for three phase four wire system is given in Fig. 27 {*see also* good practice [8-2(46)]}.

11.6.5 *Protection Measures with Surge Protection Devices (SPD's)*

11.6.5.1 Lightning surges frequently cause failure of electrical and electronic systems due to insulation breakdown or when over voltages exceed the equipment's common mode insulation level. Power line protection is fundamental, however equal importance should be given to data, communication and instrumentation lines of the equipment that need protection. Equipment is protected, if its rated impulse withstand voltage U_W at its terminals is greater than the surge overvoltage between the live conductors and earth. If not, an SPD shall be installed.

Implementing coordinated SPD's will provide protection against radiated surges for equipment {*see* good practice [8-2(48)]}. Shielding and routing of power and data lines, bonding of services and various lightning protection zones (LPZ) {*see* good practice [8-2(48)]} and earthing also plays major role in protecting electrical and electronic equipment.

SPD's are used to protect under specified conditions, electrical systems and equipment against various over voltages and impulse currents such as lightning and switching surges. SPD shall be selected according to their environmental conditions and the acceptable failure rates of the equipment and the SPD's.

11.6.5.2 *Failure of SPDs*

Possibility of failure of any line to neutral or neutral to earth connected SPDs should not be ruled out, hence measures should be taken within the SPD for safe failure or withstand in worst conditions. SPD can fail in open or short modes. SPD should not create a fire hazard during failure. Safe failure mode is expected from the SPD.

11.6.5.3 *Status indicators*

Each SPD should have inbuilt health indicator so as to show if protection is available. SPD should be installed in a way that visual inspection is easily possible. Failed SPD shall be replaced.

11.6.5.4 SPD's for power line need to be installed according to the type of service such as TN, TT, IT, etc. In general, the SPDs connected as per connection diagram given in Fig. 28 (informative) is suitable for TT connections. Reference may be made to relevant Indian Standard for such installations.

11.6.5.5 *Selection of SPD's*

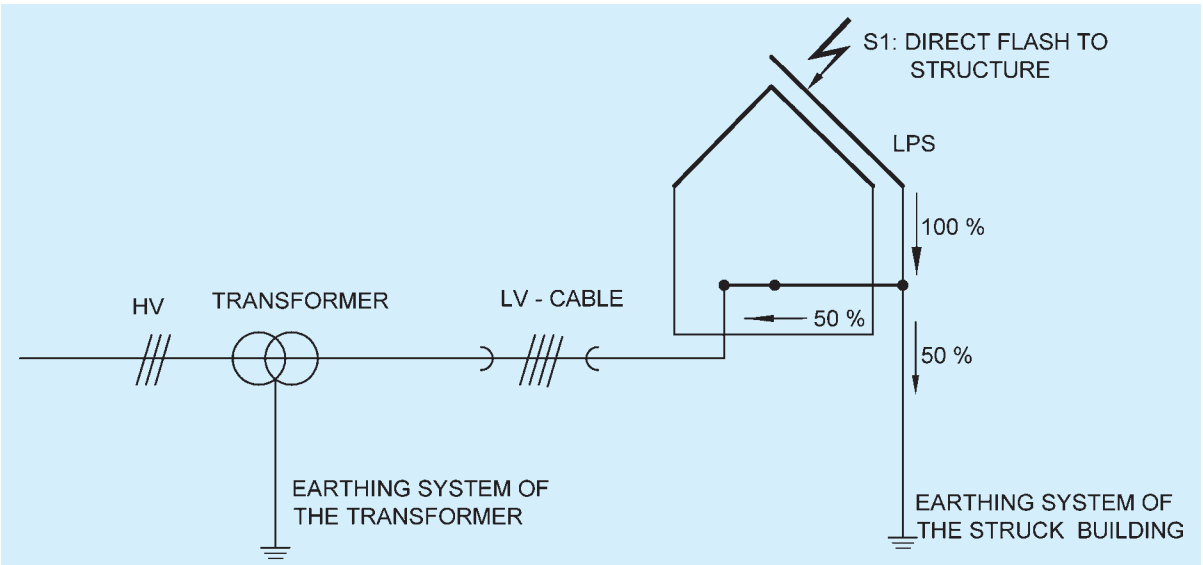
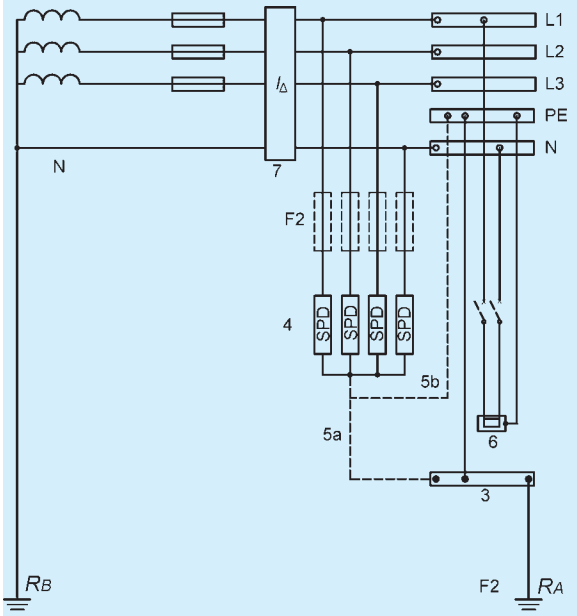


FIG. 27 BASIC EXAMPLE OF BALANCED CURRENT DISTRIBUTION

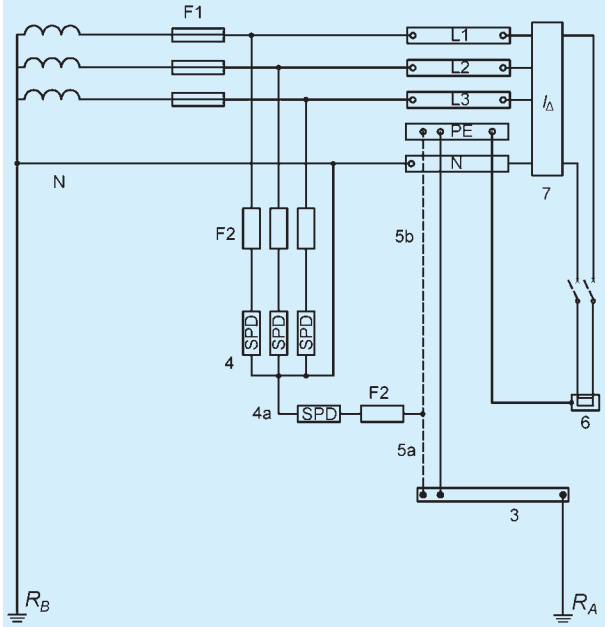
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Key

3 Main earthing terminal or bar
4 Surge protection devices providing protection against overvoltages of category II (either 5a and/or 5b)
5 Earthing connection of SPDs
6 Equipment to be protected
7 Residual current protective device (RCD)
F1 Protective device at the origin of installation
F2 Protective device required by the manufacturer of the SPD
R_A Earthing electrode (earthing resistance) of the installation
R_B Earthing electrode (earthing resistance) of the supply system

28A SPDs ON THE LOAD SIDE OF RCD



Key

3 Main earthing terminal or bar
4 Surge protection devices
4a Surge protection devices (a combination of 4-4a providing protection against overvoltages of category II (either 5a and/or 5b)
5 Earthing connection of SPDs
6 Equipment to be protected
7 Residual current protective device (RCD), placed either upstream or down stream of the bus bar
F1 Protective device at the origin of the installation
F2 Protective device required by the manufacturer of the SPDs
R_A Earthing electrode (earthing resistance) of the installation
R_B Earthing electrode (earthing resistance) of the supply system
F2 is required if F1 is more than specified value of back up fuse by manufacturer (optional for N-PE connected SPD)

28B SPDs ON THE SUPPLY SIDE OF RCD

FIG. 28 TYPICAL INSTALLATION OF SPDs IN TT SYSTEM

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SPD(s) need to be selected based on the place of installation as well the impulse voltage withstanding capacity of the equipment. I_{imp}, and I_n, are test parameters used to categorize Class I and Class II SPD(s). They are related to the maximum values of discharge currents, which are expected to occur at the LPL probability level at the location of installation (LPZ) of the SPD in the system. I_n is associated with Class II tests and I_{imp} is associated with Class I tests.

11.6.5.5.1 If no risk analysis according to good practice [8-2(47)] has been carried out or if the current value of SPD cannot be established, Class I SPDs should be installed with an I_{imp} not less than 12.5 kA (10/350 µS) for connection according to Fig. 28A or between L to N or PE. For connection according to Fig. 28B, I_{imp} shall not be less than 50 kA (10/350 µS) between N and PE for three-phase systems and 25 kA (10/350 µS) between N and PE for single-phase systems. Otherwise the currents shall be considered as per level of protection.

11.6.5.5.2 *Follow current extinguishing capability of the SPD*

Follow current is the short circuit current (rms value) which flows through the SPD when it gets switched on due to lightning strike or surges. The SPD has to restore to normal condition by breaking this short circuit current before back fuse/switchgears are stressed, in order to retain the availability of the services by the load or to retain the availability of protection in the network. Follow current extinguishing capability and short circuit withstand capacity of SPD shall be as per good practice [8-2(48)].

11.6.5.5.3 Where Class II tested SPD {*see* good practice [8-2(48)]} are required at or near the origin of installation, the value of I_n shall be not less than 5 kA for connections according to Fig. 28A or between L to N or PE. For Class II tested SPDs connected between neutral and PE for connection in Fig. 28B, I_n shall not be less than 20 kA for three-phase systems and 10 kA for single-phase systems.

11.6.5.5.4 *Voltage protection level of SPD*

The voltage protection level of SPD is the voltage that is finally exposed to the equipment. The voltage protection level (U_p) should be less than the withstand voltage of the equipment. The voltage protection level of the SPD shall be as less as possible to have better protection but it should be ensured that it should not get switched on due to normal voltage variations or during low spark over voltages {*see* good practice [8-5(48)]}. The values of the withstand voltages of the equipment at various supply voltages is given in Table 15.

Table 15 Rated Impulse Voltage for the Equipment Energized Directly from the Low Voltages Mains
(*Clause* 11.6.5.5.4)

Sl No.	Nominal Voltage of the Supply System[1] Based on IEC 60038 : 2009 'IEC Standard Voltages'[2]		Voltage Line to Neutral Derived from Nominal Voltages a.c. or d.c. up to and Including	Rated Impulse Voltage[3]			
	Three Phase	Single Phase		Overvoltage Category [4]			
				I	II	III	IV
	V	V	V	V	V	V	V
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)			50	330	500	800	1 500
ii)			100	500	800	1 500	2 500
iii)		120-240	150	800	1 500	2 500	4 000
iv)	230/400 277/480		300	1 500	2 500	4 000	6 000
v)	400/690		600	2 500	4 000	6 000	8 000
vi)	1 000		1 000	4 000	6 000	8 000	12 000

[1] *See* Annex B of IEC 60664-1:2007 'Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests' for application to existing different low voltage mains and their nominal voltages.
[2] The '/' mark indicates a four-wire three-phase distribution system. The lower value is the voltage line-to-neutral, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, while the higher value is the voltage line-to-line. Where only one value is indicated, it refers to three-wire, three-phase systems and specifies the value line-to-line.
[3] Equipment with these rated impulse voltage can be used in installations in accordance with IEC 60364-4-44 'Low-voltage electrical installations — Part 4-44: Protection for safety — Protection against voltage disturbances and electromagnetic disturbances'.
[4] *See* **4.3.3.2.2** of IEC 60664-1:2007 'Insulation coordination for equipment within low-voltage systems — Part 1: Principles, requirements and tests' for an explanation of the overvoltage categories.

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11.6.5.5.5 The preferred values of voltage protection level of SPDs, U_p is given below (*see* IEC 61643-11:2011):

0.08, 0.09, 0.10, 0.12, 0.15, 0.22, 0.33, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, 1.8, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 8.0 and 10 kV

Hence for protecting a 240 V/415 V connected equipment, selecting a $U_p \leq 1.5$ kV will be a safer choice. The U_p may be tested and certified by a third party as per the laid down test procedures. *See* Fig. 29 on connection diagram for SPD.

11.6.5.6 For small residential buildings, power line SPD at the mains incoming panel will enhance the life of electronic equipment, such as TV, music system, refrigerators, LED lights, etc.

11.6.5.7 For large buildings, power line SPD is required at incoming panel as well as for sub distribution panels based on the LPZ principle {*see* good practice [8-5(48)]}.

11.6.5.8 For industrial and commercial buildings, critical and sensitive loads such as drives, PLC's, automation panels, etc require protection with SPD in addition to SPD at incoming power panels and sub-distribution boards. SPDs shall be selected to meet the requirements of relevant LPZs.

11.6.5.9 Lifts, escalators, moving walks and fire panels shall be protected with SPD in control panels. All electrical and control panels related to safety and security of building shall be protected with appropriate SPDs.

11.6.5.10 SPDs should be installed for outdoor equipment such as CCTV cameras, LED street lights, weighbridges, firefighting systems, roof top solar PV installations, etc. This will ensure availability of the vital services provided by these equipment as and when required.

11.6.5.11 Failure of equipment and chance of fire in electrical installations are more for buildings near tall structures (for example, telecom tower). These buildings should be protected with SPD at power incoming and ring earthing to avoid fire and equipment failure.

11.6.5.12 All SPDs should have status indication to show their healthy state for discharging the lightning current. The possibility of failure of L-N as well as N-PE connected SPD cannot be ignored.

11.6.5.13 The SPD shall be installed at the entrance to ensure perfect bonding to the ground at the time of lightning {*see* good practice [8-2(44)] and [8-2(48)]}. The let through energy of the protection system shall be less than the energy that equipment can withstand. As per good practice [8-5(48)], the energy coordination method is the best method to ensure the protection of the equipment. The let through energy details of the SPD shall be provided by manufacturer.

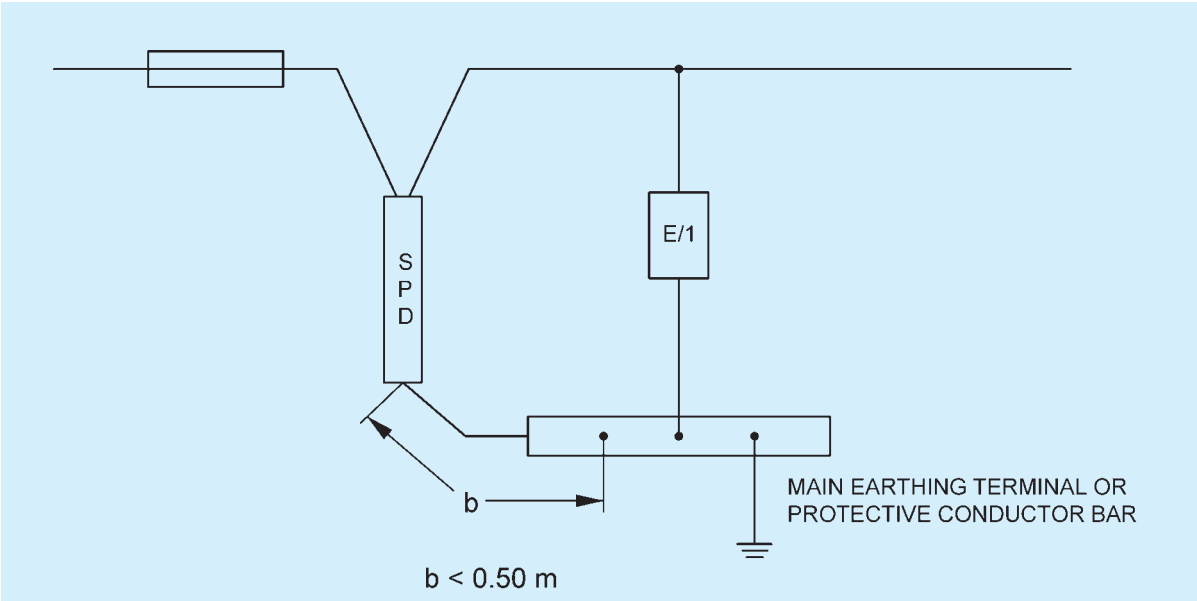


FIG. 29 EXAMPLE OF INSTALLATION OF SPDs AT OR NEAR ORIGIN OF INSTALLATION

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11.6.5.14 Maximum continuous operating voltage of the SPD (U_c) should not be less than $1.1 \times U_{nominal}$ = $1.1 \times 230 = 253$ V; however, neutral disconnect tests are done at much higher voltages (above 440 V) to simulate this condition.

The Class I SPD shall be tested to withstand sustained high voltage of minimum 460 V (L-N) under neutral disconnect condition.

11.6.5.15 Low-voltage SPDs for connection to low-voltage power systems shall be conforming to the accepted standard [8-2(49)].

11.6.5.16 SPDs for data/telecommunication line shall be selected considering following parameters:

a) Place of installation {*see* good practice [8-2(48)] for lightning protection zone concept};
b) Immunity of terminal equipment;
c) Earthing of the system to be protected (balanced/unbalanced);
d) Requirement on interface (transmission parameters: voltage, frequency, current); and
e) Mounting interface.

These SPDs shall be tested as per Table 16.

NOTE — Reference may be made to IEC 61643-21:2000 'Low voltage surge protective devices — Part 21: Surge protective devices connected to telecommunications and signalling networks — Performance requirements and testing methods' for requirements and test methods for SPDs for data/ telecommunication line.

Table 16 Voltage and Current Waveforms for Impulse-Limiting Voltage
(*Clause* 11.6.5.16)

Sl No.	Category	Type of Test	Open-Circuit Voltage[1)]	Short-Circuit Current	Minimum Number of Applications	Terminals to be Tested
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	A1	Very slow rate of rise	≥ 1 kV Rate of rise from 0.1 kV/µs to 100 kV/s	10 A, 0.1 A/µs, 2A/ µs ≥ 1 000 µs (duration)	Not applicable (NA)	X1-C X2-C X1-X2[2)]
	A2	AC	Select a test from Table 5 of IEC 61643-21:2000 'Low voltage surge protective devices — Part 21 surge protective devices connected to telecommunications and signaling networks — Performance requirements and testing methods'[1)]		Single cycle	
ii)	B1	Slow rate of rise	1 kV 10/1 000	100 A, 10/1 000	300	
	B2		1 kV to 4 kV 10/700	25 A to 100 A 5/300	300	
	B3		≥1 kV 100 V/µs	10 A to 100 A 10/1 000	300	
iii)	C1	Fast rate of rise	0.5 kV to <2 kV 1.2/50	0.25 kA to < 1 kA 8/20	300	
	C2		2 kV to 10 kV 1.2/50	1 kA to 5 kA 8/20	10	
	C3		≥1 kV 1 kV/µs	10 A to 100 A 10/1 000	300	
iv)	D1	High energy	≥ 1 kV	0.5 kA to 2.5 kA 10/350	2	
	D2		≥1 kV	0.6 kA to 2.0 kA 10/250	5	

NOTES

1 For the verification of U_p, one of the above impulse waveform of Category C is mandatory and A, B and D are optional. Unless otherwise specified, apply 5 positive and 5 negative pulses.

2 For impulse reset, select test from Category B, C and D. Unless otherwise specified, apply 3 positive and 3 negative pulses.

3 For impulse durability measurement, one impulse waveform of Category C is mandatory and A1, B and D are optional.

4 Values listed in this table are minimum requirements; other surge current ratings are possible and can also be found in other standards, for example, ITU-T K series — Recommendations.

[1)] An open-circuit voltage different from 1 kV may be used. However, it shall be sufficient to operate the SPD under test.
[2)] X1-X2 terminals shall be tested only if it is required.

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11.7 Implementation of Lightning Protection Measures for Typical Buildings

Sl No.	*Type of Building*	*Place*	*Implementation*
(1)	(2)	(3)	(4)
i)	Buildings with no steel reinforced foundation with electricity connection (one or two family private dwellings)	Close to tall structures/trees[1)]	SPD and ring earthing connected to the power incoming switchboard earth terminal
		Isolated	Class IV external LPS, SPD[2)] and ring earthing
ii)	Buildings with steel reinforced foundation with electricity connection (one or two family private dwellings)	Close to tall structures/trees[1)]	SPD[2)] and bonding of steel reinforcement to earthing bonding bar[3)]
		Isolated	Class IV external LPS connected to reinforcement and down-conductor[5)] (max every 20 m). SPD[2)] and bonding[3)] of steel reinforcement to earthing bonding bar
iii)	Buildings with steel reinforced foundation with electricity connection (less than 20 m height) [other than those covered in (ii)]	Urban/suburban/rural	Class IV External LPS connected to reinforcement and down-conductor[5)] (max every 20 m). SPD[2)] and bonding[3)] of steel reinforcement to earthing bonding bar
iv)	Residential high rise buildings (more than 20 m height) with steel reinforced columns/ pillars	Urban/suburban/rural	
v)	Educational buildings (school/ college/ training) for education or recreation for not less than 20 students	Urban/suburban/rural	Recommended [6)] LPS as per **11.3**. SPD[2)] and bonding of steel reinforcement to earthing bonding bar[3)]. Additional step/touch potential reduction measures in pathways/play grounds
vi)	Institutional buildings (Hospitals/ Jails)	Urban/suburban/rural	
vii)	Assembly buildings (theatres/ passenger stations (rail/bus/air)/ exhibition halls/religious buildings	Urban/suburban/rural	
	Assembly buildings (more than 5 000 people) Railway stations/airport/hill stations/mines	Urban/suburban/rural	In addition to LPS as per good practice [8-5(45)], [8-5(46)], [8-5(47)] and [8-5(48)], lightning safety areas shall be declared for the assembly of people during thunderstorm
viii)	Offices, banks, data centers, telephone exchanges, broad-casting stations	Urban/suburban/rural	Recommended[6)] LPS as per good practice **11.3**. SPD[2)] and bonding of steel reinforcement to earthing bonding bar[3)]. Ring earthing as per **11.5.1** for the safe assembly area.
ix)	Industrial buildings/Storage buildings (without the risk of combustible materials)	Urban/suburban/rural	

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Sl No.	*Type of Building*	*Place*	*Implementation*
(1)	(2)	(3)	(4)
x)	Hazardous Buildings (storage and handling of highly flammable or explosive materials, liquids or gases[7)]	Urban/suburban/rural	

[1)] Side flashes from trees/tall structures are expected if the building is within 5 m. To reduce the impact of side flash, metal conductors (down-conductors) connected to ring earthing need to be installed near the tall structure.
[2)] SPD shall be installed in all the incoming services like power, telephone, data , etc.
[3)] May not be possible for an existing building. Ring earthing is recommended as an alternate. Provision to bond the steel reinforcement to the earthing bus bar shall be provided during the construction of the building using a corrosion resistant metal (such as stainless steel).
[4)] Direction boards towards lightning safe area shall be shown.
[5)] Down-conductor can be avoided, if reinforcement steel is interconnected according to good practice [8 -5(44)].
[6)] *Recommended LPS* — Class of LPS as derived in a ri sk assessment calculation as per **11.3**.
[7)] Lightning protection with insulated materials can avoid safety distance of LPS from these installations.
[8)] The quality of the connectors and other components of the LPS shall be ensured by following tests:
a) Salt mist test;
b) Humid sulphurous atmosphere treatment tests;
c) Electrical tests for lightning current and resistance;
d) *Mechanical strength tests* – tensile strength, minimum elongation test; and
e) Metal compatibility tests.

11.8 Average Number of Thunderstorm Days

For the purpose of risk assessment, annual thunderstorm days in various places are provided in the informal table to be read along with Fig. 30.

12 ELECTRICAL INSTALLATIONS FOR CONSTRUCTION AND DEMOLITION SITES

12.1 General

12.1.1 Electrical hazards are a major cause of serious injury and even death in construction sites. Accidents also cause loss of productivity and destroy the morale of workers. The need to use electricity and electrical/ electronic equipment has been constantly increasing. Without these gadgets productivity and quality of work will suffer. Therefore the use of electricity and the use of gadgets has to increase. Such increase requires a proper electrical distribution system in the work site.

12.1.2 To ensure continuous supply of power during the construction activity and maintain productivity, site security, etc, the city power supply may required to be supplemented by on-site standby power generation. Some gadgets require continuity of power supply without interruption, thereby requiring UPS systems. In a typical large construction site there may be a large temporary distribution network combined with more than one source of electricity, which can make the system quite complex from the safety point of view.

12.1.3 Problem may also arise in case of lack of required training to workers in the safe use of the tools and equipment that they are required to handle in a system with multiple sources of power supply. In case of use of imported equipment which may be manufactured to their own standards, problems may arise, such as, during connection and inter-connection of equipment and tools and mismatch of plugs and sockets.

12.1.4 Practical guidance to employers, designers, manufacturers, importers, suppliers (including hirers), electrical contractors and electricians on eliminating or reducing the risk of electrocution and electric shock to any person is necessary.

12.1.5 Even though awareness exists about good practices, the same may be compromised at times in the name of speed or economy or due to ignorance and neglect. The materials, equipment, tools, cables, switchgear used in the temporary installation face far more severe environmental working conditions. Use of discarded switchgear, cables, etc, at the construction sites compounds the risk to workmen from shock and fire. The laid down standard need to be followed during construction and demolition meticulously as in the case of permanent installations during building use.

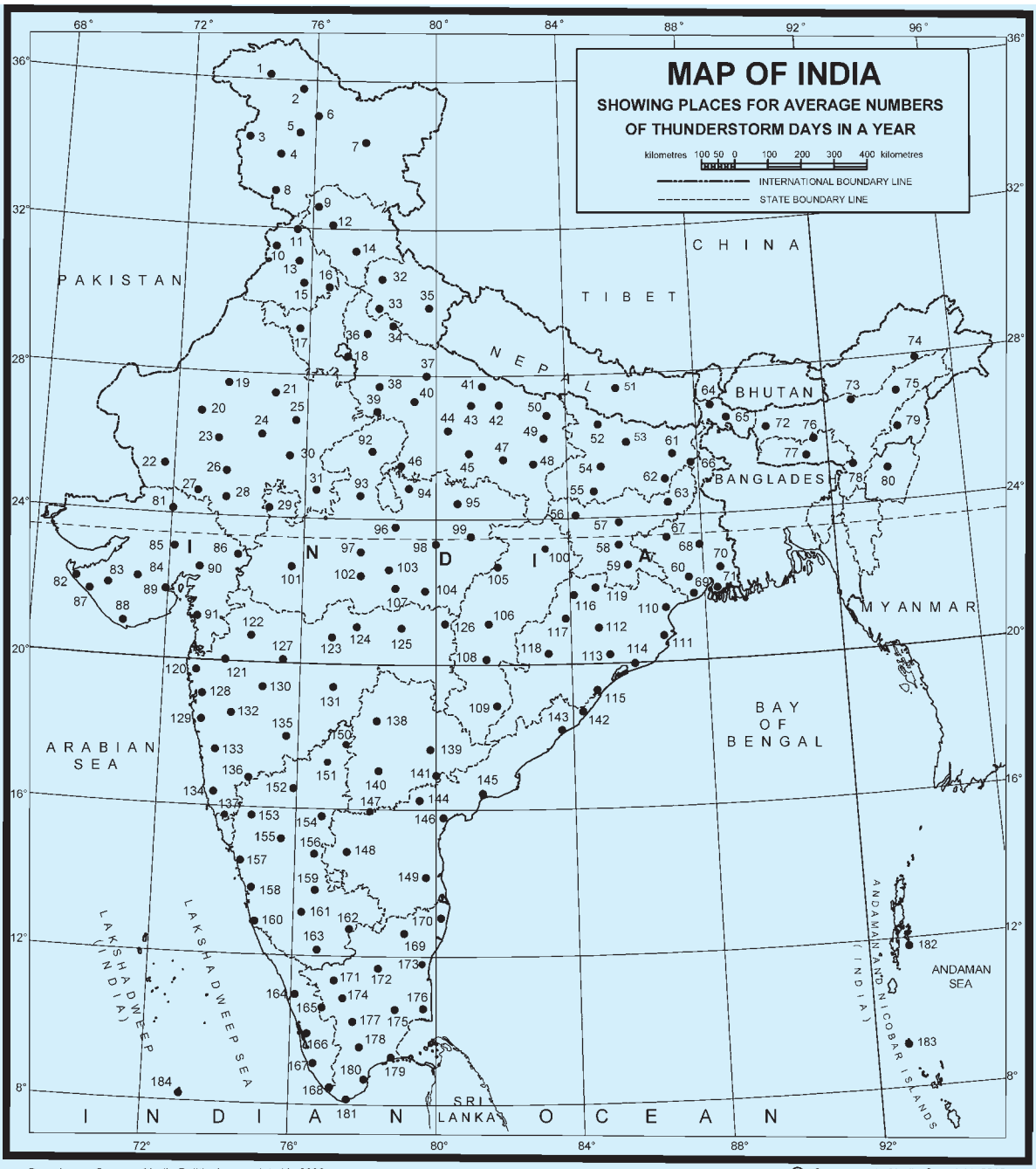
12.2 Installation and Removal of Construction Wiring

All construction wiring work shall be installed by an appropriately registered electrical worker as required by *The Indian Electricity Act*, 2003 and only by

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Sl No.	*Name of Place*	*Annual Thunder-storm Days*	*Sl No.*	*Name of Place*	*Annual Thunder-storm Days*	*Sl No.*	*Name of Place*	*Annual Thunder-storm Days*
1.	Gilgit	7	62.	Sabour	76	123.	Akola	20
2.	Skardu	5	63.	Dumka	63	124.	Amraoti	32
3.	Gulmarg	53	64.	Darjeeling	28	125.	Nagpur	45
4.	Srinagar	54	65.	Jalpaiguri	68	126.	Gondia	10
5.	Dras	3	66.	Malda	59	127.	Aurangabad	34
6.	Kargil	2	67.	Asansol	71	128.	Mumbai	16
7.	Leh	3	68.	Burdwan	39	129.	Alibag	12
8.	Jammu	26	69.	Kharagpur	76	130.	Ahmadnagar	10
9.	Dharmsala	13	70.	Kolkata	70	131.	Parbhani	32
10.	Amritsar	49	71.	Sagar Island	41	132.	Pune	22
11.	Pathankot	4	72.	Dhubri	8	133.	Mahabaleshwar	14
12.	Mandi	46	73.	Tezpur	27	134.	Ratnagiri	6
13.	Ludhiana	12	74.	Dibrugarh	98	135.	Sholapur	23
14.	Simla	40	75.	Sibsagar	103	136.	Miraj	25
15.	Patiala	26	76.	Shillong	75	137.	Vengurla	39
16.	Ambala	9	77.	Cherrapunji	49	138.	Nizambad	36
17.	Hissar	27	78.	Silchar	33	139.	Hnamkonda	43
18.	Delhi	30	79.	Kohima	34	140.	Hyderabad	28
19.	Bikaner	10	80.	Imphal	49	141.	Khammam	26
20.	Phalodi	14	81.	Deesa	7	142.	Kalingapatam	20
21.	Sikar	17	82.	Dwarka	5	143.	Vishakapatnam	46
22.	Barmer	12	83.	Jamnagar	8	144.	Rentichintala	42
23.	Jodhpur	23	84.	Rajkot	12	145.	Masulipatam	20
24.	Ajmer	26	85.	Ahmedabad	11	146.	Ongole	25
25.	Jaipur	39	86.	Dohad	17	147.	Kurnool	29
26.	Kankroli	36	87.	Porbandar	3	148.	Anantpur	22
27.	Mount Abu	5	88.	Veraval	3	149.	Nellore	18
28.	Udaipur	38	89.	Bhavnagar	11	150.	Bidar	15
29.	Neemuch	28	90.	Vadodara	8	151.	Gulbarga	34
30.	Kota	27	91.	Surat	4	152.	Bijapur	9
31.	Jhalawar	40	92.	Gwalior	53	153.	Belgaum	31
32.	Mussorie	61	93.	Guna	33	154.	Raichur	17
33.	Roorkee	74	94.	Nowgong	59	155.	Gadag	21
34.	Najibabad	36	95.	Satna	41	156.	Bellary	22
35.	Mukteswar	53	96.	Sagar	36	157.	Karwar	27
36.	Meerut	—	97.	Bhopal	44	158.	Honavar	5
37.	Bareilly	34	98.	Jabalpur	50	159.	Chikalthana	24
38.	Aligarh	30	99.	Umaria	37	160.	Mangaluru	36
39.	Agra	24	100.	Ambikapur	29	161.	Hassan	26
40.	Mainpuri	23	101.	Indore	34	162.	Bengaluru	46
41.	Bahraich	31	102.	Hoshangabad	37	163.	Mysuru	44
42.	Gonda	22	103.	Panchmarhi	30	164.	Kozhikode	39
43.	Lucknow	18	104.	Seoni	51	165.	Palghat	35
44.	Kanpur	26	105.	Pendadah	56	166.	Kochi	69
45.	Fatehpur	24	106.	Raipur	34	167.	Alleppey	51
46.	Jhansi	20	107.	Chhindwara	27	168.	Thiruvananthapuram	68
47.	Allahabad	51	108.	Kanker	37	169.	Vellore	25
48.	Varanasi	51	109.	Jagdalpur	35	170.	Chennai	47
49.	Azamgarh	1	110.	Balasore	81	171.	Udhagamandalam	24
50.	Gorakhpur	11	111.	Chandbali	75	172.	Salem	69
51.	Katmandu	74	112.	Angul	81	173.	Cuddalore	37
52.	Motihari	38	113.	Bhubaneswar	46	174.	Coimbatore	40
53.	Darbhanga	10	114.	Puri	33	175.	Trichchirapalli	41
54.	Patna	33	115.	Gopalpur	34	176.	Nagappattinam	15
55.	Gaya	38	116.	Jharsuguda	85	177.	Kodaikanal	82
56.	Daltonganj	73	117.	Sambalpur	67	178.	Madurai	39
57.	Hazaribagh	73	118.	Titlagarh	24	179.	Pamban	5
58.	Ranchi	34	119.	Rajgangpur	1	180.	Tuticorin	14
59.	Chaibasa	70	120.	Dahanu	1	181.	Cape Comorin	68
60.	Jamshedpur	66	121.	Nasik	17	182.	Port Blair	62
61.	Purnea	52	122.	Malegaon	13	183.	Car Nicobar I	18
						184.	Minicoy I	20

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The territorial waters of India extend into the sea to a distance of twelve nautical miles measured from the appropriate baseline.

The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.

The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

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FIG. 30 PLACES FOR AVERAGE NUMBER OF THUNDERSTORM DAYS IN A YEAR

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electrical workmen holding licence of the appropriate level of competence depending on the voltage, local generation, etc. The installation should be inspected prior to commissioning and at regular intervals by the Engineer-in-Charge (if he is qualified to inspect electrical installations) or by his representative, who should be competent to inspect an installation.

12.3 Provision of Indicating and Recording Instruments and Meters

Measurement is a prerequisite to analyze the performance. Construction site switchboards should have adequate instrumentation (such as, ammeters, PF meters, voltmeters, energy meters) on different branches of the distribution system so that any abnormal condition or overload is noticed. Considering the nature of varying activity in a construction site, frequent visual and instrument based inspections are necessary keeping record of the same.

12.4 RCCB/RCD

Following shall be ensured in construction and demolition sites:

a) Every electric supply to which electrical plant can be connected should incorporate an RCCB/RCD so as to protect persons who may come into contact with the electrical plant against electric shock.

b) The RCCB/RCD(s) should have a rated tripping current not exceeding 30 mA and should have the capacity to carry the load current required by the appliances permitted to be connected in that branch circuit or feeder.

c) Where construction work supply can only be obtained from a permanent wiring socket outlet, RCCB/RCD should be connected at the socket outlet.

d) Sub-mains supplying site sheds should incorporate an RCCB/RCD having a rated tripping current not exceeding 100 mA.

e) Every non-portable RCCB/RCD device on the worksite shall be trip tested by the built-in push button test monthly, and performance tested for operation before being put into service and thereafter at least once every 12 months. It shall also be subjected to an imbalance of current not less than the rated residual current and shall trip in a time not exceeding 6 s.

f) Every portable RCCB/RCD device on the worksite shall be trip tested by the built-in push button test. The test shall be done prior to use and each day while in use; and it shall be performance tested for operation before being put into service and thereafter at least once every 3 months. It shall also be subjected to an imbalance of current not less than the rated residual current and shall trip in a time not exceeding 6 s.

g) Results of RCCB/RCD tests shall be recorded and kept on site or made available for audit and kept for a minimum period of 5 years [excluding the daily push button test for portable RCCB/RCD(s)].

h) Portable RCCB/RCD(s) when tested shall be fitted with a durable, non-reusable, non-metallic tag. The tag shall include the following information:

1) The name of the person or company who performed the tests; and
2) The test or retest date.

The recommended colour coding for tags on tested RCCB/RCD, which is prescribed below should be indicated by its colour representing the period when the test was performed:

January – March	: Red
April – June	: Green
July – September	: Blue
October – December	: Yellow

j) Portable generators should be fitted with RCDs and the RCDs should be fitted with core balance earth leakage protection having a rated tripping current not exceeding 30 mA.

k) Personal hoists used on construction sites shall be supplied from a separate final sub-circuit originating from the main switchboard; and be suitably identified by marking this supply, the RCD/MCB feeding it.

12.5 Temporary Supply Switchboards

All temporary supply switchboards used on building, construction and demolition sites shall be of robust construction and either securely attached to a pole, post wall or other structure which may be of stable freestanding design and,

a) where installed in outdoor locations, should be constructed and maintained to IP23 (or higher) rating so that safe operation is not affected by the weather;

b) switchboards should incorporate the support and elevation of cables and flexible extension cords;

c) switchboard enclosures shall be provided with an insulated or covered tie-bar or similar arrangement for the anchorage of the cables

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or flexible cords in order to prevent strain and mechanical damage at the termination of the cables or cords;

d) switchboards should be provided with a door and locking facility. The doors should be designed and attached in a manner that will not damage any flexible cord connected to the board and should protect the switches from mechanical damage;

e) the door should be provided with signs (in English, Hindi and at least one local language) stating, 'KEEP CLOSED — LEADS THROUGH BOTTOM';

f) switchboards should have an insulated slot (with edges suitably shaped or covered with plastic or rubber trims to avoid damaging the cable insulation/sheath) at the bottom for the passage of leads;

g) switchboards should be attached to a permanent wall or suitable portable or temporary structure in an elevated position suitable for easy access and least interference with the activity in the area.

h) if the floor in that area is likely to be wet, additional precautions are necessary and an insulated platform should preferably be provided for access to operation of switches. Personal protective equipment such as gloves should be available, placed near the switchboard, as an alternative.

j) a clearance of at least 1.0 m should be maintained in front of all switchboards;

k) the contractor or nominated persons should ensure that all power circuits are isolated or made inaccessible so as to eliminate the risk of fire, electric shock or other injury to persons after completion of the daily work;

m) switchboards shall be legibly and indelibly marked with a set of numbers or letters or both which uniquely identify the switchboard from others on a site;

n) switchboards shall be marked to indicate the presence of live parts in accordance with symbols such as the following drawing:





p) chart indicating first aid measures for electric shock management should be placed near the switchboard;

q) 'Lock Out and Tag Out' procedures as adopted should be displayed;

r) the switchboard should be lighted properly to ensure its identification and safe working; and

s) all switchboards should have their identification names (or/and numbers) so that and communication/instructions about them are unambiguous.

12.6 Cables Used in Worksite Installations

12.6.1 Worksite poses a number of hazards to the cables. The conditions are severe compared to those in permanent installations. Cables face dust, moisture, abrasives and even impact unlike those in permanent installations. Extra care should be taken to frequently inspect the cables and discard cables which show signs of damage as a damaged insulation combined with moisture can be dangerous.

12.6.2 Cables are likely to be run over by vehicles. Suitable protection by a steel pipe or hume pipe or steel plate, whichever is appropriate, is required. Dragging of cables damages their sheath/insulation and may also cut a few strands of the conductor due to stretching, effectively reducing the current carrying capacity.

12.6.3 Overhead installation of cables is a common practice. Such installations should use a GI wire to carry the weight of the cable without causing the stretching of the cable. The carrier GI wire should be earthed. Unarmoured cables shall not be installed on metallic roofs or similar structures unless suitably protected against mechanical damage.

Overhead wiring should be positioned to avoid crossing roadways or accessways where cranes, high loads, or heavy machinery may travel. Where it is not possible to avoid accessways an effective means shall be provided to minimize the risk of the vehicular contact with the aerial wiring system. This condition may be satisfied by the placement of flagged catenary wires or cables of suitable material across the accessway 6 m on either side of the overhead wiring and 0.6 m below the lowest point of the overhead electrical cables or lower.

All aerial conductors installed on construction and demolition sites shall be insulated. Cables supported by means of a catenary shall be stranded or shall be flexible cables affording double insulation or the equivalent of double insulation. Construction wiring (including switchboards) shall be visually inspected at intervals not exceeding 6 weeks.

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12.7 Extension Cords and Fittings

12.7.1 It shall be ensured that 3-pin plugs and cord extension sockets used on flexible extension cords and portable power tools are either of non-rewirable (moulded) or transparent type. Cables that are normally used for fixed wiring should not be used as flexible extension cords.

12.7.2 Flexible extension cords shall not be located with plug socket connections in wet places or places where they may be subject to damage by liquids. Fittings for flexible cables or flexible extension cords shall be wired identically and the identity of phase, neutral and earth connections are preserved in a like manner. Bending radius limits for cables should be strictly ensured; else internal breakage of strands can occur leading to reduction of capacity, spot heating, etc.

Flexible extension cords used in multi-storeyed building construction works shall be confined to the same floor as the power source, except in case of formwork; external staging; lift or service shafts; and stairwells. Extension cords shall be confined to not more than one storey above or below the location of the switchboard and be mechanically protected in the transition area between storeys and in places where damage is likely to occur.

The recommended maximum length of a 230 V cord extension is given below:

Sl No.	*Cord Extension Set Rating*	*Conductor Area*	*Maximum Length of Flexible Cord*
	A	mm^2	m
(1)	(2)	(3)	(4)
i)	10	1.0	25
		1.5	35
		2.5	60
ii)	15	1.5	25
		2.5	40
iii)	20	2.5	30
		4.0	50

12.7.3 Joints in temporary wiring shall be avoided. Unavoidable joints should be made with suitable crimped ferrule and insulated with PVC tape on individual core joints and further protected by a sleeve or a covering of tape. Combination of teflon tape followed by PVC tape is recommended where exposure to water is anticipated.

12.7.4 Construction wiring shall be readily distinguishable from permanent wiring by using cable of a different colour or by attaching iridescent yellow tape spaced at intervals not exceeding 5 m and stamped with the words 'construction wiring'.

12.8 Electrical Plant in Service Testing

Electrical plant shall be inspected and tested in accordance with the following:

a) Movable electrical plant that is hand held or portable during operation or moved between operations and is subject to damage or harsh environment shall be examined and tested every 3 months.

b) All other electrical plant used for construction purposes shall be inspected and tested at intervals not exceeding 6 months.

c) When any equipment inspected or tested in accordance with (a) and (b) is found to be unsatisfactory, it shall be withdrawn from service immediately and have a label attached to it, 'Warning against Further Use'. Electrical plant found to be unsatisfactory shall not be returned to service until it has been repaired and retested.

d) The inspection and testing specified should be carried out by an authorized/qualified person.

e) The results of the inspection of electrical plant should be recorded and kept on site or made available for inspection by authorities. Information recorded shall include,

   1) the name of the person or company who performed the tests;
   2) the test or retest date; and
   3) identification of faulty equipment and action taken to repair or remove it from use.

12.9 Lighting

Following in respect of lighting shall be ensured in construction and demolition sites:

a) *Access lighting* — Adequate artificial lighting should be installed to illuminate the work area, if there is insufficient natural lighting. Lamps in luminaires shall be protected against mechanical damage. Luminaires installed as part of the permanent electrical installation in site accommodation, may not require further mechanical protection.

   Sufficient battery powered lighting shall be installed in stairways and passageways to allow safe access and exit from the area if there is insufficient natural lighting. If there is a loss of supply to the normal lighting in the area, it should be ensured that battery powered lighting

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has sufficient capacity to operate for one hour to allow persons to exit the building safely.

Temporary wiring supplying lighting circuits should be connected to the designated lighting circuits of the switchboard.

b) *Task lighting* — Portable luminaires shall be provided with the appropriate ingress protection (IP) rating. Task lighting in many construction site may have to move continuously in steps as the work progresses. The lighting system should also be shifted in suitable steps instead of simply extending the cables without any consideration for safety. Hand held additional lights, if any, should be taken from a socket protected by a RCCB/RCD of 30 mA setting just like hand held tools.

c) *Lift and service shaft lighting* — Lift and service shaft lighting may have either construction wiring or permanent wiring. Fluorescent lighting should be used. The lights should be located on the floor above or below the work area. It shall be ensured that the emergency lighting has sufficient battery capacity to operate for a minimum of 1 h, if there is a loss of supply to the normal lighting in the area.

d) *Lighting in means of egress* — Sufficient battery powered lighting shall be installed in stairways and passageways to allow safe access and exit from the area if there is insufficient natural lighting. If there is a loss of supply to the normal lighting in the area it shall be ensured that battery powered lighting has sufficient capacity to operate for sufficient time to allow persons to exit the building safely.

e) *Illumination of signs and warning boards* — Sufficient lighting should be available to illuminate the sign boards and warning boards. These lights may also be a part of the lighting set for means of egress.

12.10 Transportable Construction Buildings (Site Sheds)

Electrical installations to transportable construction buildings shall comply with the following:

a) If supply is by means of a flexible cord, the same shall not be taken from one transportable building to another transportable building;

b) The flexible cord supplying a transportable building should not be more than 15 m in length;

c) Each amenity in the building shall be connected/supplied by a flexible cord to a final sub-circuit protected by an RCCB/RCD device with a rated tripping current not exceeding 30 mA; these flexible cords should be protected from mechanical damage and power outlets in site sheds should be used to supply power to the equipment and lighting within the shed only; and

d) Socket-outlets installed on the outside of transportable building shall be used only to supply power to the following:

   1) Electrical equipment and lighting immediately adjacent to those transportable buildings.

   2) Other transportable buildings when the socket-outlet is part of an interconnecting system and the flexible cord supplying those transportable buildings has a maximum length of 15 m.

12.11 Lock-Out and Tag-Out Practices

Whenever an electrician is to work on a branch feeder from the switchboard it becomes necessary that the switch feeding the feeder on which work is done is to be switched-off and should be kept switched-off till the same electrician decides to switch on after completion of work either for testing or for putting the section back into service. To ensure that during the period an electrician is working on a feeder or the equipment it feeds, the practice is to put a 'Tag' on the concerned switch. The tag will carry details about which authorized worker has put the tag and when and who is authorized to remove it. This is a very critical operating practice for maintenance of the electrical system and following it is of particular importance in the case of temporary installations, where such requirements arise more often than in permanent installations.

Lock-out procedure shall be similar to the above but the difference is that the relevant switch is kept locked in off position and the key is kept by the person or the team leader who will be working on the feeder. The system should also maintain a register where the activities of this nature and the details of action (repair, transfer of the end equipment to a new location, addition of a new appliance on the feeder, etc) are recorded.

12.12 Standard Operating and Maintenance Practices in Sites with More than One Source of Electricity

12.12.1 In medium and large construction sites it is common to use local generation of electricity by a diesel generating set. The reasons may be lack of dependable local/city distribution system for continuous power supply, high cost of temporary connection charges, restrictions on use of certain equipment like welding transformers on temporary connection, etc. Apart from DG sets for power requirement of site construction

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equipment, there may be office equipment with computers, site laboratory equipment which require uninterruptible power supply. Shock hazards depend on the voltage of the system and the consequent current flow through the body. As such shock risk associated with all these sources is the same.

12.12.2 Wherever an alternative power supply is provided, proper protocols shall be adopted for the supply from different systems and the associated changeover switch or contactors. Risk increases due to existence of more than one source of power supply. System schematics, operating practice and essential interlock between the different sources of power should be displayed and followed systematically. Earthing for each system should be provided. Changeover switches should be of 4-pole in order to ensure that earth leakage protections operate properly with each one of the power sources. The system should also maintain a register where the activities related to each source of power is recorded and the actions to be taken are provided.

12.13 Earthing or Grounding

12.13.1 Earthing or grounding is an essential prerequisite for any electrical system from the aspect of safety of personnel, equipment, appliances and for avoidance of fire due to short-circuit or of feeding energy to a short circuit originating from any other cause consequent to damage to insulation by the fire.

12.13.2 The standard earthing practice is applicable to temporary installations also. The earthing sets installed at the initial development of the site can be planned to be retained as earthing sets for use even after the completion of the building for the permanent installation.

12.13.3 The minimum requirement of earthing for any temporary electrical installation is given hereunder for easy adherence to the basic minimum. It is recommended to follow the earthing requirements given in **8**.

12.13.3.1 The neutral of the system of each source or generator shall be having two distinct connection to two distinct earthing sets. All metal parts associated with electrical equipment are required to be connected to earth. The minimum requirement is the provision of two pipe earthing sets each with a pipe of 2.5 m length and separated by at least 2.5 m between them and connected to the source neutral by a conductor of cross-section more than half the size used for the phase conductor.

12.13.3.2 Earth continuity shall be maintained all over the site wherever electricity is made available and the earth continuity conductor shall have a cross-section at least more than that used for the phase conductor.

12.13.3.3 Wherever the requirements of earthing and use of RCD or RCCB cannot be satisfactorily met with at any site and electrical hand tools are required to be used, low voltage (< 50 V) appliances or self-contained battery operated tools shall be used as a safe alternative. This applies to work under damp or water logged areas also.

13 PROTECTION OF HUMAN BEINGS FROM ELECTRICAL HAZARDS

13.1 General

Danger to persons due to contact with live parts is caused by the flow of the current through the human body. The effects on the human body are dependent on the amount of the current flow and the duration of the flow. The current flow through the human body depends on the voltage and the resistance in the path. The contact resistance forms an important or significant contributor to the total resistance for the current flow. The contact resistance reduces by a factor of 100 to 1 000 due to the body part being wet and also the touch pressure at the point of contact.

13.1.1 *Physiological Effects of Electric Shock*

The following are the physiological effects of electric shock:

a) *Tetanization* — The muscles affected by the current flow involuntarily contract and letting go of gripped conductive parts is difficult.

NOTE — Very high currents do not usually induce muscular tetanization because, when the body touches such currents, the muscular contraction is so sustained that the involuntary muscle movements generally throw the subject away from the conductive part.

b) *Breathing arrest* — If the current flows through the muscles controlling the lungs, the involuntary contraction of these muscles alters the normal respiratory process and the subject may die due to suffocation or suffer the consequences of traumas caused by asphyxia.

c) *Ventricular fibrillation* — The most dangerous effect is due to the superposition of the external currents with the physiological ones, which, by generating uncontrolled contractions, induce alterations of the cardiac cycle. This anomaly may become an irreversible phenomenon since it persists even when the stimulus has ceased.

d) *Burns* — They are due to the heating deriving, by Joule effect, from the current passing through the human body.

13.1.2 On a time-current diagram, four zones to which the physiological effects of alternating current (15 to 100 Hz) passing through the human body have been related are given in Fig. 31.

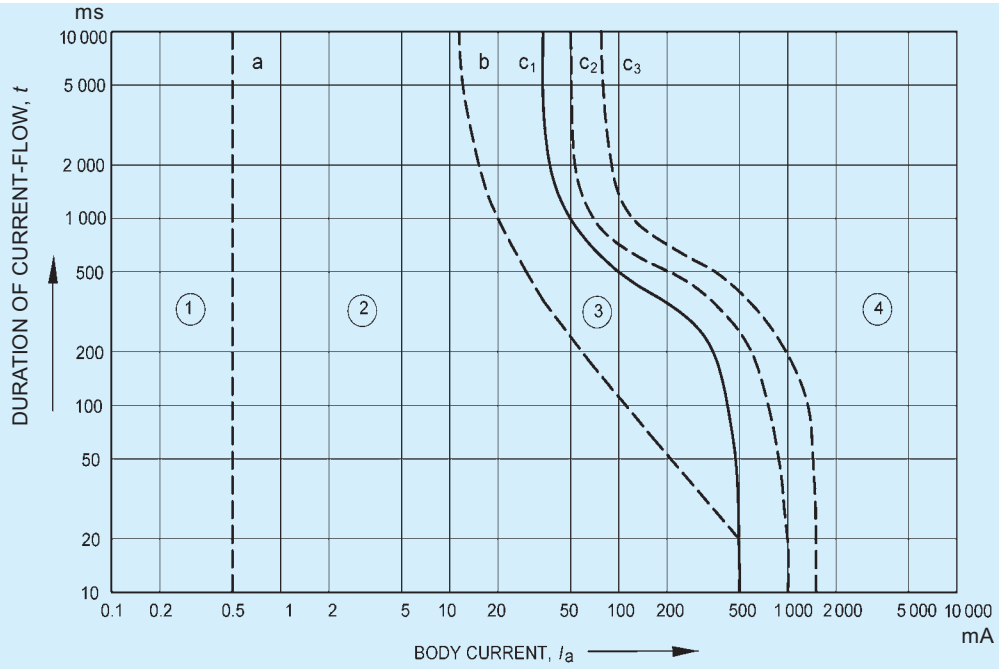
13.1.3 In general, 'special locations' involve one or more of the following environmental conditions or

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different risks, which in the absence of special arrangements, will give rise to an increased risk of electric shock:

1) Wetness or condensation, that is, reduced skin resistance;
2) Absence of clothing, that is, greater opportunity to make direct or indirect contact through increased area of bare skin and bare feet;
3) Proximity of earthed metalwork, that is, increased risk of indirect contact; and
4) Arduous or onerous site conditions, that is, conditions of use that may impair the effectiveness of the protective measures.

13.1.3.1 The additional requirements for these 'special locations' have been devised by assessing the relevant risks under each of the above categories and making adjustments to the protective measures accordingly. The



NOTES

1 As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path 'left hand to feet'. For other current paths, *see* **5** and Table III of the accepted standard [8-2 (50)].

2 The point 500 mA/100 ms corresponds to fibrillation probability in the order of 0.14 percent.

Zones	Physiological effects
Zone 1	Usually no reaction effects.
Zone 2	Usually no harmful physiological effects.
Zone 3	Usually no organic damage to be expected. Likelihood of muscular contractions and difficulty in breathing, reversible disturbances of formation and conduction of impulses in the heart, including atrial fibrillation and transient cardiac arrest without ventricular fibrillation increasing with current magnitude and time.
Zone 4	In addition to the effects of Zone 3, probability of ventricular fibrillation increasing up to about 5 percent (curve c_2), up to about 50 percent (curve c_3) and above 50 percent beyond curve c_3. Increasing with magnitude and time, pathophysiological effects such as cardiac arrest, breathing arrest and heavy burns may occur.

FIG. 31 TIME/CURRENT ZONES OF THE EFFECTS OF a.c. CURRENTS (15 HZ TO 100 HZ)

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intention is to remove or minimize the additional risks to users presented by the electrical installations within these 'special locations'. Designers, installers and operators of such installations should consider the particular requirements of the installation and design and install or operate the installation to reduce or protect against risks from these requirements. It should be however recognized, that all installations require adequate regular periodic inspection and testing, and any necessary maintenance or repair works be properly carried out.

13.2 Protection Against Electric Shocks

13.2.1 Protective measures against electric shock are based on following two common dangers:

a) Contact with an active conductor, which is live with respect to earth in normal circumstances; and is referred to as a 'direct contact' hazard.

b) Contact with a conductive part of an apparatus which is normally dead, but which has become live due to insulation failure in the apparatus; and is referred to as an 'indirect contact' hazard. The third type of shock hazard exists in the proximity of MV or LV (or mixed) earth electrodes which are passing earth-fault currents.

c) This hazard is due to potential gradients on the surface of the ground and is referred to as a 'step-voltage' hazard; shock current enters one foot and leaves by the other foot, and is particularly dangerous for four-legged animals. A variation of this danger, known as a 'touch voltage' hazard can occur, for instance, when an earthed metallic part is situated in an area in which potential gradients exist. Touching the part would cause current to pass through the hand and both feet. Animals with a relatively long front-to-hind legs span are particularly sensitive to step-voltage hazards.

NOTE — Cattle have been killed by the potential gradients caused by a low voltage (240/415 V) neutral earth electrode of insufficiently low resistance.

13.2.2 Potential-gradient problems as mentioned in **13.2.1** are not normally encountered in electrical installations of buildings, provided that equipotential conductors properly bond all exposed metal parts of equipment and all extraneous metal (that is, those which are not part of an electrical apparatus or the installation, for example structural steelwork, etc) to the protective-earthing conductor.

Potential-gradient problems do exist at the switchboards of electrical installations. Even where components, such as the metallic cubicle and operating handle are earthed, there is a possibility that for very short duration when a fault current is flowing through the metal part, the potential of the earthed metal part may be increased due to the current flow. The practice of using an insulating mat at places where the switches are to be operated, is for protection against such transient over-voltages in earthed metal parts (if the metal part is not earthed the transient overvoltage will be beyond safe limits).

With the increased use of pumped water in bathrooms for spa-baths, power showers, etc, there is a need, on occasions, to provide for motive power within the area of the bath. In order to protect against direct and indirect contact, supplies for such equipment shall be by extra-low-voltage-system with the nominal voltage not exceeding 12 V r.m.s.

It is a requirement to provide supplementary equipotential bonding by bonding all simultaneously accessible exposed and extraneous conductive parts. This should include all in-coming metallic services (including metal wastes) and any structural metalwork, including a metallic floor grid, if provided.

Protection measures as given in **13.2.3** to **13.2.5** shall also be provided for protection against electric shock.

13.2.3 *Direct-Contact Protection or Basic Protection*

The main form of protection against direct contact hazards is to contain all live parts in housings of insulating material or in metallic earthed housings, by placing out of reach (behind insulated barriers or at the top of poles) or by means of obstacles. Where insulated live parts are housed in a metal envelope, for example transformers, electric motors and many domestic appliances, the metal envelope is connected to the installation protective earthing system. Protection classification and the details of the different levels of protection are designated by IP XX and IK X {*see* good practice [8-2(6)] and IEC 62262:2002 'Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)'}. The metallic enclosure has to demonstrate an electrical continuity, then establishing a good segregation between inside and outside of the enclosure. Proper grounding of the enclosure further participates to the electrical protection of the operators under normal operating conditions. For LV appliances this is achieved through the third pin of a 3-pin plug and socket. Total or even partial failure of insulation to the metal, can raise the voltage of the envelope to a dangerous level (depending on the ratio of the resistance of the leakage path through the insulation, to the resistance from the metal envelope to earth). The minimum standard for any equipment has to be IP2X to limit the possibility of a finger touching a live part of an electrical system.

13.2.4 *Indirect-Contact Protection or Fault Protection*

A person touching the metal envelope of an apparatus with a faulty insulation is said to be making an indirect contact. An indirect contact is characterized by the fact that a current path to earth exists (through the protective earthing (PE) conductor) in parallel with the shock current through the person concerned. The hazard in such cases is dependent on the earth resistance and the

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resistance of the earth continuity conductor, which would effectively be in parallel to the path of flow of current through the human body.

Extensive tests have shown that, providing the potential of the metal envelope not greater than 50 V with respect to earth, or to any conductive material within reaching distance, no danger exists.

If the insulation failure in an apparatus is between a MV conductor and the metal envelope, it is not generally possible to limit the rise of voltage of the envelope to 50 V or less, simply by reducing the earthing resistance to a low value. The solution in this case is to create an equipotential 'Earthing systems '. Insulation faults affecting the MV substation's equipment (internal) or resulting from atmospheric overvoltages (external) may generate earth currents capable of causing physical injury or damage to equipment. Preventive measures essentially consist of,

a) connecting all substation frames to the earth bar;
b) minimizing earth resistance; and
c) fast tripping and isolation of the fault by the operation of the fuse or circuit breaker.

13.2.5 In order to provide protection against electric shock due to leakage current for human being, a 30 mA RCCB/ RCD shall be installed at distribution board incomer of buildings, such as residential, schools and hospitals. For all other buildings, a 100 mA RCCB will suffice for protection against leakage current.

13.2.6 *Additional Protection Against Electric Shocks*

In a.c. systems, additional protection by means of a residual current protective device (RCD) with sensitivity not exceeding 30 mA shall be provided for,

a) socket-outlets with a rated current not exceeding 20 A that are for use by ordinary person and are intended for general use; and
b) mobile equipment with a current rating not exceeding 32 A for use outdoors.

The residual current devices shall be independent of the line voltage, except for installation operated, tested and inspected by skilled persons.

13.3 Hazards Due to Multiple Electrical Sources

The need for reliability of power supply and continued supply for different equipment leads to provision of redundant equipment chains as well as the provision of more than one source of power.

For critical installations it is normal to have more than one service connection, preferably from two different paths, so that at least one of the paths is in service at any time.

At the next level to cover the failure of the area distribution network local standby generating systems such as diesel generating sets are provided. For extremely critical loads which cannot tolerate even short break in service UPS systems which store energy in a battery bank and release it during the power failure become necessary.

As such multiple sources have become a necessary common feature in most large buildings. Even in small buildings activities depending on computers, etc, leads us to provide a standby system with an UPS or an inverter.

Where there is more than one source the shock hazards increase due to various reasons and a proper drill and display of instructions becomes necessary so that the users and in particular the operating and maintenance personnel are warned of the different sources and the associated protocol.

13.4 Care and Design of Electrical Installations for Human Safety

Location of switches and location of electrical equipment has to be done with a view to avoid electrical hazards to the users from the angle of human safety.

Most common hazard is of direct contact and that too when associated with wet surfaces. Wet surface reduces the contact resistance and thereby increases the current flow.

The second most common hazard comes up from old or/and damaged or under-sized flexible cords used for connection of portable equipment or devices.

The recommendations for typical areas requiring special attention are given in **13.4.1** to **13.4.5**.

13.4.1 *Bath Room Installations*

13.4.1.1 *Geyser*

The geyser or a storage water heater in not a portable device as it requires connection to the electricity line as well as to the water supply lines. The electrical connection will be from a 16 A socket outlet located at least 500 mm away from the plumbing connections. The switch for the geyser should not be accessible from the bath area or the shower area, to avoid a person standing on the wet surface touching the switch. The switch should be located away from the wet floor area of a bath room and preferably outside near the entrance to the bath room. This switch should have a built in indicator to display the status.

13.4.1.2 *Shaver socket*

Shaver sockets are located near the mirror. The socket will be fed from an isolating transformer (which in addition to providing electrical isolation between the output to the shaver and the building electrical system, may also give a voltage choice selection) to avoid shock hazard.

Shaver sockets which do not have a built in isolating transformer should be protected at the back by an RCCB/ RCD of 10 mA sensitivity.

13.4.1.3 *Protection against electric shocks in bathrooms*

All circuits in bathrooms shall be protected by an RCCB/

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RCD with a sensitivity of 30 mA. The an RCCB/RCD shall be in compliance with its relevant Indian Standards.

13.4.1.4 *Protection against electric shocks in sauna heater*

All circuits in sauna shall be protected by an RCCB/ RCD with a sensitivity of 30 mA. The RCCB/RCD shall be in compliance with its relevant Indian standards.

13.4.2 *Bed Room Installations*

For the convenience of operating the lights, fan, etc, from the bed, it is quite a common practice to provide a pendant switch wired with a flexible cord. The flexible cord used should be with an outer sheath and the sheath should be securely clamped at the pendent switch. Use of twisted flexible cables without double insulation is hazardous and should be avoided.

A bed-head control set for all outlets to be controlled, mounted either on the wall accessible from the bed or mounted on the head board of the bed would be a preferable and safer alternative. This alternative requires the termination of the permanently installed wiring at a box near the bed and a flexible multicore sheathed cable for connection from the wall termination box to the control switch set mounted on the bed-head.

13.4.3 *Kitchen Installations*

Today a large number of gadgets are in use in the kitchen and it would be desirable to provide a large number of combination of 6 A/16 A sockets. As a general guideline any part of the kitchen counter should be within 1 m from a socket outlet as most kitchen appliances come with a 1.5 m or 2 m flexible cord.

The sockets should be located on the basis of the equipment layout and the general purpose outlets would be placed at 150 mm above the kitchen counter level.

For safety, all the socket outlets should be from circuits with an RCCB/RCD protection of sensitivity 30 mA. If an instant geyser is provided the same has to be wired from circuit with a 100 mA RCCB/RCD as 30 mA may cause nuisance tripping for a geyser.

13.4.4 *Protection Against Electric Shocks in Swimming Pools and the Other Basins.*

For swimming pools and other basins such as basins of swimming pools, paddling pools and their surrounding zones; areas in natural waters such as lakes in gravel pits, coastal and similar areas, specially intended to be occupied by persons for swimming, paddling and similar purposes and their surrounding zones, basins of fountains and their surrounding zones; all electrical systems provided shall be protected by residual current devices with a sensitivity not exceeding 30 mA. The RCD shall be in compliance with its product standard. All circuits for lighting, etc, in contact with water shall be at 24 V or less.

13.4.5 For protection against electric shock in other applications, reference shall be made to National Electric Code.

13.5 Earthing Requirements

Earthing is an essential need for protection against shock. Almost all devices require a proper earth connection through the earthing pin (and socket) and in turn through the earth continuity conductor.

13.6 Heating Appliances and Hot Appliances

Electrical appliance incorporating a heating element pose additional hazards from the possibility of overheating and inadvertent ignition of combustible material in the vicinity. While the installation by itself cannot be made failsafe, it is necessary to provide conspicuous indicators with the switches for the sockets used for such appliances, so that visible indication warns the user that the appliance is 'ON' (many appliances which have their own built in indication, may be in 'OFF' position in their standby mode or in the cut-off mode. Under such conditions the indication associated with the switch would be a gentle reminder.).

Almost all electrical appliances produce heat and require ventilation. The surface of the equipment is likely to be hot. Wherever the surface temperature is likely to be more than 45°C, there should be a protection against the possibility of touching the surface and getting scalded or burnt.

13.7 Switches Getting Supply from Multiple Sources

Use of critical electrical equipment requiring continued power supply even in the absence of the commercial supply are on the increase both at home and in any general office, apart from special functional buildings where multiple or redundant sources is a necessity. Use of UPS systems has become common.

Where there are such points or switches fed from multiple sources, it is desirable to mark these switches or adopt a colour code so that they are identified readily.

Many UPS and Inverters have the feature of tripping on overload followed by automatic restoration after a brief time delay. Such characteristics should be made known to the users, so that accidents do not happen by the uninformed user taking some action assuming that the power supply is not there. Shock hazards are dependent on the system voltage and the hazard level is the same whether it is from the power system or from a mini UPS of a few watts.

13.8 Protection Against Environmental Over-Voltages

Any building today has a number of metallic connections coming into the building or installed over (or near) the building such as lines for electricity, telephone, dish antenna, radio antenna, pipe lines for water supply, sewage, cable of cable TV, solar hot water system, solar photovoltaic array, cell phone tower, wind generator, etc. External disturbances such as lightning, faults in external

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systems, can induce over-voltage in the installations within the building.

Buildings are to be provided protection from lightning strikes by a system of 'Faraday Cage' on the basis of hazard assessment. But at the same time use of dish antenna for TV, cable TV (the cable for which is run from building to building on the top, apparently forming a line to catch a lightning stroke) are on the rise and are without any regulation. These installations pose hazards to the installations inside the building.

For sensitive and critical equipment it is necessary to make a separate detailed study and build in appropriate protective device such as shield, suppressor or diverter as may be appropriate for the equipment as well as the type of hazard assessed.

13.9 Flammable Atmosphere and Risk of Ignition by Electricity Leading to Fire or Explosion

13.9.1 Flammable atmospheres are part of the electrical fire and explosion hazards. They are dealt with separately because of the complexities and problems peculiar to the subject. They occur when flammable gas, vapour, mist, aerosol or dust is present in a concentration in air between the upper (UEL) and lower (LEL) explosive limits. Such mixtures ignite if there is a source of ignition also present, such as incentive arcs or sparks from electrical equipment. The risk areas are divided into following zones for flammable gases/vapours:

a) *Zone 0* — Where the flammable atmosphere is always present.

b) *Zone 1* — Where the flammable material is present during normal operations and a flammable atmosphere is likely to occur.

c) *Zone 2* — Where the flammable atmosphere is unlikely during normal operation and if it occurs it will exist only for a short time.

13.9.2 A spark such as from a switch in an explosive atmosphere can trigger a fire or an explosion. In such areas special 'flame-proof' category switches, light fittings, cables, etc, will have to be used. The installation practices are also precise. Zonal boundaries have to be determined by the occupier's specialist staff and marked on the site drawing in plan and elevation. It is a difficult task and requires knowledge of the characteristics of the material and how it disperses from the source of emission.

To illustrate by an example, if LPG leaks from a domestic gas cylinder it creates a hazardous situation. LPG is heavier than air and will settle down at the bottom on the floor with gradually changing ratio of air/LPG mixture as you go up above the floor level and it would be an explosive mixture at a height of a few centimeters above the floor level, which can easily be ignited by a spark or a flame. LPG stored in a basement (particularly if it is without exhaust picked up from floor level) can be serious situation.

Armed with the zonal boundary plans, the next step is to determine the position of the electrical equipment. Wherever possible, the risk should be avoided or minimized by locating the electrical equipment outside the risk areas or in Zone 2 areas rather than in Zones 0 and 1.

Zone 0 is usually inside reaction vessels or storage tanks. There is not much electrical equipment available for use in Zone 0 and as the risk is high it should be avoided by locating the equipment outside, example, a container can have glazed port-holes so that the interior can be viewed through one and lit from a luminaire shining through another. Zone 1 areas often occur only in the immediate vicinity of where the flammable material is processed. They are invariably surrounded by Zone 2 areas where the electrical apparatus should preferably be situated. It is sometimes possible to light outside site zones by luminaires located at high level in safe areas above the vertical zone boundaries. For flammable interiors, lighting can often be provided by positioning the luminaires outside in a safe location and shining the light through glazed panels in the roof or walls. Again, motors can be outside and drive an internal machine through a long shaft extension passing through a gas-tight seal in the wall. In some plants, it is convenient to locate the motor starters together on a starter panel in a motor control room. This room may either be in a safe area or if within the flammable zone, fed with clean air, from outside the zone, maintained at a positive pressure to ensure that gas cannot enter. Conduits for wiring should be solid drawn or seam welded with screwed joints. Where flammable gases have to be excluded from equipment, barrier seals may be necessary. Flexible metallic conduit should be lined to prevent abrasion of the cable insulation. Aluminium and aluminium alloy conduits and accessories should not be used where frictional contact with oxygen-rich items such as rusty steel might occur and cause sparking.

13.10 Protection Against Fire Due to Leakage Current in the Building

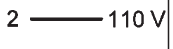
Large number of fire in the building occur due to faulty electrical installation. Mostly, the cause is assigned to over load or short-circuit fault. But there can be one more reason for causing the fire in the building. As the quality of insulation of the cables deteriorate due to ageing over a period of time, certain amount of leakage current flows in the system. This leakage current or tracking is difficult to detect and if it is allowed for a long period of time, say months or years, sparks occur which on a favourable condition, may lead to devastating fire in the building. Ignition of fire due to leakage current or tracking may be prevented by providing residual current devices of 300/500 mA as part of the main distribution board.

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ANNEX A

(*Clause* 2.2)

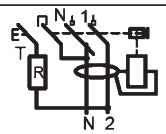
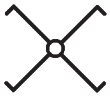
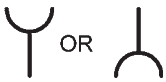
DRAWING SYMBOLS FOR ELECTRICAL INSTALLATIONS IN BUILDINGS

Sl No.	*Details*	*Symbol*	*Sl No.*	*Details*	*Symbol*
1.	Direct current		12.	Overhead Line	
2.	Alternating current, general symbol		13.	Winding, delta	
3.	Alternating current, single-phase, 50Hz		14.	Winding, star	
4.	Alternating current, three-phase, 415 V		15.	Terminals	
5.	Alternating current, three-phase with neutral, 50 Hz		16.	Resistance/Resistor	
6.	Neutral		17.	Variable resistor	
7.	Positive polarity		18.	Impedance	
8.	Negative polarity		19.	Inductance/Inductor	
9.	Direct current, 2 conductors 110 V		20.	Winding	
10.	Direct current 3 conductors including neutral 220 V		21.	Capacitance, capacitor	
11.	Underground cable		22.	Earth	

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Sl No.	*Details*	*Symbol*	*Sl No.*	*Details*	*Symbol*
23.	Fault		34.	Auto-transformer	
24.	Flexible conductor		35.	3-Phase transformer with three separate windings-Star-star-delta	
25.	Generator		36.	Starter	
26.	a.c. generator		37.	Direct-on-line-starter for reversing motor	
27.	d.c. generator		38.	Star-delta starter	
28.	Motor		39.	Auto-transformer starter	
29.	Synchronous motor		40.	Rheostatic starter	
30.	Mechanically coupled machines		41.	Switch	
31.	Induction motor, Three-phase, squirrel cage		42.	Contactor	
32.	Induction motor with wound rotor		43.	One - way switch, single pole	
33.	Transformers with two separate windings		44.	One - way switch, two pole	

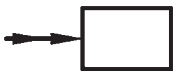
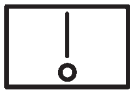
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Sl No.	*Details*	*Symbol*	*Sl No.*	*Details*	*Symbol*
45.	One - way switch, three pole		56.	Relay	
46.	Single pole pull switch		57.	Circuit-Breaker	
47.	Multiposition switch for different degrees of lighting		58.	Isolator	
48.	Two-way switch		59.	Residual current circuit breaker	
49.	Intermediate switch		60.	Surge protective device	
50.	Period limiting switch		61.	Fuse	
51.	Time switch		62.	Signal lamp	
52.	Pendant switch		63.	Link	
53.	Push botton		64.	Distribution boards, cubicle box, main fuse board with switches	
54.	Luminous push botton		65.	Socket outlet, 6A	
55.	Restricted access push botton		66.	Socket outlet, 16 A	

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Sl No.	*Details*	*Symbol*	*Sl No.*	*Details*	*Symbol*
67.	Combined Switch and Socket Outlet, 6A		78.	Indicating instrument (General symbol)	
68.	Combined switch and socket outlet, 16 A		79.	Recording instrument (General symbol)	
69.	Interlocking switch and socket outlet, 6A		80.	Integrating meter	
70.	Interlocking switch and socket outlet, 16A		81.	Watthour meter	
71.	Plug		82.	Clock	
72.	Voltmeter		83.	Master clock	
73.	Ammeter		84.	Current transformer	
74.	Wattmeter		85.	Voltage transformer	
75.	Varmeter		86.	Wiring on the surface	
76.	Power factor meter		87.	Wiring under the surface	
77.	Ohmmeter		88.	Conduit on surface	

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Sl No.	*Details*	*Symbol*	*Sl No.*	*Details*	*Symbol*
89.	Concealed conduit		101.	Storage type water heater	
90.	Wiring in conduit		102.	Bell	
91.	Lamp		103.	Buzzer	
92.	Lamp mounted on a ceiling		104.	Siren	
93.	Lamp, mounted on a wall		105.	Ceiling fan	
94.	Emergency lamp		106.	Exhaust fan	
95.	Panic lamp		107.	Fan regulator	
96.	Water-tight lighting fitting	 WT	108.	Aerial	
97.	Battern lamp holder	 BH	109.	Radio receiving set	
98.	Spot light		110.	Television receiving set	
99.	Flood light		111.	Manually operated fire alarm	
100.	Heater		112.	Automatic fire detector switch	

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ANNEX B

[*Clauses* 3.1, 4.2.1 (12) (ix), 4.7.1.2, 4.7.1.4, 4.7.1.5, 4.7.3.1, 5.3.6.8, 5.4.1.1, 5.4.1.3, 6.4.6, 8.2.1 *and* 9.1.1]

EXTRACTS FROM CENTRAL ELECTRICITY AUTHORITY (MEASURES RELATING TO SAFETY AND ELECTRIC SUPPLY) REGULATION, 2010 FURTHER AMENDED IN 2015

B-1 The following are the extracts of some of the rules:

Regulation 4, Inspection of designated officers and other safety measures

(1) The register maintained under sub-regulation (2) of regulation 3 shall be produced before the Electrical Inspector when required by him.

(2) If on inspection, the Electrical Inspector finds that the designated person does not fulfill the required qualification, he shall recommend the removal of the name of such persons from the register.

Regulation 5, Electrical safety officer

(1) All suppliers of electricity including generating companies, transmission companies and distribution companies shall designate an Electrical Safety Officer for ensuring observance of safety measures specified under these regulations in their organization, for construction, operation and maintenance of power stations, sub-stations, transmission and distribution lines.

(2) The Electrical Safety Officer shall be an Electrical Engineering degree holder with at least five years of experience in operation and maintenance of electrical installations.

(3) The Electrical Safety Officer designated under sub-regulation (1), shall carry out periodic tests as per the relevant standards and inspection of such installations for ensuring observance of safety measures specified under these regulations at intervals not exceeding one year, and keep a record thereof in Form I or Form II or Form III, as the case may be, of Schedule IV and test reports, and also keep a register of recommended safety requirements duly acknowledged by the owner with date and compliances thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

(4) For every electrical installation including factory registered under the *Factories Act*, 1948 (63 of 1948) and mines and oil field as defined in the *Mines Act*, 1952 (35 of 1952), where more than 250 kW of electrical load is connected, the owner of the installation or the management of the factory or mines, as the case may be, shall designate Electrical Safety Officer having qualification and experience specified in sub-regulation (2), for ensuring the observance of the safety provisions laid under the Act and the regulations made thereunder, who shall carry out recommended periodic tests as per the relevant standards, and inspect such installation at intervals not exceeding one year, and keep a record thereof in Form I or Form II or Form III, as the case may be, of Schedule IV to these regulations; test reports and a register of recommendations in regard with safety duly acknowledged by owner; compliances made thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

Regulation 5A, Chartered Electrical Safety Engineer

The Appropriate Government may authorize Electrical Safety Engineers having the qualification and experience as specified in sub-regulation (2) of regulation 5 to assist the owner or supplier or consumer of electrical installations for the purpose of self-certification under regulation 30 and regulation 43.

Regulation 8, Keeping of records and inspection thereof

(1) The generating company or licensee shall maintain records of the maps, plans and sections relating to supply or transmission of electricity and submit the same to the Electrical Inspector for inspection as and when required by him.

(2) The Electrical Inspector shall supply a copy of the report of inspection referred to in sub-regulation (1), to the generating company or licensee, as the case may be.

Regulation 12, General safety requirements pertaining to construction, installation, protection, operation and maintenance of electric supply lines and apparatus

(1) All electric supply lines and apparatus shall be of sufficient rating for power, insulation and estimated fault current and of sufficient

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mechanical strength, for the duty cycle which they may be required to perform under the environmental conditions of installation, and shall be constructed, installed, protected, worked and maintained in such a manner as to ensure safety of human beings, animals and property.

(2) Save as otherwise provided in these regulations, the relevant code of practice of the Bureau of Indian Standards or National Electrical Code, if any, may be followed to carry out the purposes of this regulation and in the event of any inconsistency, the provisions of these regulations shall prevail.

(3) The material and apparatus used shall conform to the relevant specifications of the Bureau of Indian Standards or International Electro-Technical Commission where such specifications have already been laid down.

(4) All electrical equipment shall be installed above the Mean Sea Level (MSL) as declared by local Municipal Authorities and where such equipment is to be installed in the basement, consumer shall ensure that the design of the basement should be such that there is no seepage or leakage or logging of water in the basement.

Regulation 13, Service lines and apparatus on consumer's premises

(1) The supplier shall ensure that all electric supply lines, wires, fittings and apparatus belonging to him or under his control, which are on a consumer's premises, are in a safe-condition and in all respects fit for supplying electricity and the supplier shall take precautions to avoid danger arising on such premises from such supply lines, wires, fittings and apparatus.

(2) Service lines placed by the supplier on the premises of a consumer which are underground or which are accessible shall be so insulated and protected by the supplier as to be secured under all ordinary conditions against electrical, mechanical, chemical or other injury to the insulation.

(3) The consumer shall, as far as circumstances permit, take precautions for the safe custody of the equipment on his premises belonging to the supplier.

(4) The consumer shall also ensure that the installation under his control is maintained in a safe condition.

Regulation 14, Switchgear on consumer's premises

(1) The supplier shall provide a suitable switchgear in each conductor of every service line other than an earthed or earthed neutral conductor or the earthed external conductor of a concentric cable within a consumer's premises, in an accessible position and such switchgear shall be contained within an adequately enclosed fireproof receptacle:

Provided that where more than one consumer is supplied through a common service line, each such consumer shall be provided with an independent switchgear at the point of rigid junction to the common service.

(2) Every electric supply line other than the earthed or earthed neutral conductor of any system or the earthed external conductor of a concentric cable shall be protected by a suitable switchgear by its owner.

Regulation 15, Identification of earthed and earthed neutral conductors and position of switches and switchgear therein

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be complied with:

(i) an indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor which is to be connected thereto, to enable such conductor to be distinguished from any live conductor and such indication shall be provided—

(a) where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply;

(b) where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor, at the point where such connection is to be made;

(c) in all other cases, at a point corresponding to the point of commencement of supply or at such other points as may be approved by an Electrical Inspector.

(ii) no cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductor shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two wire-system or in any earthed or earthed neutral conductor of a

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multi-wire system or in any conductor connected thereto.

Provided that the above requirement shall not apply in case of —

(a) a link for testing purposes, or

(b) a switch for use in controlling a generator or transformer.

Regulation 16, Earthed terminal on consumer's premises

(1) The supplier shall provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply.

Provided that in the case of installation of voltage exceeding 250 V the consumer shall, in addition to the aforementioned earthing arrangement, provide his own earthing system with an independent electrode.

Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the date to be specified by the State Government in this behalf if he is satisfied that the consumer's earthing arrangement is efficient.

(2) The consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier.

(3) The supplier may recover from the consumer the cost of installation on the basis of schedule of charges published by him in advance and where such schedule of charges is not published, the procedure laid down, in regulations 63 shall apply.

Explanation — For the purposes of sub-regulation (1), the expression "Point of commencement of supply of electricity" shall mean the point at the incoming terminal of the switchgear installed by the consumer.

Regulation 17, Accessibility of bare conductors

Where bare conductors are used in a building, the owner of such conductors shall —

(a) ensure that they are inaccessible;

(b) provide in readily accessible position switches for rendering them dead whenever necessary; and

(c) take such other safety measures as are specified in the relevant Indian Standards.

Regulation 18, Danger notices

The owner of every installation of voltage exceeding 250 V shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language of the District, with a sign of skull and bones of a design as per IS-2551 on

(a) every motor, generator, transformer and other electrical plant and equipment together with apparatus used for controlling or regulating the same;

(b) all supports of overhead lines of voltage exceeding 650 V which can be easily climbed upon without the aid of ladder or special appliances;

(c) luminous tube sign requiring supply, X-ray and similar high frequency installations of voltage exceeding 650V but not exceeding 33 kV:

Provided that where it is not possible to affix such notices on any generator, motor, transformer or other apparatus, they shall be affixed as near as possible thereto, or the word 'danger' and the voltage of the apparatus concerned shall be permanently painted on it:

Provided further that where the generator, motor, transformer or other apparatus is within an enclosure one notice affixed to the said enclosure shall be sufficient for the purposes of this regulation.

Explanation — For the purpose of clause (b), rails, tubular poles, wooden supports, reinforced cement concrete poles without steps, I-sections and channels, shall be deemed as supports which cannot be easily climbed upon.

Regulation 19, Handling of electric supply lines and apparatus

(1) Before any conductor or apparatus is handled, adequate precautions shall be taken, by earthing or other suitable means, to discharge electrically such conductor or apparatus, and any adjacent conductor or apparatus if there is danger therefrom, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon.

(2) Every person who is working on an electric supply line or apparatus or both shall be provided with tools and devices such as gloves, rubber shoes, safety belts, ladders, earthing devices, helmets, line testers, hand lines and the like for protecting him from mechanical and electrical injury and such tools

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and devices shall always be maintained in sound and efficient working condition.

(3) No person shall work on any live electric supply line or apparatus and no person shall assist such person on such work, unless he is designated in that behalf, and takes the safety precautions given in Schedule-III.

(4) Every telecommunication line on supports carrying a line of voltage exceeding 650 V but not exceeding 33 kV shall, for the purpose of working thereon, be deemed to be a line of voltage exceeding 650 V.

(5) All non-current carrying metal parts of switchgear and control panels shall be properly earthed and insulating floors or mat conforming to IS-15652:2006, of appropriate voltage level shall be provided in front of panels for the safety of operating personnel.

(6) All panels shall be painted with the description of its identification at front and at the rear.

Regulation 22, Cables protected by bituminous materials

(1) Where the supplier or the owner has brought into use an electric supply line, other than an overhead line, which is not completely enclosed in a continuous metallic covering connected with earth and is insulated or protected in situ by composition or material of a bituminous character, —

(i) any pipe, conduit, or the like into which such electric supply line may have been drawn or placed shall, unless other arrangements are approved by the Electrical Inspector in any particular case, be effectively sealed at its point of entry into any street box so as to prevent any flow of gas to or from the street box, and;

(ii) such electric supply line shall be periodically inspected and tested where accessible, and the result of each such inspection and test shall be duly recorded by the supplier or the owner.

(2) The supplier or the owner after the coming into force of these regulations, shall not bring into use any further electric supply line as aforesaid which is insulated or protected in situ by a composition or material known to be liable to produce noxious or explosive gases on excessive heating.

Regulation 23, Street boxes

(1) Street boxes shall not contain gas pipes, and precautions shall be taken to prevent, as far as reasonably possible, any influx of water or gas.

(2) Where electric supply lines forming part of different systems pass through the same street box, they shall be readily distinguishable from one another and all electric supply lines of voltage exceeding 650 V at or in street boxes shall be adequately supported and protected so as to prevent risk of damage to or danger from adjacent electric supply lines.

(3) All street boxes shall be regularly inspected for the purpose of detecting the presence of gas and if any influx or accumulation is discovered, the owner shall give immediate notice to any authority or company who have gas mains in the neighbourhood of the street box and in cases where a street box is large enough to admit the entrance of a person after the electric supply lines or apparatus therein have been placed in position, ample provision shall be made —

(i) to ensure that any gas which may be accident have obtained access to the box shall escape before a person is allowed to enter; and

(ii) for the prevention of danger from sparking.

(4) The owners of all street boxes or pillars containing circuits or apparatus shall ensure that their covers and doors are kept closed and locked and are so provided that they can be opened only by means of a key or a special appliance.

Regulation 24, Distinction of different circuits

The owner of every generating stations, substation, junction-box or pillar in which there are any circuits or apparatus, whether intended for operation at different voltages or at the same voltage, shall ensure by means of indication of a permanent nature that the respective circuits are readily distinguishable from one another.

Regulation 25, Distinction of the installations having more than one feed

The owner of every installation including substation, double pole structure, four pole structure or any other structure having more than one feed, shall ensure by means of indication of a permanent nature, that the installation is readily distinguishable from other installations.

Regulation 26, Accidental charging

(1) The owners of all circuits and apparatus shall so arrange them that there shall be no danger

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of any part thereof becoming accidently charged to any voltage beyond the limits of voltage for which they are intended.

(2) Where alternating current and direct current circuits are installed on the same box or support, they shall be so arranged and protected that they shall not come into contact with each other when live.

Regulation 27, Provisions applicable to protective equipment

(1) Fire buckets filled with clean dry sand and ready for immediate use for extinguishing fires, in addition to fire extinguishers suitable for dealing with fires, shall be conspicuously marked fire extinguishers suitable for dealing with fires, shall be conspicuously marked and kept in all generating stations, enclosed substations and switching-stations in convenient locations.

(2) The fire extinguishers shall be tested for satisfactory operation as per relevant Indian Standard at least once a year and record of such tests shall be maintained.

(3) First-aid boxes or cupboards conspicuously marked and equipped with such contents as the State Government may specify, shall be provided and maintained in every generating station, enclosed substation, enclosed switching station and in vehicles used for maintenance of lines so as to be readily accessible during all working hours and all such boxes and cupboards shall, except in the case of unattended substations and switching stations, be kept in charge of responsible persons who are trained in first-aid treatment and one of such persons shall be available during working hours.

(4) Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of 5 MW and above and enclosed substation with transformation capacity of 5 MVA and above for use in the event of fire or smoke.

Provided that where more than one generator with capacity of 5 MW and above is installed in a power station, each generator shall be provided with at least two separate gas masks in an accessible and conspicuous place.

Provided further that adequate number of gas masks shall be provided by the owner at every generating station and enclosed substation with capacity less than 5 MW and 5 MVA respectively.

Regulation 28, Display of instructions for resuscitation of persons suffering from electric shock

(1) Instructions, in English or Hindi and the local language of the District and where Hindi is the local language, in English and Hindi for the resuscitation of persons suffering from electric shock, shall be affixed by the owner in a conspicuous place in every generating station, enclosed substation, enclosed switching station, mines and in every factory, as defined in clause (m) of section 2 of the *Factory Act*, 1948 (63 of 1948) in which electricity is used and in such other premises where electricity is used as the Electrical Inspector may, by notice in writing served on the owner, direct.

(2) The owner of every generating station, enclosed substation, enclosed switching station and every factory or other premises to which these regulations apply, shall ensure that all designated persons employed by him are acquainted with and are competent to apply the instructions referred to in sub-regulation (1).

(3) In every manned generating station, substation or switching station of voltage exceeding 650 V, an artificial respirator shall be provided and kept in good working condition.

Regulation 29, Precautions to be adopted by consumers, owners, occupiers, electrical contractors, electrical workmen and suppliers

(1) No electrical installation work, including additions, alternations, repairs and adjustments to existing installations, except such replacement of lamps, fans, fuses, switches, domestic appliances of voltage not exceeding 250 V and fittings as in no way alters its capacity or character, shall be carried out upon the premises of or on behalf of any consumer, supplier, owner or occupier for the purpose of supply to such consumer, supplier, owner or occupier except by an electrical contractor licensed in this behalf by the State Government and under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognized by the State Government.

Provided that in the case of works executed for or on behalf of the Central Government and in the case of installations in mines, oil fields and railways, the Central Government and in other cases the State Government, may, by notification in the Official Gazette, exempt

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on such conditions as it may impose, any such work described therein either generally or in the case of any specified class of consumers, suppliers, owners or occupiers.

(2) No electrical installation work which has been carried out in contravention of sub-regulation (1) shall either be energized or connected to the works of any supplier.

Regulation 30, Periodical inspection and testing of installations

(1) Where an installation is already connected to the supply system of the supplier or trader, every such installation shall be periodically inspected and tested at intervals not exceeding five years either by the Electrical Inspector or by the supplier as may be directed by the State Government in this behalf or in the case of installations belonging to, or under the control of the Central Government, and in the case of installation in mines, oilfields and railways, by the Central Government.

(2) The periodical inspection and testing of installations of voltage equal to or below the notified voltage belonging to the supplier or consumer, shall be carried out by the supplier or owner or consumer and shall be self-certified.

(3) The periodical inspection and testing of installations of voltage above the notified voltage belonging to the supplier or consumer shall be carried out by the Electrical Inspector:

Provided that the supplier or owner or consumer has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

Provided further that the electrical installations of mines, oil-fields and railways shall be periodically inspected and tested by the Electrical Inspector of the Appropriate Government.

(4) Where the supplier is directed by the Central Government or the State Government, as the case may be, to inspect and test the installation, such supplier shall report on the condition of the installation to the consumer concerned in the Forms I, II and III as specified in Schedule-IV and shall submit a copy of such report to the Electrical Inspector.

(5) The Electrical Inspector may, on receipt of such report, accept the report submitted by the supplier or record variations as the circumstances of each case may require and may recommend that the defects may be rectified as per report.

(6) In the event of the failure of the owner of any installation to rectify the defects in his installation pointed out by the Electrical Inspector in his report and within the time indicated therein, such installation shall be liable to be disconnected under the directions of the Electrical Inspector after serving the owner of such installation with a notice for a period not less than forty eight hours:

Provided that the installation shall not be disconnected in case an appeal is made under sub section (2) of section 162 of the Act and the appellate authority has stayed the orders of disconnection.

(7) It shall be the responsibility of the owner of all installations to maintain and operate the installation in a condition free from danger and as recommended by the manufacturer or by the relevant codes of practice of the Bureau of Indian Standards.

Regulation 31, Testing of consumer's installation

(1) Upon receipt of an application for a new or additional supply of electricity and before connecting the supply or reconnecting the same after a period of six months, the supplier shall either test the installation himself or accept the test results submitted by the consumer when the same has been duly signed by the licensed Electrical Contractor.

(2) The supplier shall maintain a record of test results obtained at each supply point to a consumer, in a Schedule-V.

(3) If as a result of such inspection and test, the supplier is satisfied that the installation is likely to be dangerous, he shall serve on the applicant a notice in writing requiring him to make such modifications as are necessary to render the installation safe and may refuse to connect or reconnect the supply until the required modifications have been completed.

Regulation 32, Installation and testing of generating units

The capacity above which generating units including generating units producing electricity from renewable sources of energy will be required to be inspected by the Electrical Inspector before commissioning, shall be as per the notification to be issued by the Appropriate Government, under the sub-section (1) of section 162 of the Act.

Regulation 33, Precautions against leakage before connection

(1) The supplier shall not connect with his works

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the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that installation or apparatus of a magnitude detrimental to safety which shall be checked by measuring the installation resistance as under, -

(i) all equipment shall have the insulation resistance (IR) value as stipulated in the relevant Indian Standards;

(ii) on application of 500 V d.c. between each live conductor and earth for a period of one minute the insulation resistance of installation and equipment of voltage not exceeding 650 V shall be at least 1 MEGA OHM or as specified in the relevant Indian Standard;

(iii) on application of 2.5 kV d.c. between each live conductor and earth for a period of one minute, the insulation resistance of installation and equipment of voltage exceeding 650 V but not exceeding 33 kV shall be at least 5 MEGA OHM or as specified in the relevant standard;

(2) If the supplier declines to make a connection under the provision of sub-regulation (1) he shall convey to the applicant the reasons in writing for so declining.

Regulation 34, Leakage on consumer's premises

(1) If the Electrical Inspector or the supplier has reasons to believe that there is leakage in the system of a consumer which is likely to affect injuriously the use of electricity by the supplier or by other persons, or which is likely to cause danger, he may give the consumer notice in writing that he desires to inspect and test the consumer's installation.

(2) If on such notice being given the consumer does not give all reasonable facilities for inspection and testing of his installation, or when an insulation resistance of the consumer's installation is so low as to prevent safe use of electricity, the supplier may, and if directed so to do by the Electrical Inspector shall discontinue the supply of electricity to the installation but only after giving to the consumer forty eight hours notice in writing of disconnection of supply and shall not recommence the supply until he or the Electrical Inspector is satisfied that the cause of the leakage has been removed.

Regulation 35, Supply and use of electricity

(1) The electricity shall not be supplied, transformed, converted, inverted or used or continued to be supplied, transformed, converted, inverted or used unless the conditions contained in sub-regulations (2) to (8) are complied with.

(2) The following controls of requisite capacity to carry and break the current shall be placed as near as possible after the point of commencement of supply so as to be readily accessible and capable of being easily operated to completely isolate the supply to the installation, such equipment being in addition to any equipment installed for controlling individual circuits or apparatus, namely—

(i) a linked switch with fuse or a circuit breaker by consumers of voltage which does not exceed 650 V;

(ii) a linked switch with fuse or a circuit breaker by a consumer of voltage exceeding 650 V but not exceeding 33 kV having aggregate installed transformer or apparatus capacity up to 1000 kVA to be supplied at voltage upto 11 kV and 2500 kVA at higher voltages (above 11 kV and not exceeding 33 kV);

(iii) a circuit breaker by consumers at voltage exceeding 650 V but not exceeding 33 kV having an aggregate installed transformer and apparatus capacity above 1000 kVA and supplied at voltage upto 11 kV and above 2500 kVA at higher voltages (above 11 kV and not exceeding 33 kV);

(iv) a circuit breaker by a consumer of voltage exceeding 33 kV.

Provided that where the point of commencement of supply and the consumer apparatus are near each other, one linked switch with fuse or circuit breaker near the point of commencement of supply shall be considered sufficient.

(3) In case of every transformer the following shall be provided; namely—

(i) on primary side of transformers a linked switch with fuse or circuit breaker of adequate capacity:

Provided that the linked switch on the primary side of the transformer may be of such capacity as to carry the full load current and to break only the magnetising current of the transformer:

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Provided further that for all transformers:

(a) having a capacity of 5000 kVA and above installed before the year 2000; and

(b) having a capacity 1000 kVA and above installed in or after the year 2000,

a circuit breaker shall be provided:

Provided also that the linked switch on the primary side of the transformer shall not be required for the unit auxiliary transformer and generator transformer;

(ii) in respect of all transformers installed in or after the year 2000, on the secondary side of all transformers a circuit breaker of adequate rating shall be installed:

Provided that for suppliers' transformers of capacity below 1000 kVA, a linked switch with fuse or circuit breaker of adequate rating shall be installed on secondary side.

(4) Except in the case of composite control gear designed as a unit each distinct circuit is to be protected against excess energy by means of suitable cut-out or a circuit breaker of adequate breaking capacity suitably located and so constructed as to prevent danger from overheating, arcing or scattering of hot metal when it comes into operation and to permit for ready renewal of the fusible metal of the cut-out without danger.

(5) The supply of electricity to each motor or a group of motors or other apparatus meant for operating one particular machine shall be controlled by a suitable linked switch or a circuit breaker or an emergency tripping device with manual reset of requisite capacity placed in such a position as to be adjacent to the motor or a group of motors or other apparatus readily accessible to and easily operated by person incharge and so connected in the circuit that by its means all supply of electricity can be cut off from the motor or group of motors or apparatus from any regulating switch, resistance of other device associated therewith.

(6) All insulating materials shall be chosen with special regard to the circumstances of their proposed use and their mechanical strength shall be sufficient for their purpose and so far as is practicable of such a character or so protected as to maintain adequately their insulating property under all working conditions in respect of temperature and moisture; and

(7) Adequate precautions shall be taken to ensure that no live parts are so exposed as to cause danger.

(8) Every consumer shall use all reasonable means to ensure that where electricity is supplied by a supplier no person other than the supplier shall interfere with service lines and apparatus placed by the supplier on the premises of the consumer.

Regulation 36, Provisions for supply and use of electricity in multi-storeyed building more than 15 metres in height

(1) The connected load and voltage of supply above which inspection is to be carried out by an Electrical Inspector for a multi-storeyed building of more than fifteen meters height shall be notified by the Appropriate Government.

(2) Before making an application for commencement of supply or recommencement of supply after an installation has been disconnected for a period of six months or more, the owner or occupier of a multi-storeyed building shall give not less than thirty days notice in writing to the Electrical Inspector specify therein the particulars of installation and the supply of electricity shall not be commenced or recommenced within this period, without the approval in writing of the Electrical Inspector.

(3) The supplier or owner of the installation shall provide at the point of commencement of supply a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the 3-phase, 4-wire circuit and fixed in a conspicuous position at not more than 1.70 metres above the ground so as to completely isolate the supply to the building in case of emergency.

(4) The owner or occupier of a multi-storeyed building shall ensure that electrical installations and works inside the building are carried out and maintained in such a manner as to prevent danger due to shock and fire hazards, and the installations is carried out in accordance with the relevant codes of practice.

(5) No other service pipes and cables shall be taken along the ducts provided for laying power cables and all ducts provided for power cables and other services shall be provided with fire barrier at each floor crossing.

Regulation 37, Conditions applicable to installations of voltage exceeding 250 Volts

The following conditions shall be compiled with where

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electricity of voltage above 250 V is supplied, coverted, transformed or used, namely—

(i) All conductors, other than those of overhead lines, shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanically continuous and adequately protected against mechanical damage unless the said conductors are accessible only to an designated person or are installed and protected so as to prevent danger:

Provided that non-metallic conduits conforming to the relevant Indian Standard Specifications may be used for installations of voltage not exceeding 650 V:

(ii) All metal works, enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall be connected with an earthing system as per standards laid down in the Indian Standards in this regard and the provisions of regulation 41.

(iii) Every switchboard shall comply with the following—

(a) a clear space of not less than one metre in width shall be provided in front of the switchboard;

(b) if there are any attachments or bare connections at the back of the switchboard, the space, if any, behind the switchboard shall be either less than twenty centimetres or more than seventy five centimetres in width, measured from the farthest protruding part of any attachment or conductor;

(c) if the space behind the switchboard exceeds seventy five centimetres in width, there shall be a passage way from either end of the switchboard, clear to a height of 1.8 m.

(iv) In case of installations provided in premises where inflammable materials including gases and chemicals are produced, handled or stored, the electrical installations, equipment and apparatus shall comply with the requirements of flame proof, dust tight, totally enclosed or any other suitable type of electrical fittings depending upon the hazardous zones as per the relevant Indian Standard Specifications.

(v) Where an application has been made to a supplier for supply of electricity to any installation, he shall not commence the supply or where the supply has been discontinued for a period of six months and above, recommence the supply unless the consumer has compiled with, in all respects the conditions of supply set out in these regulations.

(vi) Where a supplier proposes to supply or use electricity at or to recommence supply of voltage exceeding 250 V but not exceeding 650 V after it has been discontinued for a period of six months, he shall, before connecting or reconnecting the supply, give notice in writing of such intention to the Electrical Inspector.

(vii) If at any time after connecting the supply, the supplier is satisfied that any provision of these regulations are not being observed he shall give notice of the same in writing to the consumer and the Electrical Inspector, specifying how the provisions have not been observed and to rectify such defects in a reasonable time and if the consumer fails to rectify such defects pointed out, he may discontinue the supply after giving the consumer a reasonable opportunity of being heard and recording reasons in writing and the supply shall be discontinued only on written orders of an officer duly notified by the supplier in this behalf and shall be restored with all possible speed after such defects are rectified by the consumer to the satisfaction of the supplier.

Regulation 39, Precautions against failure of supply and notice of failures

(1) The layout of the electric supply lines of the supplier for the supply of electricity throughout his area of supply shall under normal working conditions be sectionalised and so arranged, and provided with switchgear or circuit-breakers, so located, as to restrict within reasonable limits the extent of the portion of the system affected by any failure of supply.

(2) The supplier shall take all reasonable precautions to avoid any accidental interruptions of supply, and also to avoid danger to the public or to any employee or designated person when engaged on any operation during and in connection with the installation, extension, replacement, repair and maintenance of any works.

(3) The supplier shall send to the Electrical Inspector a notice of failure of supply of such kind as the Electrical Inspector may from time-to-time require to be notified to him, and such

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notice shall be sent by the earliest mode of communication after the failure occurs or after the failure becomes known to the supplier and shall be in the Form given in Schedule-VI.

(4) For the purpose of testing or for any other purpose connected with the efficient working of the supplier's installations, the supply of electricity may be discontinued by the supplier for such period as may be necessary, subject to not less than twenty four hours notice being given by the supplier to all consumers likely to be affected by such discontinuance:

Provided that no such notice shall be given in cases of emergency.

Regulation 40, Test for resistance of insulation

(1) Where any electric supply line for use at voltage not exceeding 650 V has been disconnected from a system for the purpose of addition, alteration or repair, such electric supply line shall not be reconnected to the system until the supplier or the owner has applied the test prescribed under regulation 33.

(2) The provision under sub-regulation (1) shall not apply to overhead lines except overhead insulated cables, unless the Electrical Inspector otherwise directs in any particular case.

Regulation 41, Connection with earth

The following condition shall apply to the connection with earth of systems at voltage normally exceeding 125 V but not exceeding 650 V, namely—

(i) neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2-phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the substation.

(ii) the earth electrodes so provided, shall be inter-connected to reduce earth resistance.

(iii) neutral conductor shall also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

(iv) in the case of a system comprising electric supply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

(v) the connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

(vi) in a direct current three wire system, the middle conductor shall be earthed at the generating station only, and the current from the middle conductor to earth shall be continuously recorded by means of a recording ammeter, and if at any time the current exceeds one-thousandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

(vii) where the middle conductor is earthed by means of a circuit breaker with a resistance connected in parallel, the resistance shall not exceed ten ohms and on the opening of the circuit breaker, immediate steps shall be taken to improve the insulation of the system, and the circuit breaker shall be reclosed as soon as possible.

(viii) the resistance shall be used only as a protection for the ammeter in case of earths on the system and until such earths are removed and immediate steps shall be taken to locate and remove the earth.

(ix) in the case of an alternating current system, there shall not be inserted in the connection with earth any impedance, other than that required solely for the operation of switchgear or instruments, cut-out or circuit breaker, and the result of any test made to ascertain whether the current, if any, passing through the connection with earth is normal, shall be duly recorded by the supplier.

(x) no person shall make connection with earth by the aid of, nor shall he keep it in contact with, any water mains not belonging to him except with the consent of the owner thereof and of the Electrical Inspector.

(xi) alternating current systems which are connected with earth as aforesaid shall be electrically interconnected:

Provided that each connection with earth is bonded to the metal sheathing and metallic armouring, if any, of the electric supply lines concerned.

(xii) the frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, of all transformers and any other apparatus used for regulating or controlling electricity, and all electricity consuming apparatus, of voltage exceeding 250 V but not exceeding 650 V shall be

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earthed by the owner by two separate and distinct connections with earth.

(xiii) neutral point of every generator and transformer shall be earthed by connecting it to the earthing system by not less than two separate and distinct connections.

(xiv) all metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings, other than portable hand lamps and portable and transportable apparatus, unless provided with earth terminal and to class-II apparatus and appliances:

Provided further that where the supply voltage is not exceeding 250 V and where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and efficiently earthed.

(xv) All earthing systems shall —

(a) consist of equipotential bonding conductors capable of carrying the prospective earth fault current and a group of pipes, rods and plate electrodes for dissipating the current to the general mass of earth without exceeding the allowable temperature limits as per relevant Indian Standards in order to maintain all non-current carrying metal works reasonably at earth potential and to avoid dangerous contact potentials being developed on such metal works;

(b) limit earth resistance sufficiently low to permit adequate fault current for the operation of protective devices in time and to reduce neutral shifting;

(c) be mechanically strong, withstand corrosion and retain electrical continuity during the life of the installation and all earthing systems shall be tested to ensure efficient earthing, before the electric supply lines or apparatus are energised.

(xvi) all earthing systems belonging to the supplier shall in addition, be tested for resistance on dry day during the dry season not less than once every two years.

(xvii) a record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Electrical Inspector when required.

Explanation — The expression "Class-II apparatus and appliance" shall have the same meaning as is assigned to it in the relevant Indian Standards.

Regulation 42, Earth leakage protective device

The supply of electricity to every electrical installation other than voltage not exceeding 250 V, below 2 kW and those installations of voltage not exceeding 250 V, which do not attract provisions of section 54 of the Act, shall be controlled by an earth leakage protective device whose maximum earth leakage threshold for tripping should not exceed 30 milliamps for domestic connections and 100 milliamps for all other installations, so as to disconnect the supply instantly on the occurrence of earth fault or leakage of current:

Provided that such earth leakage protective device shall not be required for overhead supply lines having protective devices which are effectively bonded to the neutral of supply transformers and conforming to regulation 73.

Regulation 43, Approval by electrical inspector and self-certification

(1) Every electrical installation of notified voltage and below shall be inspected, tested and shall be self-certified by the owner of the installation before commencement of supply or recommencement after shutdown for six months and above for ensuring observance of safety measures specified under these regulations and such owner shall submit the report of self-certification in the Form-I or Form-II or Form-III, as the case may be, of Schedule-IV to the Electrical Inspector.

(2) The voltage above which inspection and testing of electrical installations including installations of supplier or consumer shall be carried out by the Electrical Inspector shall be notified by the Appropriate Government.

(3) Every electrical installation of voltage above the notified voltage and all the apparatus of the generating stations and above the capacity specified under regulation 32, shall be required to be inspected and tested by the Electrical Inspector before commencement of supply or recommencement after shutdown for six months and above for ensuring observance of safety measures specified under these regulations:

Provided that the owner or supplier or

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consumer has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

(4) The Electrical Inspector may, on receipt of self-certification report referred to in sub-regulation (1), accept the report submitted by the supplier or owner and record variations as the circumstances of each case may require and may recommend that the defects may be rectified as recommended:

Provided further that every electrical installation covered under section 54 of the Act including every electrical installations of mines, oil fields and railways shall be inspected and tested by the Electrical Inspector of the Appropriate Government as specified in sub-regulation (3).

(5) Before making an application to the Electrical Inspector for permission to commence or recommence supply in installations above the notified voltage after an installation has been disconnected for six months, the supplier shall ensure that electric supply lines or apparatus of more than notified voltage belonging to him are placed in position, properly joined and duly completed and examined, and the supply of electricity shall not be commenced by the supplier for installations of voltage needing inspection under these regulations unless the provisions of regulations 12 to 29, 33 to 35, 44 to 51 and 55 to 77 have been complied with and the approval in writing of the Electrical Inspector has been obtained by him:

Provided that the supplier may energise the aforesaid electric supply lines or apparatus for the purpose of tests specified in regulation 46 and after successful testing, the owner may energise the section of a line to prevent theft of conductors or towers, subject to compliance of all the provisions of these regulations.

(6) The owner of any installations of voltage above the notified voltage, shall, before making application to the Electrical Inspector for approval of his installation or additions thereto, other than an overhead line, and satisfy himself that they withstand the application of the testing voltage set out in sub-regulation (1) of regulation 46 and shall duly record the results of such tests and forward them to the Electrical Inspector:

Provided that an Electrical Inspector may direct such owner to carry out such tests as he deems necessary or accept the certified tests of the manufacturer in respect of any particular apparatus in place of the tests required by this regulation.

(7) The owner of any installation who makes any addition or alternation to his installation shall not connect to the supply his apparatus or electric supply lines, comprising the said alternations or additions, unless and until such alteration or addition has been approved in writing by the Electrical Inspector or self-certified by the owner of the installation, as the case may be.

Regulation 44, Use of electricity at voltage exceeding notified voltage

(1) The Electrical Inspector shall not authorize the supplier to commence supply or where the supply has been discontinued for a period of six months and above, to recommence the supply at voltage exceeding notified voltage to any consumer unless—

(i) all conductors and apparatus situated on the premises of the consumer are so placed as to be inaccessible except to a designated person and all operations in connection with the said conductors and apparatus are carried out by a designated person;

(ii) the consumer has provided and agrees to maintain a separate building or a locked weather proof and fire proof enclosure of agreed design and location, to which the supplier at all times shall have access for the purpose of housing his apparatus and metering equipment, or where the provision for a separate building or enclosure is impracticable, the consumer has segregated the aforesaid apparatus of the supplier from any other part of his own apparatus:

Provided that such segregation shall be by the provision of fire proof walls, if the Electrical Inspector considers it to be necessary:

Provided further that in the case of an outdoor installation the consumer shall suitably segregate the aforesaid apparatus belonging to the supplier from his own;

(iii) all pole type substations are constructed and maintained in accordance with regulation 50.

(2) The owner shall observe the following conditions, where electricity at voltage exceeding 650 V is supplied, converted, transformed or used,—

(i) he shall maintain safety clearances for electrical apparatus as per Bureau of

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Indian Standard specification so that sufficient space is available for easy operation and maintenance without any hazard to the operating and maintenance personnel working near the equipment and for ensuring adequate ventilation;

(ii) he shall not allow any encroachment below such installation:

Provided that where the Electrical Inspector comes across any such encroachment, he shall direct the owner to remove such encroachments;

(iii) the minimum safety working clearances specified in Schedule-VII shall be maintained for the bare conductors or live parts of any apparatus in outdoor substations excluding overhead lines of installations of voltage exceeding 650 V;

(iv) he shall ensure that the windings of motors or other apparatus within reach from any position in which a person may require to be, are suitably protected so as to prevent danger;

(v) he shall ensure that where a transformer or transformers are used, suitable provision shall be made, either by connecting with earth, a point of the circuit at the lower voltage or otherwise, to guard against danger by reason of the said circuit becoming accidentally charged above its normal voltage by leakage from or contact with the circuit at the higher voltage;

(vi) a substation or a switching station with apparatus having more than 2000 litres of oil shall not be located in the basement where proper oil draining arrangement cannot be provided;

(vii) where a substation or a switching station with apparatus having more than 2000 litres of oil is installed, whether indoor or outdoors, he shall take the following measures, namely—

(a) the baffle walls of four hours fire rating shall be provided between the apparatus,—

(i) where there is a single phase transformer banks in the switch-yards of generating stations and substations;

(ii) on the consumer premises;

(iii) where adequate clearance between the units is not available.

(b) provisions shall be made for suitable oil soakpit and where use of more than 9000 litres of oil in any one oil tank, receptacle or chamber is involved, provision shall be made for the draining away or removal of any oil which may leak or escape from the tank, receptacle or chamber containing the same, and special precautions shall be taken to prevent the spread of any fire resulting from the ignition of the oil from any cause and adequate provision shall be made for extinguishing any fire which may occur;

(c) spare oil shall not be stored in the vicinity of any oil filled equipment in any such substation or switching station;

(d) all the transformers and switchgears shall be maintained in accordance with the maintenance schedules prepared in accordance with the relevant codes of practice of Bureau of Indian Standards;

(e) dry type of transformers only shall be used for installations inside the residential and commercial buildings;

(viii) without prejudice to the above measures, he shall take adequate fire protection arrangement for quenching the fire in the apparatus;

(ix) he shall ensure that the transformers of 10 MVA and above rating or in case of oil filled transformers with oil capacity of more than 2000 liters are provided with fire fighting system as per IS-3034:1993 or with Nitrogen Injection Fire Protection system;

(x) where it is necessary to locate the substation, or switching station in the basement, he shall take the following measures, namely—

(a) the room shall necessarily be in the first basement at the periphery of the basement;

(b) the entrances to the room shall be provided with the fire resisting doors of 2 hour fire rating and the door shall always be kept closed and a notice of this effect shall be affixed on outer side of the door;

(c) a curb (sill) of a suitable height shall be provided at the entrance in order to prevent the flow of oil from a

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ruptured transformer into other parts of the basement;

(d) direct access to the transformer room shall be provided from outside and the surrounding walls shall be lined with fire bricks;

(e) the cables to primary side and secondary side shall have sealing at all floors and wall opening of atleast two hours rating;

(f) Fire Retardant Low Smoke (FRLS) cable of two hours rating shall be used.

(xi) he shall ensure that oil filled transformers installed indoors in other than residential or commercial buildings are placed at the ground floor or not below the first basement;

(xii) he shall ensure that cable trenches inside the substations and switching stations containing cables are filled with sand, pebbles or similar non-inflammable materials or completely covered with non-inflammable slabs;

(xiii) he shall ensure that unless the conditions are such that all the conductors and apparatus may be made dead at the same time for the purpose of cleaning or for other work, the said conductors and apparatus shall be so arranged that these may be made dead in sections, and that work on any such section may be carried on by a designated person without danger;

(xiv) only persons designated under sub-regulation (1) of regulation 3, shall carry out the work on live lines and apparatus.

(3) All apparatus shall be protected against lighting and apparatus exceeding 220 kV shall also be protected against switching over voltages.

(4) The equipment used for protection and switching shall be adequately co-ordinated with the protected apparatus to ensure safe operation and to maintain the stability of the inter-connected units of the power system.

(5) The minimum clearance specified in Schedule-VIII shall be maintained for bare conductors or live parts of any apparatus in outdoor substations, excluding overhead lines of High Voltage Direct Current installations.

(6) There shall not be tapping of another transmission line from the main line for 66 kV and above class of lines.

Regulation 45, Inter-locks and protection for use of electricity at voltage exceeding 650 volts

(1) The owner shall ensure the following namely—

(i) isolators and the controlling circuit breakers shall be inter-locked so that the isolators cannot be operated unless the corresponding breaker is in open position.

(ii) isolators and the corresponding earthing switches shall be inter-locked so that no earthing switch can be closed unless and until the corresponding isolator is in open position;

(iii) where two or more supplies are not intended to be operated in parallel, the respective circuit breakers or linked switches controlling the supplies shall be inter-locked to prevent possibility of any inadvertent paralleling or feedback;

(iv) when two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of a transformer in case the primary breaker of that transformer trips;

(v) all gates or doors which give access to live parts of an installation shall be inter-locked in such a way that these cannot be opened unless the live parts are made dead and proper discharging and earthing of these parts should be ensured before any person comes in close proximity of such parts;

(vi) where two or more generators operate in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.

(2) The following protection shall be provided in all systems and circuits to automatically disconnect the supply under abnormal conditions, namely—

(i) over current protection to disconnect the supply automatically if the rated current of the equipment, cable or supply line is exceeded for a time which the equipment, cable or supply line is not designed to withstand;

(ii) earth fault or earth leakage protection to disconnect the supply automatically if the earth fault current exceeds the limit of current for keeping the contact potential within the reasonable values;

(iii) gas pressure type and winding and oil temperature protection to give alarm and

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tripping shall be provided on all transformers of rating 1000 kVA and above;

(iv) transformers of capacity 10 MVA and above shall be protected against incipient faults by differential protection;

(v) all generators with rating of 100 kVA and above shall be protected against earth fault or leakage;

(vi) all generators of rating 1000 kVA and above shall be protected against fault within the generator winding using restricted earth fault protection or differential protection or by both;

(vii) high speed bus bar differential protection along with local breaker back up protection shall be commissioned and shall always be available at all 132 kV and above voltage substations and switching stations and generating stations connected with the grid:

Provided that in respect of existing 132 kV substations and switching stations having more than one incoming feeders, the high speed bus bar differential protection along with local breaker back up protection, shall be commissioned and shall always be available;

(viii) every generating station and substation connected to the grid at 220 kV and above shall be provided with disturbance recording and event logging facilities and all such equipment shall be provided with time synchronization facility for global common time reference but wherever numerical relays with provision of recording fault data are installed, disturbance recorder and event logger may not be installed;

(ix) distance protection and carrier communication protection shall be provided for all lines connecting to 400/220 kV substation.

Regulation 46, Testing, operation and maintenance

(1) Before approval is accorded by the Electrical Inspector under regulation 43 the manufacturer's test certificates shall, if required, be produced for all the routine tests as required under the relevant Indian standards.

(2) No new apparatus, cable or supply line of voltage exceeding 650 Volts shall be commissioned unless such apparatus, cable or supply line are subjected to site tests as per relevant code of practice of the Bureau of Indian Standards.

(3) No apparatus, cable or supply line of voltage exceeding 650 V which has been kept disconnected, for a period of six months or more, from the system for alterations or repair, shall be connected to the system until such apparatus, cable or supply line are subjected to the relevant tests as per code of practice of Bureau of Indian Standards.

(4) Notwithstanding the provisions of this regulation, the Electrical Inspector may require certain tests to be carried out before or after charging the installations.

(5) All apparatus, cables and supply lines shall be maintained in healthy conditions and tests shall be carried out periodically as per the relevant code of practice of the Bureau of Indian Standards.

(6) Records of all tests, trippings, maintenance works and repairs of all equipment cables and supply lines shall be duly kept in such a way that these records can be compared with earlier ones.

(7) It shall be the responsibility of the owner of all installations of voltage exceeding 650 V to maintain and operate the installations in a condition free from danger and as recommended by the manufacturer or by the relevant codes of practice of the Bureau of Indian Standards.

(8) Failures of transformers and reactors of 20 MVA or MVAR and higher capacity shall be reported by the consumer and the suppliers of electricity, within forty eight hours of the occurrence of the failure, to the Central Electricity Authority and the reasons for failure and measures to be taken to avoid recurrence of failure shall be sent to the Central Electricity Authority within one month of the occurrence in the format given in Schedule-IX.

Regulation 47, Precautions to be taken against excess leakage in case of metal sheathed electric supply lines

The following precautions shall be taken in case of electric supply lines other than overhead lines, for use at voltage exceeding 650 V; namely—

(i) the conductors of the cable except the cable with thermoplastic insulation without any metallic screen or armour shall be enclosed in metal sheathing which shall be electrically continuous and connected with earth, and the

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conductivity of the metal sheathing shall be maintained and reasonable precautions taken where necessary to avoid corrosion of the sheathing;

(ii) the resistance of the earth connection with metallic sheath shall be kept low enough to permit the controlling circuit breaker or cut-out to operate in the event of any failure of insulation between the metallic sheath and the conductor.

Explanation — For the purpose of this regulation;

(a) in the case of thermoplastic insulated and sheathed cables with metallic armour the metallic wire or tape armour, shall be considered as metal sheathing.

(b) where an electric supply line as aforesaid has concentric cables and the external conductor is insulated from an outer metal sheathing and connected with earth, the external conductor may be regarded as the metal sheathing for the purpose of this regulation provided that the foregoing provisions as to conductivity are compiled with.

Regulation 48, Connection with earth for apparatus exceeding 650 Volts

(1) All non-current carrying metal parts associated with an installation of voltage exceeding 650 V shall be effectively earthed to a grounding system or mat which shall,

(i) limit the tough and step potential to tolerable values;

(ii) limit the ground potential rise to tolerable values so as to prevent danger due to transfer of potential through ground, earth wires, cable sheath, fences, pipe lines, etc;

(iii) maintain the resistance of the earth connection to such a value as to make operation of the protective device effective;

(2) In the case of star connected system with earthed neutrals or delta connected system with earthed artificial neutral point —

(i) the neutral point of every generator and transformer shall be earthed by connecting it to the earthing system not by less than two separate and distinct connections:

Provided that the neutral point of a generator may be connected to the earthing system through an impedance to limit the fault current to the earth:

Provided further that in the case of multi-machine systems neutral switching may be resorted to, for limiting the injurious effect of harmonic current circulation in the system;

(ii) the generator or transformer neutral shall be earthed through a suitable impedance where an appreciable harmonic current flowing in the neutral connection causes interference, with communication circuits;

(iii) in case of the delta connected system the neutral point shall be obtained by the insertion of a grounding transformer and current limiting resistance or impedance wherever considered necessary at the commencement of such a system.

(3) In case of generating stations, substations and industrial installations of voltage exceeding 33 kV, the system neutral earthing and protective frame earthing may be, if system design so warrants, integrated into common earthing grid provided the resistance to earth of combined mat does not cause the step and touch potential to exceed its permissible values.

(4) Single phase system of voltage exceeding 650 V shall be effectively earthed.

(5) In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be connected with earth.

(6) Where a supplier proposes to connect with earth an existing system for use at voltage exceeding 650 V which has not hitherto been so connected with earth, he shall give not less than fourteen days notice in writing together with particulars of the proposed connection with earth to the telegraphy-authority established under the *Indian Telegraph Act*, 1885 (13 of 1885).

(7) Where the earthing lead and earth connection are used only in connection with earthing guards erected under overhead lines of voltage exceeding 650 V where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage, the earth resistance shall not exceed twenty five ohms and the project authorities shall obtain No Objection Certificate (NOC) from Railway Authorities and Power and Telecommunication Co-ordination Committee before energisation of the facilities.

(8) Every earthing system belonging to either the supplier or the consumer shall be tested for its resistance to earth on a dry day during dry

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season not less than once a year and records of such tests shall be maintained and produced, if so required, before the Electrical Inspector.

Regulation 49, General conditions as to transformation and control of electricity

(1) Where electricity of voltage exceeding 650 V is transformed, converted, regulated or otherwise controlled in substations or switching stations including outdoor substations and outdoor switching stations to be transformed or in street boxes constructed underground, the following provisions shall be observed, namely—

(i) substations and switching stations shall preferably be erected above ground, but where necessarily constructed underground due provisions for ventilation and drainage shall be made and any space housing switchgear shall not be used for storage of any materials especially inflammable and combustible materials or refuse;

(ii) outdoor substations except pole type substations and outdoor switching stations shall, unless the apparatus is completely enclosed in a metal covering connected with earth, the said apparatus also being connected with the system by armoured cables, be efficiently protected by fencing not less than 1.8 m in height or other means so as to prevent access to the electric supply lines and apparatus therein by an undesignated person and the fencing of such area shall be earthed efficiently;

(iii) underground street boxes, other than substations, which contain transformers shall not contain switches, cut-outs or other apparatus required for controlling or other purposes shall be fixed in separate receptacle above ground wherever practicable.

(2) Where electricity is transformed, suitable connection shall be made by connecting with earth a point of the system at the lower voltage and also to guard against danger by reason of the said system becoming accidently charged above its normal voltage by leakage from a contact with the system at the higher voltage.

Regulation 50, Pole type substations

Where platform type construction is used for a pole type substation and sufficient space for a person to stand on the platform is provided, a substantial hand rail shall be built around the said platform and if the hand rail is of metal, it shall be connected with earth:

Provided that in the case of pole type substation on wooden supports and wooden platform the metal hand-rail shall not be connected with earth.

Regulation 52, Supply to luminous tube sign installations of voltage exceeding 650 Volts but not exceeding 33 kV

(1) Any person who proposes to use or who is using electricity for the purpose of operating a luminous tube sign installation, or who proposes to transform or is transforming electricity to a voltage exceeding 650 V but not exceeding 33 kV for any such purpose shall comply with the following conditions, namely—

(i) all live parts of the installation, including all apparatus and live conductors in the secondary circuit, but excluding the tubes except in the neighbourhood of their terminals, shall be inaccessible to undesignated persons and such parts shall be effectively screened;

(ii) irrespective of the method of obtaining the voltage of the circuit which feeds the luminous discharge tube sign, no part of any conductor of such circuit shall be in metallic connection, except in respect of its connection with earth, with any conductor of the supply system or with the primary winding of the transformer;

(iii) all live parts of an exterior installation shall be so disposed as to protect them against the effects of the weather and such installations shall be so arranged and separated from the surroundings as to limit, as far as possible, the spreading of fire;

(iv) the secondary circuit shall be permanently earthed at the transformer and the core of every transformer shall be earthed;

(v) where the conductors of the primary circuit are not in metallic connection with the supply conductors, one phase of such primary circuit shall be permanently earthed at the motor generator or convertor, or at the transformer and an earth leakage circuit breaker of sufficient rating shall be provided on the side of voltage not exceeding 250 V to detect the leakage in such luminous tube sign installations;

(vi) a sub-circuit which forms the primary circuit of a fixed luminous discharge tube

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sign installation shall be reserved solely for such purpose;

(vii) a separate primary final sub-circuit shall be provided for each transformer or each group of transformers having an aggregate input not exceeding 1,000 volt-amperes, of a fixed luminous discharge tube sign installation;

(viii) an interior installation shall be provided with suitable adjacent means for disconnecting all phases of the supply except the "neutral" in a 3-phase, 4-wire circuit;

(ix) for installations on the exterior of a building a suitable emergency fire-proof linked switch to operate on all phases except the neutral in a 3-phase, 4-wire circuit shall be provided and fixed in a conspicuous position at not more than 1.70 metres above the ground.

(x) a special "caution" notice shall be affixed in a conspicuous place on the door of every enclosure of voltage exceeding 650 V but not exceeding 33 kV to the effect that the supply must be cut off before the enclosure is opened;

(xi) where static condensers are used, they shall be installed on the load side of the fuses and the primary side of the transformers where the voltage does not exceed 250 V;

(xii) where static condensers are used on primary side, provision shall be made for automatic or manual discharging of the condensers when the supply is cut-off;

(xiii) before using the static condensers or any interrupting device on the voltage exceeding 650 V, the executing agencies shall test and ensure that automatic discharging device is functional thereon.

(2) The owner or user of any luminous tube sign or similar installation of voltage exceeding 650 V but not exceeding 33 kV shall not bring the same into use without giving to the Electrical Inspector not less than fourteen days notice in writing of his intention so to do.

Regulation 58, Clearance above ground of the lowest conductor of overhead lines

(1) No conductor of an overhead line, including service lines, erected across a street shall at any part thereof be at a height of less than —

(i) for lines of voltage not exceeding 650 Volts - 5.8 metres

(ii) for lines of voltage exceeding 650 Volts but not exceeding 33 kV - 6.1 metres

(2) No conductor of an overhead line, including service lines, erected along any street shall at any part thereof be at a height less than-

(i) for lines of voltage not exceeding 650 Volts - 5.5 metres

(ii) for lines of voltage exceeding 650 Volts but not exceeding 33 kV - 5.8 metres

(3) No conductor of an overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than—

(i) for lines of voltage upto and including 11,000 Volts, if bare - 4.6 metres

(ii) for lines of voltage upto and including 11,000 Volts, if insulated 4.0 metres

(iii) for lines of voltage exceeding 11,000 Volts but not exceeding 33 kV - 5.2 metres

(4) For lines of voltage exceeding 33 kV the clearance above ground shall not be less than 5.2 metres plus 0.3 metre for every 33,000 Volts or part thereof by which the voltage of the line exceeds 33,000 Volts;

Provided that the minimum clearance along or across any street shall not be less than 6.1 metres.

(5) For High Voltage Direct Current (HVDC) lines, the clearance above ground shall not be less than—

Sl No.	*d.c. Voltage (kV)*	*Ground Clearance (mtrs.)*
1.	100 kV	6.1
2.	200 kV	7.3
3.	300 kV	8.5
4.	400 kV	9.4
5.	500 kV	10.6
6.	600 kV	11.8
7.	800 kV	13.9

(6) Ground clearance shall be as specified in schedule-X.

Regulation 60, Clearance from buildings of lines of voltage and service lines not exceeding 650 Volts

(1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

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(2) Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearance from any accessible point, on the basis of maximum sag, shall be observed, namely—

(i) for any flat roof, open balcony, verandah roof and lean-to-roof—

(a) when the line passes above the building a vertical clearance of 2.5 metres from the highest point, and

(b) when the line passes adjacent to the building a horizontal clearance of 1.2 metres from the nearest point, and

(ii) for pitched roof —

(a) when the line passes above the building a vertical clearance of 2.5 metres immediately under the line, and

(b) when the line passes adjacent to the building a horizontal clearance of 1.2 metres.

(3) Any conductor so situated as to have a clearance less than that specified above shall be adequately insulated and shall be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg.

(4) The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

(5) Vertical and horizontal clearances shall be as specified in schedule-X.

Explanation — For the purpose of this regulation, the expression "building" shall be deemed to include any structure, whether permanent or temporary.

Regulation 61, Clearance from buildings of lines of voltage exceeding 650 V

(1) An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

(2) Where an overhead line of voltage exceeding 650 V passes above or adjacent to any building or part of a building it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than-

(i)	for lines of voltage exceeding 650 Volts upto and including 33,000 Volts	- 3.7 metres
(ii)	for lines of voltage exceeding 33 kV	- 3.7 metres plus 0.30 metre for every additional 33,000 Volts or part thereof.

(3) The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than-

(i)	for lines of voltage exceeding 650 V upto and including 11,000 Volts	- 1.2 metres
(ii)	for lines of voltage exceeding 11,000 Volts and up to and including 33,000 V	- 2.0 metres
(iii)	for lines of voltage exceeding exceeding 33 kV	- 2.0 metres plus 0.3 metre for every additional 33 kV or part thereof.

Regulation 63, Erection or alteration of buildings, structures, flood banks and elevation of roads

(1) If at any time subsequent to the erection of an overhead line, whether covered with insulating material or not or underground cable, any person proposes to erect a new building or structure or flood bank or to raise any road level or to carry out any other type of work whether permanent or temporary or to make in or upon any building, or structure or flood bank or road, any permanent or temporary addition or alteration, he and the contractor whom he employs to carry out the erection, addition or alteration, shall, give intimation in writing of his intention to do so, to the supplier or owner and to the Electrical Inspection and shall furnish therewith a scale drawing showing the proposed building, structure, flood bank, road or any addition or alteration and scaffolding thereof required during the construction.

(2) On receipt of such intimation, the supplier or owner shall examine,—

(i) whether the line or underground cable

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under reference was laid in accordance with the provisions of these regulations and any other law for the time being in force;

(ii) whether it is technically feasible;

(iii) whether it meets the requirement of Right of Way (ROW);

(iv) whether such person was liable to pay the cost of alteration of the overhead line or underground cable and if so, issue a notice within a period of thirty days, to such person together with an estimate of the cost of the expenditure likely to be incurred to so alter the overhead line or underground cable and require him to deposit, within thirty days of the receipt of the notice, with the supplier or owner, the amount of the estimated cost.

(3) If such person disputes the cost of alteration of the overhead line or underground cable estimated by the supplier or owner or even the responsibility to pay such cost, the dispute may be referred to the Electrical Inspector who shall after hearing both parties decide upon the issue in accordance with sub-regulation (4).

(4) The Electrical Inspector shall estimate the cost of alteration of overhead line or underground cable on the following basis, namely:

(i) the cost of material used on the alteration after crediting the depreciated cost of the material which shall be available from the existing line or underground cable;

(ii) the wages of labour employed in affecting the alteration;

(iii) supervision charges and charges incurred by the supplier or owner in complying with the provisions of section 67 of the Act, in respect of such alterations.

(5) Any addition or alteration to the building or structure shall be allowed only after the deposit of such estimated cost to the supplier or owner.

(6) No work upon such building, structure, flood bank, road and addition or alteration thereto shall be commenced or continued until the Electrical Inspector has certified that the provisions of regulations 58, 60, 61 and regulation 76 should not be contravened either during or after the aforesaid construction:

Provided that the Electrical Inspector may, if he is satisfied that the overhead line or underground cable has been so guarded as to secure the protection of persons or property from injury, certify that the work may be executed prior to the alteration of the overhead line or underground cable or in the case of temporary addition or alteration, without alteration of the overhead line or underground cable.

(7) The supplier or owner shall, on receipt of such deposit, alter the overhead line or underground cable in such a way that it does not contravene the provisions of regulations 58, 60, 61 and regulation 76 either during or after such construction within two months from the date of such deposit or within such longer period as the Electrical Inspector may permit for reasons to be recorded in writing.

Regulation 64, Transporting and storing of material near overhead lines

(1) No rods, pipes or similar material shall be taken below, or in the vicinity of, any bare overhead conductors or lines if these contravene the provisions of regulations 60 and 61 unless such materials are transported under the direct supervision of a person designated in this behalf by the owner of such overhead conductors or lines.

(2) No rods, pipes or other similar materials shall be brought within the flash over distance of bare live conductors or lines.

(3) No material or earth work or agricultural produce shall be dumped or stored, no trees grown below or in the vicinity of, bare overhead conductors, or lines to contravene the provision of regulations 60 and 61.

(4) No flammable material shall be stored under the electric supply line.

(5) No fire shall be allowed above underground cables.

(6) Firing of any material below electric lines shall be prohibited.

Regulation 65, General clearances

(1) For the purpose of computing the vertical clearance of an overhead line, the maximum sag of any conductor shall be calculated on the basis of the maximum sag in still air and the maximum temperature as specified under regulations 57 and computing any horizontal clearance of an overhead line the maximum

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deflection of any conductor shall be calculated on the basis of the wind pressure specified under regulations 57.

(2) No blasting for any purpose shall be done within 300 metres from the boundary of a substation or from the electric supply lines of voltage exceeding 650 V or tower structure thereof without the written permission of the owner of such substation or electric supply lines or tower structures; and in case of mining lease hold area, without the written permission of the Electrical Inspector of Mines.

(3) No cutting of soil within ten meters from the tower structure of 132 kV and above voltage level shall be permitted without the written permission of the owner of tower structure.

(4) No person shall construct brick kiln or other polluting units near the installations or transmission lines of 220 kV and above within a distance of 500 metres.

Regulation 73(3), Safety and protective devices

3) The owner of every overhead line of voltage exceeding 650 V shall make adequate arrangements as per relevant Indian Standards to prevent undesignated persons from ascending any of the supports of such overhead lines which can be easily climbed upon without the help of a ladder or special appliances.

Explanation — For the purpose of this regulation, rails, reinforced cement concrete poles and pre-stressed cement concrete poles without steps, tubular poles, wooden supports without steps, I-sections and channels' shall be deemed as supports which cannot be easily climbed upon.

Regulation 76, Laying of cables

(1) No underground power cable of voltage exceeding 33 kV shall be laid without a minimum underground depth of 1.2 meters.

(2) No underground telecommunication cable shall be laid without a minimum separation distance of 0.6 meters to the underground power cable of voltage exceeding 33 kV.

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ANNEX C

[*Clauses* 4.2.1 (26) *and* 4.2.2.2]

AREA REQUIRED FOR TRANSFORMER ROOM AND SUBSTATION FOR DIFFERENT CAPACITIES

C-1 The requirement for area for transformer room and substation for different capacities of transformers is given below for guidance:

Sl No.	*Capacity of Transformer(s)*	*Total Transformer Room Area, Min*	*Total Substation Area (Incoming, HV Panels, MV Panels, Transformer Roof but Without Generators), Min*	*Suggested Minimum Face Width*
	kVA	m^2	m^2	m
(1)	(2)	(3)	(4)	(5)
i)	1 × 160	14.0	90	9.0
ii)	2 × 160	28.0	118	13.5
iii)	1 × 250	15.0	91	9.0
iv)	2 × 250	30.0	121	13.5
v)	1 × 400	16.5	93	9.0
vi)	2 × 400	33.0	125	13.5
vii)	3 × 400	49.5	167	18.0
viii)	2 × 500	36.0	130	14.5
ix)	3 × 500	54.0	172	19.0
x)	2 × 630	36.0	132	14.5
xi)	3 × 630	54.0	176	19.0
xii)	2 × 800	39.0	135	14.5
xiii)	3 × 800	58.0	181	14.0
xiv)	2 × 1 000	39.0	149	14.5
xv)	3 × 1 000	58.0	197	19.0

NOTES

1 The areas given in respect of the different categories of rooms hold good, if they are provided with independent access doors in accordance with local regulations.

2 The minimum height of substation room/HV switch room/MV switch room shall be arrived at considering 1 200 mm clearance requirement from top of the equipment to the below of the soffit of the beam. In case cable entry/exit is from above the equipment (transformer, HV switchgear, MV switchgear), height of substation room/HV switch room/MV switch room shall also take into account requirement of space for turning radius of cable above the equipment height

3 Additional space will be required in cases where the load requirement calls for redundancy for enhanced reliability through addition of switchgear, such as, bus couplers, etc.

4 For transformers of other capacity, it may lead to some minor changes in dimensioning.

ANNEX D

(*Clause* 4.3.2)

ADDITIONAL AREA REQUIRED FOR GENERATOR IN ELECTRIC SUBSTATION

D-1 The requirement of additional area for generator in electric substation for different capacities of generators is given in the table below for guidance.

NOTES

1 The space requirements vary for specific installations due to factors such as derating due to site conditions (temperature, altitude etc); type of cooling (radiator, heat exchanger, cooling tower, etc); type of ventilation; noise suppression system and special characteristics of loads, if any.

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2 If the generator is located away from the substation, then additional switchgear will be required, area requirement for which can be estimated from the norms given in Annex C.

3 The area requirement suggested below covers the space requirement for day-tank and not the space for the bulk fuel storage.

Sl No.	*Capacity* kVA	*Area* m^2	*Clear Height below the Soffit of the Beam* m
(1)	(2)	(3)	(4)
i)	25	56	3.6
ii)	48	56	3.6
iii)	100	65	3.6
iv)	150	72	3.6
v)	248	100	4.2
vi)	350	100	4.2
vii)	480	100	4.2
viii)	600	110	4.6
ix)	800	120	4.6
x)	1 010	120	6.5
xi)	1 250	120	6.5
xii)	1 600	150	6.5
xiii)	2 000	150	6.5

NOTE — The area and height required for generating set room given in the above table are for general guidance only and may be finally fixed according to actual requirements.

ANNEX E

(*Clause* 9.4)

CHECKLIST FOR INSPECTION, HANDING OVER AND COMMISSIONING OF VARIOUS EQUIPMENT OF SUBSTATION

E-1 Typical format for checklist for inspection, handing over and commissioning of HV cables is given below.

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each HV cable.

HV CABLE INSPECTION, HANDING OVER AND COMMISSIONING DETAILS

A) DETAILS OF WORK

1) Scope of works :
2) Handed over by :
3) Taken over by :
4) Date of commissioning :
5) Date of handing over :
6) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		

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Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
iii)	As built GA drawing/layout		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed over by

Authorized signatory

Taken over by

Authorized signatory

B) QUALITY CHECK LIST

Item: Installation of HV Cables
Make:

Sl No.	*Tests Parameters*	*Bench Mark*	*Actual Observations*	*Remark*
(1)	(2)	(3)	(4)	(5)
i)	Cable size			
ii)	Voltage grade			
iii)	Type of material			
iv)	Check for routing			
v)	Meggering using 2.5 kV insulation tester			
	R-Y			
	Y-B			
	B-R			
	R-E			
	Y-E			
	B-E			
vi)	Minimum width of trench			
vii)	Minimum depth of trench			
viii)	Hume pipes used			
ix)	Hume joints with collar properly aligned and packed with 75 mm of cement concrete			
x)	Cable laying with suitable rollers			
xi)	Bending radius			
xii)	Cable tagging			
xiii)	Hi-Pot test (18 kV)			
xiv)	Sealing of cable ends, if not being terminated immediately			
xv)	Trench closing			

C) HI-POT TEST REPORT

1) Date of testing:
2) Equipment details:
   Cable details
   Location :
   Panel No. :
   Size :

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3) Insulation Resistance Test (Value in MΩ, using 5 kV Megger):

Reference	*Measured Values MΩ*	
	Before	After
R-E		
Y-E		
B-E		
R-Y		
Y-B		
B-R		

4) Winding Resistance Test:

Applied Voltage kV	*Measured Current* mA
R = Y + B + E	
Y = B + R + E	
B = R + Y + E	

5) Remarks

E-2 Typical format for checklist for handing over and commissioning of HV panels is given below.

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each HV panel.

HV PANEL INSPECTION, HANDING OVER AND COMMISSIONING DETAILS

Project:

Owner:

Package:

Contractor:

A) HANDING OVER DETAILS

1) Scope of works :
2) Panel name and number :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed over by

Authorized signatory

Taken over by

Authorized signatory

B) QUALITY CHECK LIST

Item: HV panel
Make:
Relevant Indian Standard:
As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observations*
(1)	(2)	(3)	(4)
	Physical Checks for:		
	Circuit Breaker		
i)	Dimension enclosure		
ii)	Gauge		
iii)	Paint		
iv)	Degree of protection		
v)	Front doors		
vi)	Back cover		
vii)	Extension type enclosure		
viii)	Type of circuit breaker		
ix)	Number of circuit breakers		
x)	Type of surge arresting device included in the circuit breakers		
xi)	Earthing terminal		
xii)	Front plate with view glass		
xiii)	Space for mounting of current transformers		
xiv)	Space for mounting of potential transformers		
xv)	Cable entry		
xvi)	Interlocking with isolator		
xvii)	Earthing switch for cable in cable chamber		
xviii)	Earthing switch interlock with circuit breaker only it can be operated in 'OFF' condition		
xv)	Low voltage plug and socket		
xvi)	Vents for breaker/busbar/cable chambers		
xvii)	Insulation level		
xviii)	Toggle switch		
xix)	Ammeter selector switch		
xx)	Voltmeter selector switch		
xxi)	Trip/Neutral/Close		
xxii)	Local/remote selector switch		
xxiii)	LED lamps		
xxiv)	Mechanical operation		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observations*
(1)	(2)	(3)	(4)
xxv)	Remote operation		
xxvi)	Local operation		
xxvii)	Interlocking with isolator		
	Meters		
xxviii)	Voltmeter		
xxix)	Ammeter		
xxx)	Tri vector meter		
xxxi)	Power factor meter		
xxxii)	Frequency meter		
	Specification Checks for		
xxxiii)	Rated current		
xxxiv)	Rated voltage		
xxxv)	Rated short circuit breaking capacity		
xxxvi)	Contact resistance		
xxxvii)	Control wiring		
xxxviii)	All control circuits Alarm and trip for OTI/WTI/Buchholz/ PRV		
xxxix)	SF6 pressure alarm and trip operation test		

C) COMMISSIONING REPORT

Customer:

Project:

Contractor:

Panel Name:

Location:

Breaker Details:

*INSULATION TEST (*MΩ*):*

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS:

Over Current, Earth Fault and Undervoltage Relay	
CT ratio: Earth fault >Settings: I_o> Settings: Under voltage relay:	

GENERAL CHECKS:

Breaker ‘ON’/’OFF’	
Meters reading	
Indicating lamps	
Control supply	

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

E-3 Typical format for checklist for handing over and commissioning of transformers is given below.

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each transformer.

TRANSFORMER INSPECTION, HANDING OVER AND COMMISIONING DETAILS

Project:

Owner:

Package:

Contractor:

A) HANDING OVER DETAILS

1) Scope of works :
2) Transformer No. :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No. (1)	*Description* (2)	*Applicable* (3)	*Not Applicable* (4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed over by

Authorized signatory

Taken over by

Authorized signatory

B) QUALITY CHECK LIST

Item: Transformer

Make:

Relevant Indian Standard:

As-built Drawing No:

Sl No. (1)	*Test Parameters* (2)	*Bench Mark* (3)	*Actual Observation* (4)
	Physical Checks for:		
i)	Transformer Sl No.		
ii)	Dimension of enclosure		
iii)	Enclosure – Degree of protection		
iv)	Gauge		
v)	Paint		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
vi)	Provision for lifts and jacking		
vii)	Wheels		
viii)	Locking facility for wheel		
ix)	Enclosure door (if applicable)		
x)	Enclosure door interlock wiring		
xi)	Removable case for access of taps		
xii)	Earthing terminal		
xiii)	Disconnecting type chamber for cable termination		
xiv)	LT side flanges (Bus ducts/Cables/ Overhead)		
xv)	Oil temperature indicator (relay unit)		
xvi)	Winding temperature indicator (relay unit)		
xvii)	Marshalling box winding and door switch		
xviii)	Thermistors for alarm and trip		
xix)	Separate neutral earthing chamber		
xx)	Rating and diagram plate		
xxi)	Tap changing options name plate		
xxii)	Oil level in conservator tank		
xxiii)	Oil level in breather cup		
xxiv)	Operation of PRV		
xxv)	Oil leakage (if applicable)		
xxvi)	Clearances around transformer		
xxvii)	Body earthing resistance		
xxviii)	Neutral earthing resistance		
	Specification checks for:		
xxix)	Rating of transformer		
xxx)	Type		
xxxi)	Winding conductor		
xxxii)	Primary voltage		
xxxiii)	HV winding connections		
xxxiv)	Secondary voltage		
xxxv)	LV side connections		
xxxvi)	Vector symbol		
xxxvii)	System of supply		
xxxviii)	Impedance percentage		
xxxix)	Oil temperature rise		
xl)	Winding temperature rise		
xli)	Tap changing		
xlii)	Tapping range		
xliii)	Insulation type		
xliv)	Type of cooling		
xlv)	Vector group test		
xlvi)	Polarity test		
xlvii)	Magnetizing test		
xlviii)	Tan delta test (as per capacity)		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
xlix)	Breakdown voltage test: *Oil sample – I (Top)* *Oil sample – II (Bottom)*		

C) COMMISSIONING REPORT

Customer:

Project:

Contractor:

Transformer Number:

Location:

Rating:

INSULATION TEST (MΩ):

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS:

Transformer Protection Relay **(WTI Scanner):** Winding temperature alarm set Winding temperature trip set **(OTI Scanner):** Oil temperature alarm set Oil temperature trip set	
Buchholz Relay	

GENERAL CHECKS:

Breaker 'ON'/'OFF'	
Meters reading	
Indicating lamps	
Control supply	

E-4 Typical format for checklist for handing over and commissioning of MV/LV panel is given below.

NOTE — Format given below covers a basic minimum check list; it should be augmented for specific and special cases. The checklist has to be repeated for each MV/LV panel.

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

MV/LV PANEL INSPECTION, HANDING OVER AND COMMISIONING DETAILS

Project:

Owner:

Package:

Contractor:

A) HANDING OVER DETAILS

1) Scope of works :
2) Panel name :
3) Location :
4) Handed over by :
5) Taken over by :
6) Date of commissioning :
7) Date of handing over :
8) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing		
iv)	Manufacturer's test certificates		
v)	Operation and maintenance manual		

Handed over by

Authorized signatory

Taken over by

Authorized signatory

B) QUALITY CHECK LIST

Item: MV/LV Panel

Make:

Relevant Indian Standard:

As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
	Physical Checks for:		
i)	Dimension enclosure		
ii)	Paint		
iii)	Degree of protection		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
iv)	Front doors		
v)	Back cover		
vi)	Earthing terminal		
vii)	Front plate with view glass		
viii)	Cable entry		
ix)	Indication lamps		
x)	Check for any damages		
xi)	Check for rubber beading for the panel sections		
xii)	Coupling of panel		
xiii)	Coupling of busbars		
xiv)	Coupling of earth bus		
xv)	Number of shipping sections		
xvi)	Fish plate tightening		
xvii)	Any damages in busbar supports		
xviii)	Make of MCCB		
	Specification Checks For		
xix)	Rated current		
xx)	Rated voltage		
xxi)	Rated short circuit capacity		
	Circuit Breaker:		
xxii)	Current rating		
xxiii)	Interlocks with other CB/relay		
xxiv)	Compartment		
xxv)	End terminals segregation		
	Bus bar:		
xxvi)	Earth bus bar		
xxvii)	Main bus bar		
xxviii)	Link bus bar		
xxix)	Bus bar sleeve		
	3 Phase – Potential transformer:		
xxx)	Make		
xxxi)	Ratio		
xxxii)	Class		
xxxiii)	Serial Nos.		
	Current transformer:		
xxxiv)	Make		
xxxv)	Ratio		
xxxvi)	Class		
xxxvii)	Serial No’s		
	Multi digital meter:		
xxxviii)	Make		
xxxix)	Input voltage		
xl)	Input current		

Free Standard provided by BIS via BSB Edge Private Limited to Directorate State Fire Prevention Services - Gandhinagar(dir-sfps-gnr@gujarat.gov.in) 43.250.164.250 [for non-commercial use only].

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observation*
(1)	(2)	(3)	(4)
	Wiring:		
xli)	For potential transformer		
xlii)	For current transformer		
xliii)	Incomer		
xliv)	Outgoing		

C) COMMISSIONING REPORT

Customer:

Project:

Contractor:

Panel Name:

Location:

Breaker Details:

INSULATION TEST (M Ω):

R-Y	Y-B	B-R	R-E	Y-E	B-E	R-N	Y-N	B-N

RELAY SETTINGS:

GENERAL CHECKS:

Breaker 'ON'/'OFF'	
Meters reading	
Indicating lamps	
Control supply	

ANNEX F

(*Clause* 9.4)

CHECKLIST FOR INSPECTION, HANDING OVER AND COMMISSIONING OF EARTHING PITS

F-1 Typical format for checklist for inspection, handing over and commissioning of earthing pits is given below:

Project:

Owner:

Package:

Contractor:

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A) HANDING OVER DETAILS

1) Scope of works :
2) Handed over by :
3) Taken over by :
4) Date of commissioning :
5) Date of handing over :
6) Details of enclosures :

Sl No.	*Description*	*Applicable*	*Not Applicable*
(1)	(2)	(3)	(4)
i)	Quality check list		
ii)	Site test report		
iii)	As built GA drawing/layout		

Handed over by

Authorized signatory

Taken over by

Authorized signatory

B) QUALITY CHECK LIST

Item: Installation of earthing pit

As-built Drawing No:

Sl No.	*Test Parameters*	*Bench Mark*	*Actual Observations*	*Remarks*
(1)	(2)	(3)	(4)	(5)
1)	Material (Cu/GI/Copper bonded) and size			
2)	Depth of the pit			
3)	Check for length of pipe/rod and size of the plate and strip			
4)	For copper earthing, brazing done on both surfaces before jointing; and on one side in case of exothermic welding			
5)	Packing of pit by sand, salt and charcoal/earth enhancing material			
6)	Check connection for tightness			
7)	Check for distance between earth pits			
8)	Interconnection of earth strips			
9)	Earth enhancing material used in earth pits			

C) TEST REPORT: EARTH PIT

Date of testing :

Equipment details :

Earth pit

1) Location :
2) Serial No. :

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3) Earth pit No. :
4) Type of earthing :
5) Description :
6) Size of earth conductor :

Earth Pit Test: Values (Ω)

Ref	Measured Values Ω
Pit	
Width grid	

ANNEX G

(*Clause* 9.3.2.6)

FORM OF COMPLETION CERTIFICATE

I/ We certify that the installation detailed below has been installed by me/us and tested and that to the best of my/our knowledge and belief, it complies with *Central Electricity Authority (Measures Relating to Safety and Electricity Supply) Regulations*, 2010 as amended up-to-date.

Electrical Installation at .....

A) INSTALLATION DATA

Voltage and system of supply .....

a) Particulars of Works:
   1) Internal electrical installation

Sl No.	*Description*	*No.*	*Total Load*	*Type of System of Wiring*
i)	Light point			
ii)	Fan point			
iii)	Plug point			
	3-pin 6 A			
	3-pin 16 A			
	5-pin 6 A			
	6-pin 16 A			

   2) Others

Sl No.	*Description*	*HP/kW*	*Type of Starting*
i)	Motors		
	1)		
	2)		
	3)		
ii)	Other plants		
	1)		
	2)		
	3)		

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3) If the work involves installations of overhead line and/or underground cable

i)	1) Type and description of over headline	
	2) Total length and No. of spans	
	3) No. of street lights and its description	
ii)	1) Total length of underground cable and its size	
	2) No. of joints:	
	End joint:	
	Tee joint:	
	Straight through joint:	

b) Earthing:

i)	Description of earthing electrode	
ii)	No. of earth electrodes	
iii)	Size of main earth lead	
iv)	Earth electrode resistance	

The date on which the measurements for item (iv) was taken has to be recorded.

NOTE — The above data should be supported by an appropriate drawing and tables indicating the reference points at which the measurements were taken at the construction/installation stage.

B) PRE-COMMISSIONING TEST DATA

a) *Test Results:*

1) Appropriate drawings showing the points at which the measurements were taken should accompany this report.
2) Environmental notes pertaining to the day on which the tests are conducted:
   i) Temperature:
   ii) Date and time:
   iii) Previous day/days history from the aspect of rain (as it would affect the test results):
3) List of test instruments used:

   (Please record the calibration certificate date, calibration authority and the validity date of each instrument listed.)

   i) .....
   ii) .....
4) Results:

   i) Insulation resistance

a)	Insulation resistance of the whole system of conductors to earth	…… Megaohm
b)	Insulation resistance between the phase conductor and neutral:	
	Between phase R and neutral	…… Megaohm
	Between phase Y and neutral	…… Megaohm
	Between phase B and neutral	…… Megaohm
c)	Insulation resistance between the phase conductors in case of polyphase supply	
	Between phase R and phase Y	…… Megaohm
	Between phase Y and phase B	…… Megaohm
	Between phase B and phase R	…… Megaohm
d)	Insulation resistance between neutral conductor and earth in case of systems with neutral solidly earthed at the source	…… Megaohm

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ii) Polarity test:

Polarity of non-linked single pole branch switches:

iii) Earth continuity test:

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead ……Ohm.

iv) Earth electrode resistance:

a) Resistance of each earth electrode:

1) ……. Ohm
2) ……. Ohm
3) ……. Ohm
4) ……. Ohm

b) Resistance of each earth grid:

1) ……. Ohm
2) ……. Ohm
3) ……. Ohm
4) ……. Ohm

v) Lightning protective system:

a)	Designed lightning protection level (LPL)	……
b)	Total roof area (L X W)	…… m^2
c)	Air-termination mesh size (L X W)	…… m x m
d)	Number of vertical rods/terminal (Down-conductors)	……
e)	Distance between down-conductors	…… m
f)	Impulse current rating of SPD, if provided	…… kA
g)	Voltage protection level of incoming SPD	…… kV
h)	Resistance of down-conductor for reinforced concrete structure/PEB structures, if natural components are used as per National Building Code of India (Part 8/Section 2) 'Building Services, Electrical and Allied Installations'	…… ohm
j)	Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure	……. ohm

Signature of Supervisor
Name and Address

Signature of Contractor
Name and Address

Persons witnessing the test:

Name	Designation/Address	Signature	Remarks
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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parenthesis indicates the number of the reference in this Section.

Sl No.	*IS No.*	*Title*
(1)	IS 8270 (Part 1) : 1976	Guide for preparation of diagrams, charts and tables for electrotechnology: Part 1 Definitions and classification
	IS 1885	Electrotechnical vocabulary
	(Part 16/Sec 3) : 1967	Lighting, Section 3 Lamps and auxiliary apparatus
	(Part 17) : 1979	Switchgear and controlgear (*first revision*)
	(Part 32) : 1993	Electrical cables (*first revision*)
	(Part 78) : 1993	Generation, transmission and distribution of electricity — General
	IS 12032	Graphical symbols for diagrams in the field of electrotechnology
	(Part 6) : 1987	Protection and conversion of electrical energy
	(Part 7) : 1987	Switchgear, controlgear and protective devices
(2)	IS 16246 : 2015	Specification of elastomer insulated cables with limited circuit integrity when affected by fire
(3)	IS 694 : 2010	Polyvinyl chloride insulated unsheathed and sheathed cables/cords with rigid and flexible conductor for rated voltages up to and including 450/750 V (*fourth revision*)
(4)	IS/IEC 62271-202 : 2014	High-voltage switchgear and controlgear—Part 202: High-voltage/low-voltage prefabricated substation
(5)	IS/IEC 60947-1 : 2007	Low-voltage switchgear and controlgear — Part 1: General rules (*first revision*)
	IS/IEC 60947-2 : 2003	Low-voltage switchgear and controlgear — Part 2 : Circuit breakers
	IS/IEC 60947-3 : 1999	Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units
	IS/IEC 60947-4-1 : 2000	Low-voltage switchgear and controlgear — Part 4 : Contractors and motor-starters — Section 1 : Electromechanical contactors and motors-starters
	IS/IEC 60947-4-2 : 1999	Low-voltage switchgear and controlgear : Part 4 — Contractors and Motor-Starters, Section 2 A.C. Semiconductor Motor Controllers and Starters
	IS/IEC 60947-4-3 : 1999	Low-voltage switchgear and controlgear — Part 4: A.C. semiconductor controllers and contactors for non-motor loads
	IS/IEC 60947-5-1 : 2003	Low-voltage switchgear and controlgear — Part 5 : Control circuit devices and switching elements, Section 1 : Electromechanical control circuit devices
	IS/IEC 60947-5-2 : 2007	Low-voltage switchgear and control gear — Part 5: Control circuit devices and switching elements, Section 2 Proximity switches
(6)	IS/lEC 60529 : 2001	Degrees of protection provided by enclosures (IP code)

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Sl No.	*IS No.*	*Title*
(7)	IS 7752 (Part 1) : 1975	Guide for improvement of power factor in consumer installation: Part 1 Low and medium supply voltages
(8)	IS 5216	Recommendations on safety procedures and practices in electrical work
	(Part 1) : 1982	General (*first revision*)
	(Part 2) : 1982	Life saving techniques (*first revision*)
(9)	IS 10028 (Part 2) : 1981	Code of practice for selection, installation and maintenance of transformers: Part 2 Installation
(10)	IS 10118 (Part 3) : 1982	Code of practice for selection, installation and maintenance of switchgear and controlgear: Part 3 Installation
(11)	IS 732 : 1989	Code of practice for electrical wiring installations (*third revision*)
(12)	IS 10118 (Part 2) : 1982	Code of practice for selection, installation and maintenance of switchgear and controlgear: Part 2 Selection
(13)	IS 1646 : 2015	Code of practice for fire safety of buildings (general): Electrical installations (*third revision*)
(14)	IS/IEC 60470 : 2000	High-voltage switchgear alternating current contactors and contactor-based motor starters
	IS/IEC 62271-1 : 2007	High-voltage switchgear and controlgear — Part 1: Common specifications
	IS/IEC 62271-100 : 2008	High-voltage switchgear and controlgear — Part 100: Alternating-current circuit-breakers
	IS/IEC 62271-103 : 2011	High-voltage switchgear and controlgear — Part 103: Switches for rated voltages above 1 kV up to and including 52 kV
	IS/IEC 62271-104 : 2009	High-voltage switchgear and controlgear — Part 104: Alternating current for rated voltages of 52 kV and above
	IS/IEC 62271-105 : 2002	High-voltage switchgear and controlgear — Part 104: Alternating current switch-fuse combinations
	IS/IEC 62271-111 : 2012	High-voltage switchgear and controlgear — Part 104: Automatic circuit reclosers and fault interrupters for alternating current systems up to 38 kV
	IS/IEC 62271-200 : 2003	High-voltage switchgear and controlgear — Part 104: a.c. metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV
	IS/IEC 62271-201 : 2006	High-voltage switchgear and controlgear — Part 104: a.c. insulation-enclosed switchgear and control-gear for rated voltages above 1 kV and up to and including 52 kV
	IS/IEC 62271-203 : 2003	High-voltage switchgear and controlgear — Part 203: Gas-insulated metal-enclosed switchgear for rated voltages above 52 kV
(15)	IS 1255 : 1983	Code of practice for installation and maintenance of power cables (up to and including 33 kV rating) (*second revision*)
(16)	IS 8084 : 1976	Specification for interconnecting bus-bars for a.c. voltage above 1 kV up to and including 36 kV
(17)	IS 1180 (Part 1) : 2014	Specification for outdoor type oil immersed distribution transformers up to and including 2 500 kVA, 33kV: Part 1 Mineral oil immersed (*fourth revision*)

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Sl No.	*IS No.*	*Title*
	IS 2026	Power transformers
	(Part 1) : 2011	General (*second revision*)
	(Part 2) : 2010	Temperature-rise (*first revision*)
	(Part 3) : 2009 IEC 60076-3 : 2000	Insulation levels, dielectric tests and external clearances in air (*third revision*)
	(Part 4) : 1977	Terminal marking, tappings and connections (*first revision*)
	(Part 5) : 2011	Ability to withstand short circuit (*first revision*)
	(Part 7) : 2009 IEC 60076-7 : 2005	Loading guide for oil-immersed power transformers
	(Part 8) : 2009 IEC 60076-8 : 1997	Applications guide
	(Part 10) : 2009 IEC 60076-10 : 2001	Determination of sound levels
	IS 11171 : 1985	Dry-type power transformers
(18)	IS 8623 (Part 1) : 1993	Low-voltage switchgear and controlgear assemblies: Part 1 Requirements for type-tested and partially type-tested assemblies
	IS/IEC 60947-1 : 2007	Low-voltage switchgear and controlgear — Part 1: General rules (*first revision*)
	IS/IEC 60947-2 : 2003	Low-voltage switchgear and controlgear — Part 2: Circuit breakers
	IS/IEC 60947-3 : 1999	Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units
	IS/IEC 60947-4-1 : 2000	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 1 Electromechanical contactors and motors-starters
	IS/IEC 60947-4-2 : 2011	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 2 a.c. semiconductor motor controllers and starters (*first revision*)
	IS/IEC 60947-4-3 : 2011	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 3 a.c. semiconductor motor controllers and contactors for non-motor loads (*first revision*)
	IS/IEC 60947-5-1 : 2003	Low-voltage switchgear and controlgear — Part 5: Control circuit devices and switching elements, Section 1 Electromechanical control circuit devices
	IS/IEC 60947-5-2 : 2007	Low-voltage switchgear and control gear — Part 5: Control circuit devices and switching elements, Section 2 Proximity switches
	IS/IEC 61439 (Part 0) : 2014	Low-voltage switchgear and controlgear assemblies — Part 0 Guidance to specifying assemblies
(19)	IS 11353 : 1985	Guide for uniform system of marking and identification of conductors and apparatus terminals
(20)	IS 8623(Part 2) : 1993	Specification for low-voltage switchgear and controlgear assemblies: Part 2 Particular requirements for busbar trunking systems (busways) (*first revision*)
(21)	IS 13010 : 2002	Specification for a.c. watthour meters, class 0.5, 1 and 2 (*first revision*)
	IS 13779 : 1999	Specification for a.c. static watthour meters, class 1 and 2 (*first revision*)
	IS 8530 : 1977	Specification for maximum demand indicators, class 1

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Sl No.	*IS No.*	*Title*
	IS 14372 : 1996	Specification for volt-ampere hour meters for full power factor range
	IS 14415 : 1997	Specification for volt-ampere hour meters for restricted power factor range
	IS 14697 : 1999	Specification for a.c. static transformer operated watt-hour and var-hour meters, class 0.2 S and 0.5 S
	IS 15844 : 2010	Specification for alternating current direct connected static prepayment meters for active energy (Class 1 and 2)
	IS 16444 : 2015	Specification for a.c. static direct connected watthour smart meter class 1 and 2
(22)	IS 15707 : 2006	Code of practice for testing, evaluation, installation and maintenance of a.c. electricity meters
(23)	IS/IEC 60079-1 : 2007	Explosive atmospheres — Part 1 : Equipment protection by flameproof enclosures “d”
(24)	IS 5578 : 1984	Guide for marking of insulated conductors (*first revision*)
	IS 11353 : 1985	Guide for uniform system of marking and identification of conductors and apparatus terminals
(25)	lS/lEC 60309-1 : 2002	Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements (*first revision*)
	lS/lEC 60309-2 : 2002	Plugs, socket-outlets and couplers for industrial purposes — Part 2: Dimensional interchangeability requirements for pin and contact-tube accessories (*first revision*)
(26)	IS 2206(Part 1) : 1984	Flameproof electric lighting fittings: Part 1 Well-glass and bulkhead types (*first revision*)
	IS 3528 : 1966	Specification for water-proof electric lighting fittings
	IS 3553 : 1966	Specification for water-tight electric lighting fittings
	IS 5077 : 1969	Specification for decorative lighting outfits
	IS 10322 (Part 5/ Sec 5) : 2013	Luminaires: Part 5 Particular requirements, Section 5 Flood lights (*first revision*)
(27)	IS 12640 (Part 1) : 2016 IEC 61008-1 : 2012	Residual current operated circuit- breakers without integral overcurrent protection for household and similar uses (RCCBs) — Part 1: General rules (*second revision*)
	IS 12640 (Part 2) : 2016 IEC 61009-1 : 2012	Residual current operated circuit- breakers with integral overcurrent protection for household and similar uses (RCBOs) — Part 2: General rules (*second revision*)
	IS 14614 : 1998 IEC 1543 : 1995	Residual current operated protective devices (RCDs) for household and similar use — Electromagnetic compatibility
	IS/IEC 60898-1 : 2002	Electrical accessories — Circuit breakers for over current protection for household and similar installations — Part 1: Circuit breakers for a.c. operation
	IS/IEC 60947-1 : 2007	Low-voltage switchgear and controlgear — Part 1: General rules (*first revision*)
	IS/IEC 60947-2 : 2003	Low-voltage switchgear and controlgear — Part 2: Circuit breakers

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Sl No.	*IS No.*	*Title*
	IS/IEC 60947-3 : 1999	Low-voltage switchgear and controlgear — Part 3: Switches, disconnectors, switch-disconnectors and fuse combination units
	IS/IEC 60947-4-1 : 2000	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 1 Electro-mechanical contactors and motors-starters
	IS/IEC 60947-4-2 : 2011	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 2 a.c. semiconductor motor controllers and starters (*first revision*)
	IS/IEC 60947-4-3 : 2011	Low-voltage switchgear and controlgear — Part 4: Contractors and motor-starters, Section 3 a.c. semiconductor motor controllers and contactors for non-motor loads (*first revision*)
	IS/IEC 60947-5-1 : 2003	Low-voltage switchgear and controlgear — Part 5: Control circuit devices and switching elements, Section 1 Electro-mechanical control circuit devices
	IS/IEC 60947-5-2 : 2007	Low-voltage switchgear and control gear — Part 5: Control circuit devices and switching elements, Section 2 Proximity switches
(28)	IS 3961	Recommended current ratings for cables
	(Part 1) : 1967	Paper insulated lead sheathed cables
	(Part 2) : 1967	PVC insulated and PVC sheathed heavy duty cables
	(Part 3) : 1968	Rubber insulated cables
	(Part 5) : 1968	PVC insulated light duty cables
	(Part 6) : 2016	Crosslinked polyethylene insulated PVC sheathed cables
(29)	IS 2086 : 1993	Specification for carriers and bases used in rewirable type electric fuses for voltages up to 650 V (*third revision*)
	IS 13703(Part 1) : 1993	Specification for low-voltage fuses for voltages not exceeding 1 000 V a.c. or 1 500 V d.c.: Part 1 General requirements
(30)	IS 2672 : 1966	Code of practice for library lighting
	IS 4347 : 1967	Code of practice for hospital lighting
	IS 6665 : 1972	Code of practice for industrial lighting
	IS 8030 : 1976	Specification for luminaires for hospitals
(31)	IS 4648 : 1968	Guide for electrical layout in residential buildings
(32)	IS 900 : 1992	Code of practice for installation and maintenance of induction motors (*second revision*)
(33)	IS 3480 : 1966	Specification for flexible steel conduits for electrical wiring
	IS 3837 : 1976	Accessories for rigid steel conduits for electrical wiring (*first revision*)
	IS 3419 : 1989	Fittings for rigid non-metallic conduits (*second revision*)
	IS 9537	Conduits for electrical installations
	(Part 1) : 1980	General requirements
	(Part 2) : 1981	Rigid steel conduits
	(Part 3) : 1983	Rigid plain conduits of insulating materials
	IS 14768	Conduit fittings for electrical installations
	(Part 1) : 2000	General requirements
	(Part 2) : 2003	Metal conduit fittings

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Sl No.	*IS No.*	*Title*
	IS 14772 : 2000	General requirements for enclosures for accessories for household and similar fixed electrical installations
(34)	IS 14930	Conduit systems for electrical installations
	(Part 1) : 2001	General requirements
	(Part 2) : 2001	Particular requirements — conduit systems buried underground
(35)	IS 14927	Cable trunking and ducting systems for electrical installations
	(Part 1) : 2001	General requirements
	(Part 2) : 2001	Cable trunking and ducting systems intended for mounting on walls or ceiling
(36)	IS 9537	Conduits for electrical installations
	(Part 1) : 1980	General requirements
	(Part 2) : 1981	Rigid steel conduits
(37)	IS 3837 : 1976	Accessories for rigid steel conduits for electrical wiring (*first revision*)
	IS 14768	Conduit fittings for electrical installations
	(Part 1) : 2000	General requirements
	(Part 2) : 2003	Metal conduit fittings
	IS 14772 : 2000	General requirements for enclosures for accessories for household and similar fixed electrical installations
(38)	IS 9537	Conduits for electrical installations
	(Part 1) : 1980	General requirements
	(Part 3) : 1981	Rigid plain conduits of insulating materials
(39)	IS 3419 : 1989	Fittings for rigid non-metallic conduits (*second revision*)
	IS 14772 : 2000	General requirements for enclosures for accessories for household and similar fixed electrical installations
(40)	IS 13021(Part 1) : 1991	Specification for a.c. supplied electronic ballasts for tubular florescent lamps: Part 1 General and safety requirements
(41)	IS 1258 : 2005	Bayonet lamp holders (*fourth revision*)
(42)	IS 418 : 2004	Tungsten filament lamps for domestic and similar general lighting purposes (*fourth revision*)
	IS 1569 : 1976	Capacitors for use in tubular fluorescent high pressure mercury and low pressure sodium vapour discharge lamp circuit (*first revision*)
	IS 2215 : 2006	Specification for starters for fluorescent lamps (*third revision*)
	IS 2418	Specification for tubular fluorescent lamps for general lighting service
	(Part 1) : 1977	Requirements and tests (*first revision*)
	(Part 2) : 1977	Standard lamp data sheets (*first revision*)
	(Part 3) : 1977	Dimensions of G-5 and G-13 bi-pin caps (*first revision*)
	(Part 4) : 1977	Go and no-go gauges for G-5 and G-13 bi-pin caps (*first revision*)
	IS 3323 : 1980	Bi-pin lampholders for tubular fluorescent lamps (*first revision*)
	IS 3324 : 1982	Holders for starters for tubular fluorescent lamps (*first revision*)
	IS 9900	Specification for high pressure mercury vapour lamps
	(Part 1) : 1981	Requirements and tests
	(Part 2) : 1981	Standard lamp data sheets
	(Part 3) : 1981	Dimensions of lamp caps
	(Part 4) : 1981	Go and no-go gauges of lamp caps

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Sl No.	*IS No.*	*Title*
(43)	IS 374 : 1979	Electric ceiling type fans and regulators (*third revision*)
(44)	IS 3043 : 1987	Code of practice for earthing
(45)	IS/IEC 62305-3 : 2010	Protection against lightning — Part 3: Physical damage to structures and life hazard
(46)	IS/IEC 62305-1 : 2010	Protection against lightning — Part 1: General principles
(47)	IS/IEC 62305-2 : 2010	Protection against lightning — Part 2: Risk management
(48)	IS/IEC 62305-4 : 2010	Protection against lightning — Part 4: Electrical and electronic systems within structures
(49)	IS 16463 (Part 11) : 2016 IEC 61643-11 : 2011	Low-voltage surge protective devices: Part 11 Surge protective devices connected to low-voltage power systems — Requirements and test methods
(50)	IS 8437 (Part 1) : 1993 IEC Pub 479-l (1984)	Guide on effects of current passing through the human body: Part 1 General aspects (*first revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 8/Section 3) deals with the planning, selection, design considerations, and installation of air conditioning, heating and mechanical ventilation system for different types of building application and in towns and cities under all the climatic zones of India. It covers all aspects including the goals and objectives, basis of design, input parameters for design, guidelines for design of system, performance parameters, available system options, pre-planning considerations, range of equipment and system components, building management system, installation of the system, testing, commissioning and handing over and also operation and maintenance of the air conditioning, heating and mechanical ventilation system.

Indian construction industry is poised to add an-order-of-magnitude built foot-print in the coming years. With the advent of information technology and computers becoming part of our life-style, the requirement of air conditioning of built environment is being increasingly felt and met with. The challenge faced for this unprecedented development is the lack of material resources and natural resources like energy, water and clean air. Therefore, the selection of air conditioning and mechanical ventilation system, optimally suited for the specific type of building application and its climatic zone, becomes critical. It is necessary for the owner, designer, builder and developer to understand the provisions of this Section, and consult an air conditioning engineer at the planning stage.

Sustainable buildings movement in the country has gained tremendous momentum. The Part 11 'Approach to Sustainability' of the Code, deals with all aspects of sustainable buildings, from selection of site, building design, energy and water efficient systems, use of recycled material resources, construction, third party commissioning, operation and maintenance of sustainable buildings. It is expected that by following the provisions of this Section in conjunction with those given in Part 11, India will adopt sustainable buildings as the way of life, as has been the practice for centuries, prior to the onslaught of industrial revolution in India.

Computerized weather data is now available, and has been included for around 60 locations across the country, covering all the five climatic zones. This data is based on the latest values obtained from India Metrological Department, Government of India.

This Section was first formulated in 1970 and was subsequently revised in 1983 and 2005. The major modifications made in 2005 version of the Code included addition of several new terms and their definitions; incorporation of a new clause on design criteria; inclusion of 'indoor air quality' as one of the factors that needed to be controlled in the conditioned space; incorporation of recommendation for independent air handling unit rooms for each floor of large and multi-storeyed buildings; inclusion of inside design conditions for various applications replacing earlier Table 2 and Table 3; revision of provisions on minimum outside fresh air in the light of the then accepted international norms thus covering a wider variety and a larger number of applications; addition of new details on temperature, humidity, vibration and noise; updation of provisions on application considerations, covering a wide variety of commercial applications, such as, offices, hotels, restaurants and computer rooms; inclusion of a new clause on statutory regulation/safety considerations; description of various system options available, under the clause on design considerations; updation of provisions on the characteristics and application of options available in piping, water distribution systems and piping layout; revision of provisions on air filters; revision of the clause on energy conservation and energy management to include concepts like energy targets, demand targets and consumption targets, the factors to be considered in system design that influence energy aspects, the need for analysis of operation of systems during various seasons of the year, and the need to incorporate energy recovery strategies. Apart from above, 'Automatic Controls' included in the 1983 version had been replaced by Building Management System, which addressed not only the control function, but also had a telling impact on operation and maintenance as well, most importantly on the opportunities afforded to implement various energy conservation strategies; provisions on packaged air conditioners and room air conditioners were elaborated; provisions on heating were revised; provisions on symbols, units, colour code and identification of services, pipe work services, duct work services, valve labels and charts, and also on inspection, commissioning and testing were updated; and list of various parameters to be checked for performance of air handling unit, hydronic system balancing, and

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finally, the hand-over procedure were included.

Since the last revision of the Code in 2005, there has seen tremendous emphasis on energy conservation to meet the challenges posed by the climatic change. Hence the building design practices, the system components and principal equipment have gone through major development. The current revision fully recognizes the latest developments in the field of air conditioning, heating and mechanical ventilation.

The significant modifications made in this revision of this Section include amongst others, the following key changes:

a) Definitions of several new terms have been added relating to the new concepts introduced in this revision.

b) Clause on refrigerants has been modified to include new refrigerants with zero ozone depletion potential and ultra-low global warming potential. These are now manufactured in India and are commercially available, or are in advanced stage of development in the research and development laboratories. Water, Ammonia, CO_2, and other natural refrigerants are making a comeback and are described with relevant details.

c) Planning considerations have been expanded to include the available options of variable refrigerant flow system; inverter technology, district cooling system, and hybrid central plant using chilled beams and radiant floor components. Planning clause also identifies the thrust on envelope optimization using energy modelling, day lighting simulation, solar shade analysis and wind modelling software to optimize the air conditioning load. Such buildings are thus designed to utilize the most energy efficient air conditioning system to bring the annual energy consumption to a minimum, which could be generated through renewable energy resources.

d) Outdoor design conditions for air conditioning load calculation and heating requirement have been based on the latest weather data tabulated for around 60 cities, covering all the five climatic zones of India. These are derived from the latest weather data taken from India Metrological Department, Government of India.

e) Indoor design conditions for comfort air conditioning, heating, and mechanical ventilation have been based on adaptive comfort conditions for the specific climatic zone, as per the procedure described in this completely revised clause.

   The Committee explored the possibility of including heating degree day and cooling degree day in this Section. It was noted that at present, there was no scientific research in the country in public domain for arriving at heating degree day (HDD) and cooling degree day (CDD) of India and the same is being researched. It was also noted that suitable software tools were since available which provided better assessment of the cooling and heating requirements for the space. Therefore, heating degree day (HDD) and cooling degree day (CDD) was not included.

f) The central plant equipment clause has been revised to include active and passive chilled beams, radiant floor for cooling/heating of space, underfloor air distribution to minimise stratification, geo-thermal cooling and heating, and recently developed high-efficiency cooling towers with very low approach to ambient wet-bulb temperature.

g) Clauses on unitary/distributed equipment have been expanded and also direct/indirect evaporative cooling units have been included.

h) Provisions for specialized applications have been further detailed where provisions have also been now included for data centres and underground metro stations.

j) Refrigeration is common for summer air conditioning and for cold stores. Cold storage is key to India's food security by minimising food wastage. Therefore, a new clause has been introduced in this revision, on refrigeration for cold stores, describing the latest state-of-the-art technologies locally adopted.

k) Heating is required for indoor comfort conditions during winter months in northern part of India. This clause now describes the most efficient strategies for winter heating, using reverse cycle operation, solar heating systems, electric heat pump, and ground source heat pump.

m) Ventilation has now taken the centre-stage for sustainability in design, construction and operation of buildings. Natural ventilation and passive architecture are dealt in Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code, with further strategies for sustainable buildings covered in Part 11 'Approach to Sustainability' of the Code. However, modern system of mechanical ventilation for industries, commercial kitchen, underground car parking, and for open tunnels connecting underground metro stations, has been now covered in this Section. It also covers demand control ventilation, where

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fresh air input for the control of indoor air quality, varies in direct proportion to the occupancy. Newly developed axial flow fans with aerofoil profile blades and acoustic silencers, has also been covered including criteria for solution of most efficient fan for the specific application.

n) Installation practices for the air conditioning, heating and mechanical ventilation system have been modified to suit the vast options of components now available. The clause identifies the procedure and precautions to be taken for each major component of the central system; unitary/distributed systems; fan; ducting and piping support; and for insulation. Emphasis is laid on ease of maintenance/repair/replacement; for noise and vibration isolation, and for centralized monitoring and control through computerized building automation system.

p) Symbols, colour coding and identification of services clause has been modified to match with the international practices.

q) Measurement and verification of building performance is now widely practiced and has put strong emphasis on integrated building management system for modern building complexes. Therefore, the clause on building automation system has been upgraded to include the latest practices for web-based monitoring and control of performance parameters.

r) Testing, balancing, commissioning and handing over of the air-conditioning, heating and mechanical ventilation system clause has been extensively revised to include state-of-the-art procedures adopted.

This revision aims to make a difference in the quality of environment and in building usage, in response to growing concerns and expectations in with regard to indoor air quality, energy conservation, water conservation, environmental impact and building safety.

The provisions on natural ventilation are given in Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code.

The provisions of this Section are without prejudice to the various Acts, Rules and Regulations including *The Factories Act*, 1948 and the rules and regulations framed thereunder.

The information contained in this Section is based largely on the following Indian Standards:

IS 659 : 1964	Safety codes for air conditioning (*revised*)
IS/ISO 817	Refrigerants — Designation and safety classification (*second revision*) (*Under print*)
IS 1391	Specification for room air conditioners:
(Part 1) : 1992	Unitary air conditioners (*second revision*)
(Part 2) : 1992	Split air conditioners (*second revision*)
IS 2379 : 1990	Colour code for identification of pipelines (*first revision*)
IS 3315 : 1994	Specification for evaporative air coolers (desert coolers) (*second revision*)
IS 8148 : 2003	Specification for packaged air conditioners (*first revision*)

Assistance has also been derived from the following publications in the preparation of this Section:

Guidelines, Standards and Handbooks of American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)

Handbooks of Indian Society of Heating, Refrigerating and Air Conditioning Engineers (ISHRAE)

India Model for Adaptive Comfort, CEPT University, Ahmedabad

ISO 7730 : 2005 Ergonomics of the thermal environment Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria

ISO 16484-1 : 2010 Building automation and control systems (BACS) Part 1: Project specification and implementation

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties using this Section are encouraged to investigate the possibility of applying the most recent edition of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 3 Air Conditioning, Heating and Mechanical Ventilation

1 SCOPE

1.1 This Code (Part 8/Section 3) covers the planning, design considerations, installation, testing, commissioning and handing over and also operation and maintenance of air conditioning, heating and mechanical ventilation systems for buildings. It also covers refrigeration for cold storages.

1.2 The provisions of this Section aim to ensure an air conditioning, heating and mechanical ventilation system which can provide comfort by managing air temperature, humidity, indoor air quality and distribution of conditioned air for the specific use and occupancy of built space while giving due consideration to minimising energy consumption and other resources.

1.3 The provisions on natural ventilation are covered in Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code.

1.4 The provisions in respect of air conditioning, heating and mechanical ventilation system in sustainable buildings are covered in Part 11 'Approach to Sustainability' of the Code, which shall be used in conjunction with this Section.

2 TERMINOLOGY

For the purpose of this Section the definitions given below and those given in the accepted standard [8-3(1)] shall apply.

2.1 Air Conditioning — The process of treating air so as to control simultaneously its temperature, humidity, purity, distribution and movement and pressure to meet the requirements of the conditioned space.

2.2 Air System Balancing — Adjusting air flow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc, or by using automatic control devices, such as constant-air-volume or variable-air-volume (VAV) boxes.

NOTE — Air system should be balanced in order to minimise throttling losses. For fans, its speed should be adjusted to meet design flow conditions. By creating correct air flow at fans and outlet, system performance can be increased.

2.3 Atmospheric Pressure — The force per unit area exerted against a surface by the weight of the air above that surface. It is the pressure indicated by a barometer. Standard atmospheric pressure or standard atmosphere or barometric pressure is the pressure of 76 cm of mercury column having a density of 13.595 1 g/cm^3 under standard gravity of 980.665 cm/s^2 (10 332 mm of water column/101.325 kPa).

NOTE — Generally atmospheric pressure is used as a datum for indicating the system pressures in air conditioning and accordingly, pressures are mentioned above the atmospheric pressure or below the atmospheric pressure considering the atmospheric pressure to be zero. A 'U' tube manometer will indicate zero pressure when pressure measured is equal to atmospheric pressure.

2.4 Building Energy Simulation — Use of computer models for design and optimization of building's energy performance, to compare the cost-effectiveness of energy conservation measures in the design stage as well as assessing various performance optimization measures during the operational stage.

2.5 Building Integrated Renewable Energy — Integration of renewable energy application in parts of the building envelope such as the roof, skylights, or facades.

2.6 Building Management System (BMS) — An energy management system relating to the overall operation of the building in which it is installed. It often has additional capabilities, such as equipment monitoring, protection of equipment against power failure, and building security. It may also be a direct digital control (DDC) system where the mode of control uses digital outputs to control processes or elements directly.

NOTE — Mechanical and electrical equipment installed in the building, such as, air conditioning, ventilation, lighting, lifts, power, pumping stations, fire fighting systems, security systems are controlled and managed through BMS.

2.7 Buildings Related Illnesses (BRI) — The diagnosable illness attributed directly to the specific air-borne building contaminants, like Legionnaire's disease, occupational asthma, etc.

NOTE — Indicators of BRI include complaints of cough, chest tightness, chills, fever and muscle aches. Occupants may need prolonged recovery times after leaving the building.

2.8 Coefficient of Performance, Compressor, Heat Pump — Ratio of the compressor heating effect (heat pump) to the rate of energy input to the shaft of the compressor, in consistent units, in a complete heat pump, under designated operating conditions.

2.9 Coefficient of Performance, Compressor, Refrigerating — Ratio of the compressor refrigerating effect to the rate of energy input to the shaft of the

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compressor, in consistent units, in a complete refrigerating plant, under designated operating conditions.

2.10 Coefficient of Performance (Heat Pump) — Ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete operating heat pump plant or some specific portion of that plant, under designated operating conditions.

2.11 Coefficient of Performance (Refrigerating) — Ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating plant or some specific portion of that plant, under designated operating conditions.

2.12 Cooling Load — Amount of cooling per unit time required by the conditioned space or product; or heat that a cooling system shall remove from a controlled system over time.

2.13 Cooling Tower — An enclosed device, often tower like, for evaporatively cooling water by contact with air.

2.14 Dedicated Outdoor Air System (DOAS) — A unit that is used to separately condition outdoor air brought into the building for ventilation or to replace air that is being exhausted.

2.15 Demand Based Ventilation — Intelligent airflow management that adjusts outside ventilation air based on the number of occupants and the ventilation demands that those occupants create.

2.16 Design Pressure Difference — The desired pressure difference between a given space and an adjacent space measured at the boundary of the given space under a specified set of conditions, such as, that required in various spaces of hospital, clean rooms, protected space in case of smoke control operation, etc.

2.17 Dew Point Temperature — The temperature at which condensation of moisture begins when the air is cooled at same pressure.

2.18 Dry-Bulb Temperature — The temperature of the air, read on a thermometer, taken in such a way as to avoid errors due to radiation.

2.19 Duct System — A continuous passageway for the transmission of air which, in addition to the ducts, may include duct fittings, dampers, plenums, grilles and diffusers.

2.20 Economizer, Air — It consist of duct, damper and control system that allow outside air to cool the building when outside air is cooler than inside.

2.21 Economizer, Water — In this system the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat transfer or mass transfer to the environment without the use of mechanical cooling.

2.22 Effective Temperature — Combined effects of air temperature, humidity, air movement, mean radiant temperature, clothing and activity on the sensation of warmth or cold felt by the human body. Numerically equivalent to the temperature of still air producing similar thermal sensation as produced by combination of above six parameters of thermal comfort.

2.23 Energy Efficiency Ratio (EER) — Ratio of net cooling capacity in BTU/h to total rate of electric input in watts under designated operating conditions.

2.24 Energy Recovery Unit — A heat exchanger assembly for transferring energy between two isolated fluid sources. The recovery system may be of air-to-air design or a closed loop hydronic system design. The system will include all necessary equipment, such as fans and pumps, associated ducts or piping and all controls (operating and safety), and other custom-designed features

2.25 Evaporative Cooling — The process of evaporating part of a liquid by supplying the necessary latent heat from the sensible heat of the main bulk of the liquid which is thus cooled.

2.26 Fire Damper — The damper, normally held open, installed in an air distribution system or in a wall or floor assembly and designed to close automatically in the event of a fire in order to maintain the integrity of the fire separation.

2.27 Geothermal Heat Pump — A heating and/or cooling system utilizes the earth's crust, as heat source (in the winter) or a heat sink (in the summer) by using fluid to be pumped into the earth and circulated in order to exchange heat for the purpose of heating or cooling applications

2.28 Global Warming Potential (GWP) —The relative measure of how much a given mass of a refrigerant contributes to global warming over a given time period compared to the same mass of carbon dioxide over the same period.

NOTE —The GWP value of carbon dioxide is taken to be 1.0. The GWP value of a refrigerant is calculated over a time horizon. The time horizon can greatly affect the numerical value of GWP. Usually the GWP values are reported over a 100 years' time horizon.

2.29 Heating Load — Heating rate required to replace heat loss from the space being controlled.

2.30 Heat Pump — A thermodynamic heating/ refrigerating system to transfer heat. The condenser and evaporator may change roles to transfer heat in either direction. By receiving the flow of air or other fluid, a heat pump is used to cool or heat. Heat pumps may be

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the air source with heat transfer between the indoor air stream to outdoor air or water source with heat transfer between the indoor air stream and a hydronic source (ground loop, evaporative cooler, cooling tower, or domestic water).

2.31 Heat Recovery — Use of heat that would otherwise be wasted from a system or process, for example, heat-recovery chiller which uses hot waste gases as a heat source.

2.32 Hybrid Building — A building which contains both active and passive systems of heating or cooling. It requires small amount of non-renewable energy to maintain required amount of coefficient of performance (COP).

2.33 Hydronic Systems — The water systems that transfer heat to or from a conditioned space or process with hot or chilled water. The water flows through piping that connects a chiller or the water heater to suitable terminal heat transfer units located at the space or process.

2.34 Hydronic System Balancing — Adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves or by using automatic control devices, such as automatic flow control valves.

2.35 Indirect-Direct Cooling — The cooling which involves the following two stages:

a) The first stage, in which the air is made to pass through heat exchanger for sensible cooling (no direct contact of air and water), whereby the leaving air dry-bulb temperature (DBT) as well as the wet-bulb temperature (WBT) are reduced; and

b) The second stage, in which the air after the first stage is made to pass through the evaporative air-cooling (adiabatic cooling) application where water and air are in direct contact and there is simultaneous removal of sensible heat and the addition of moisture to the air giving lower DBT.

2.36 The resultant of this two stage cooling is that the leaving air DBT is lower than ambient WBT.

NOTE — The first stage cooling is through indirect cooling. In this method, air-dry bulb and wet-bulb temperature are reduced without direct contact of air with water and through heat exchange only.

2.37 Indoor Air Quality (IAQ) — Air quality that refers to the nature of unconditioned or conditioned air that circulates throughout the space/area where one works or lives, that is, the air one breathes when indoors.

2.38 Infiltration/Exfiltration — The phenomenon of air leaking into (infiltration) or leaking out (exfiltration) out of an air conditioned space.

2.39 Latent Heat — Change of enthalpy during a change of state, usually expressed in kcal/kg. With pure substances, latent heat is absorbed or rejected at constant temperature at any pressure.

2.40 Latent Heat Load — Cooling load required to remove latent heat.

2.41 Mean Radiant Temperature — The uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure.

2.42 Mixed Mode Building — A hybrid approach to space conditioning that uses a combination of natural ventilation and mechanical systems. These buildings utilize mechanical cooling only when and where it is necessary to supplement the natural ventilation.

2.43 Naturally Conditioned Building — A building in which the ventilation system rely on opening and closing of window of the space to maintain the thermal comfort of the space rather than mechanical systems.

2.44 Operative Temperature — A uniform temperature of a radiantly black enclosure in which an occupant would exchange the same amount of heat by radiation plus convection as in the actual non-uniform environment. It is the combined effects of the mean radiant temperature and air temperature calculated as average of the two. It is also known as dry resultant temperature or resultant temperature.

2.45 Ozone Depletion Potential (ODP)—A relative capability of a refrigerant or a gas to degrade ozone in the atmosphere as compared to trichlorofluoromethane [R-11 or Clorofluorocarbon-11(CFC-11)]. The ODP of CFC-11 is taken to be 1.0.

2.46 Passive Cooling — A building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or zero energy consumption by using natural ventilation, air cooling and shades.

2.47 Passive Heating — Passive heating uses the energy of natural source such as the sun, to keep the occupants of the building comfortable by design approach of building without the use of mechanical or electrical heating systems.

2.48 Plenum — An air compartment connected to one or more distributing ducts.

2.49 Positive Ventilation — The supply of outside air by means of a mechanical device, such as a fan.

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2.50 Psychrometric Chart — A chart graphically representing the thermodynamic properties of moist air.

2.51 Recirculated Air — The return air that has been passed through the conditioning apparatus before being re-supplied to the space.

2.52 Refrigerant — The fluid used for heat transfer in a refrigerating system, which absorbs heat at a low temperature and a low pressure of the fluid and rejects heat at a higher temperature and a higher pressure of the fluid, usually involving changes of state of the fluid.

2.53 Relative Humidity — Ratio of the partial pressure of actual water vapour in the air as compared to the partial pressure of maximum amount of water that may be contained at its dry-bulb temperature.

NOTE — When the air is saturated, dry-bulb, wet-bulb and dew point temperatures are all equal, and the relative humidity is 100 percent.

2.54 Return Air — Air returned from conditioned or refrigerated space.

2.55 Sensible Heat — Heat which is associated with a change in temperature; in contrast to a heat interchange in which a change of state (latent heat) occurs.

2.56 Sensible Cooling — The process of removing sensible heat (lowering the dry-bulb temperature) from the air passing through it under specified conditions of operation.

2.57 Shade Factor — The ratio of instantaneous heat gain through the fenestration with shading device to that through the fenestration.

2.58 Sick Building Syndrome (SBS) — A term used to describe the presence of acute non-specific symptoms in the majority of people, caused by working in buildings with an adverse indoor environment.

NOTE — SBS could be a cluster of complex irritative symptoms like irritation of the eyes, blockened nose and throat, headaches, dizziness, lethargy, fatigue irritation, wheezing, sinusitis, congestion, skin rash, sensory discomfort from odours, nausea, etc. These symptoms are usually short-lived and experienced immediately after exposure; and may disappear when one leaves the building.

2.59 Smoke Barrier — A continuous membrane, either vertical or horizontal, such as a wall, floor, or ceiling assembly, that is designed and constructed to restrict the movement of smoke in conjunction with a smoke control system.

2.60 Smoke Damper — A damper similar to fire damper, however, having provision to close automatically on sensing presence of smoke in air distribution system or in conditioned space.

2.61 Smoke Management — A smoke control method that utilizes natural or mechanical systems to maintain a tenable environment for the means of egress from a large-volume space or to control and reduce the migration of smoke between the area on fire and communicating spaces.

2.62 Stack Effect — The vertical airflow within buildings caused by the temperature-created density differences between the building interior and exterior or between two interior spaces.

2.63 Static Pressure — The normal force per unit area that would be exerted by a moving fluid on a small body immersed in it if the body were carried along with the fluid. Practically, it is the normal force per unit area at a small hole in a wall of the duct through which the fluid flows (piezometer) or on the surface of a stationary tube at a point where the disturbances, created by inserting the tube, cancel. It is supposed that the thermodynamic properties of a moving fluid depend on static pressure in exactly the same manner as those of the same fluid at test depend upon its uniform hydrostatic pressure.

2.64 Supply Air — The air that has been passed through the conditioning apparatus and taken through the duct system and distributed in the conditioned space.

2.65 Terminal Devices — Devices fixed in the air conditioned space for distribution of conditioned supply air and return of air such as, supply and return air grilles and diffusers.

2.66 Thermal Adaptation — The gradual diminution of the people's response to repeated environmental stimulation and subsumes all processes which building occupants undergo in order to improve the fit of the indoor climate.

2.67 Thermal Comfort — That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

2.68 Thermal Insulation Material — A material used over the conducting material to retard the flow of heat energy in the form of heat loss or gain to facilitate the temperature control as the process and prevent permeability of moist vapour and reduces condensation on cold surfaces.

2.69 Thermal Energy Storage — Storage of thermal energy, sensible, latent or combination thereof for use in central system for air conditioning or refrigeration. It uses a primary source of refrigeration for cooling and stored thermal energy for reuse at peak demand or for backup as planned.

2.70 Velocity Pressure — The pressure exerted by movement of air which makes the air to travel to longer

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distance in ducts. This pressure is always in the direction of flow.

2.71 Variable Refrigerant Flow (VRF) System — A heating and/or cooling system in which the flow of the refrigerant can be varied according to the load.

2.72 Water Hardness — The hardness in water represented by the sum of calcium and magnesium salts in water, which may also include aluminium, iron, manganese, zinc, etc.

2.73 Water Treatment — The treatment of water circulating in a hydronic system, so that it can be used without creating undue corrosion or scaling to the piping systems and other deleterious effects.

2.74 Wet-Bulb Temperature — The temperature at which liquid or solid water, by evaporating into air, can bring the air to saturation adiabatically at the same temperature. Wet-bulb temperature is the temperature indicated by a wet-bulb thermometer constructed and used according to specifications.

3 REFRIGERANTS

3.1 Refrigerants are classified into two classes based on their toxicity, namely Class A having lower chronic toxicity and Class B having higher chronic toxicity. They are classified into four classes based on their flammability, namely, Class 1 (no flame propagation), Class 2L (lower flammability), Class 2 (flammable) and Class 3 (higher flammability).

Refrigerants shall be designated and classified for safety in accordance with the accepted standard [8-3(2)].

3.1.1 *Matrix Diagram of Safety Group Classification System*

The toxicity and flammability classifications for refrigerants as per **3.1** yield eight safety groups, namely, A1, A2L, A2, A3, B1, B2L, B2 and B3. These safety groups are represented by the matrix shown below:

	Safety Group	
Toxicity →	Lower Toxicity	Higher Toxicity
Flammability ↓		
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1

3.2 While selecting refrigerants, manufacturers and designers shall adopt balanced approach considering environmental impact and human health. The key criteria that shall be considered are as follows:

a) *Ozone depletion potential* (*ODP*) — ODP of the refrigerant should preferably be zero and shall be as permitted under *The Ozone Depleting Substances (Regulation and Control) Amendment Rules*, 2014 as amended from time to time (*see* Note);

b) *Global warming potential* (*GWP*) — GWP of the refrigerant should preferably be low to reduce greenhouse gas (GHG) emissions, which is in line with the on-going discussion for phase-down of production and consumption of Hydrofluorocarbons (HFCs);

c) Refrigerant with zero ODP and low GWP should be adopted for balance approach considering overall environmental impact;

d) *Flammability* — The refrigerant should preferably be non-flammable/having flammability as low as possible, and suitable risk mitigation process/infrastructure (sensors, ventilation, etc) should be opted to mitigate the risk of flammability, if any, in line with the accepted standards;

e) *Toxicity* — The refrigerant should have toxicity as low as possible, and suitable risk mitigation strategies/infrastructure (sensors, ventilation, etc) should be opted to handle toxicity, if any in line with the accepted standards; and

f) The refrigerant should also support other key performance parameters, including high energy efficiency, low emissions, chemical and thermal stability and material compatibility.

NOTE — The production and consumption of ozone depleting substances (ODS) including HCFCs, for example, HCFC-22 and HCFC-123 is being phased out by 2030. The import of refrigeration and air conditioning equipment containing HCFCs has already been banned from 01 July 2015, and the manufacturing of all such equipment with HCFC will be banned in the country from 01 January 2025 in accordance with *The Ozone Depleting Substances (Regulation and Control) Amendment Rules*, 2014.

For ODP, GWP and safety group (flammability and toxicity) of different refrigerants, reference shall be made to Table 1. As there are ongoing developments with respect to refrigerants with HCFC Phase-out Management Plan (HPMP) and HFC phase down proposals, latest regulations applicable at the time of selection of equipment/systems with various possible refrigerants shall be followed. As research is going on for alternative refrigerants to various HCFC/HFC/HFO refrigerants, it is recommended that project teams should make a conscious effort to select equipment/systems with refrigerant with high energy efficiency, least negative impacts on health, safety and environment as per the latest developments.

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Table 1 ODP and GWP Values (100 Year Values) and Safety Group of Different Refrigerant Types
(*Clause* 3.2)

Sl No.	Refrigerant		ODP	GWP	Safety Group {*see* Accepted Standard [8-3(2)]}
	Refrigerant Number	Composition Designating Prefix			
(1)	(2)	(3)	(4)	(5)	(6)
i)	Hydrochlorofluorocarbons (HCFC):				
a)	R-22	HCFC	0.055	1 810	A1
b)	R-123	HCFC	0.02	77	B1
ii)	Hydrofluorocarbons (HFC) and their blends:				
a)	R-32	HFC	0	677	A2L
b)	R-134a	HFC	0	1 430	A1
c)	R-245fa	HFC	0	858	B1
d)	R-404A	HFC	0	3 922	A1
e)	R-407C	HFC	0	1 774	A1
f)	R-407F	HFC	0	1 825	A1
g)	R-410A	HFC	0	2 088	A1
h)	R-507A	HFC	0	3 985	A1
j)	R-448A	HFC	0	1 386	A1
iii)	Hydrofluoroolefins (HFO):				
a)	R-1233zd(E)	HFO	~0	1	A1
b)	R-1234ze(E)	HFO	0	0.97	A2L
c)	R-1234yf	HFO	0	0.31	A2L
d)	R-1336mzz(Z)	HFO	0	2.0	A1
e)	R-514A	HFO	0	1.75	B1
iv)	Hydrofluoroolefins (HFO)/Hydrofluorocarbons (HFC) Blends:				
a)	R-452A	HFO and HFC blend	0	2141	A1
b)	R-452B	HFO and HFC blend	0	675	A2L
c)	R-513A	HFO and HFC blend	0	573	A1
v)	Natural refrigerants:				
a)	R-718 (Water)	–	0	0	A1
b)	R-744 (Carbon dioxide)	–	0	1	A1
c)	R-717 (Ammonia)	–	0	0	B2L
d)	R-290 (Propane)	HC	0	3.3	A3

3.3 Suggested list of refrigerants which may be used for various applications is given below (*see also* Note under **3.2**):

a) *Air conditioning*:
   1) *Residential, small unitary light commercial, VRF application* — R-22, R-32, R-410A, R-452B and R-290.
   2) *Chillers for comfort, industrial and process application* — R-123, R-134a, R-245fa, R-407C, R-513A, R-1233zd(E), R-514A, R-1234ze(E), R-1234yf, R-717 and R-718.
   3) *Transport, mobile application* — R-134a, R-407C and R-1234yf.

b) *Refrigeration*:
   1) *Stationary and transport, mobile application* — R-744, R-717, R-404A, R-452A, R-134a, R-290.

4 PLANNING

4.1 Fundamental Requirements

4.1.1 The objective of installing air conditioning, heating and mechanical ventilation in buildings shall be to provide comfortable conditions without compromising on health and safety of occupants.

4.1.2 Air conditioning, heating and mechanical ventilation installation shall aim at controlling and optimizing the following factors in the building:

a) Air quality
b) Air movement,
c) Dry-bulb temperature,
d) Relative humidity,
e) Noise and vibration,
f) Energy efficiency, and
g) Fire safety.

4.1.3 All plans, design drawings, specifications and data for air conditioning, heating and mechanical ventilation systems of all buildings and serving all occupancies within the scope of the Code, shall be supplied to the Authority, where called for (*see* Part 2 'Administration' of the Code).

4.1.4 The plans and design drawings for air conditioning, heating and mechanical ventilation (HVAC) systems shall include all details and data necessary for review of installation such as,

a) building: name, type and location;
b) owner: name;
c) use of building;
d) orientation: north direction on plans and design drawings;
e) general plans: dimensions and height of all rooms;
f) intended use of internal spaces;
g) detail or description of wall construction, including insulation and finish;
h) detail or description of roof, ceiling and floor construction, including insulation and finish;
j) detail or description of windows and outside doors, including sizes, weather stripping, storm sash, sills and storm doors;
k) internal load, such as people, equipment, computer/server load and lighting load;
m) layout showing the location, size and components of the HVAC equipment being installed;
n) information regarding air distribution system;

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p) information on air and water flow rates;
q) information regarding location, size and accessibility of shafts;
r) information regarding type and location of dampers (both volume control and fire/smoke dampers) used in air conditioning system, such as, whether motorized or manually operated;
s) location and grade of the required fire separations;
t) water softening arrangement; and
u) Information on presence of any chemical fumes or gases.

4.2 Design Considerations

4.2.1 Cooling and heating load estimate shall be carried out prior to design and installation of HVAC equipment. Calculation of cooling and heating load shall take into account the following factors:

a) Recommended indoor temperature, relative humidity, air velocity, mean radiant temperature, clothing and activity;
b) Outside design conditions as specified in **5**;
c) Details of building construction and orientation of exposures of building components;
d) Fenestration area, thermal properties and shading factors;
e) *Occupancy* — Number of people and their schedule of activities;
f) *Ventilation* — Requirement for fresh air;
g) Infiltration, air leakage;
h) *Internal load* — Equipment, computer/server and lighting;
j) Effective volume; and
k) Occupancy, lighting and equipment schedule.

4.2.2 The design of air conditioning, heating and mechanical ventilation system and its associated controls shall also take into account the following:

a) Nature of application,
b) Permissible control limits,
c) Fire safety,
d) Opportunities for heat recovery,
e) Energy efficiency,
f) Filtration standard,
g) Hours of use,
h) Suitable diversity factor based on usage,
j) Outdoor and indoor air quality, and
k) Availability of make-up water for cooling towers.

4.2.3 Due consideration shall also be given to air conditioning load encountered during off-peak hours including night time and weekend/holidays.

4.2.4 Consideration shall be given to the anticipated future changes, permanent or temporary, in building load and the system shall be so designed that maximum operational efficiency is maintained throughout.

4.2.5 Special applications like hospitals/operating theatres, computer rooms, data centers and telecommunication rooms, clean rooms, laboratories, libraries, museums/art galleries, sound recording studios, etc, shall be handled differently.

4.2.6 Computer based hourly load calculation and energy simulation tools may be used for HVAC equipment sizing and to identify effect of various energy conservation measures on energy consumption.

4.3 Equipment Room for Central Air Conditioning Plant

4.3.1 This room shall be located preferably within the building being air conditioned and closer to external wall for facilitating ventilation and equipment movement. The equipment may also be installed in a separate service block which should also be located as close as possible to the load/building being conditioned. The clear headroom below soffit of beam should be minimum 4.5 m for larger capacity chillers (500 TR and above) and minimum 3.6 m for smaller plants.

4.3.2 The floors of the equipment rooms should be finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

4.3.3 Supporting of pipe within plant room spaces should be normally from the floor. However, outside plant room areas, structural provisions shall be made for supporting the water pipes from the floor/ceiling slabs. All floor and ceiling supports shall be isolated from the structure to prevent transmission of vibrations.

4.3.4 Equipment rooms, wherever necessary, shall have provision for mechanical ventilation. In hot and dry climate, evaporative air cooling may also be considered.

4.3.5 Plant machinery in the plant room shall be placed on levelled plain/reinforced cement concrete foundation block and provided with anti-vibratory supports or alternatively on inertia bases. Supports for appliances shall be designed and constructed to sustain vertical and horizontal loads within the stress limitations specified in the Part 6 'Structural Design' of the Code. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement should also be considered (*see also* **12.6.4**).

4.3.6 Appropriate sound insulation and noise control measures shall be taken in plant room space as per

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Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code. Acoustic treatment as may be required shall be provided in plant room space in accordance with **12.1.9** to prevent noise transmission to adjacent occupied areas.

4.3.7 In case air conditioning plant room is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases. Fire egress and emergency battery backup lighting shall be provided for the plant room operator.

4.3.8 Floor drain channels or dedicated drain pipes in slope shall be provided within plant room space for effective disposal of waste water, if necessary by automatic level controlled sump pumps. Fresh water connection may also be provided in the air conditioning plant room.

4.3.9 *Thermal Energy Storage*

Thermal storage may be used for limiting maximum demand, by controlling peak electricity load through reduction of chiller capacity, and by taking advantage of high system efficiency during low ambient conditions. Thermal storage will also help in reducing operating cost by using differential time-of-the day power tariff, where applicable.

In case of central plant designed with thermal energy storage, its location shall be decided in consultation with the air conditioning engineer. For roof top installations, structural provision shall take into account load coming on the building/structure due to the same. For open area surface installation, horizontal or vertical system options shall be considered and approach ladders for manholes provided. Buried installation shall take into account loads due to movement of vehicles above the area. Provision for adequate expansion tank and its connection to thermal storage tanks shall be made.

4.4 Equipment Room for Air Handling Units and Package Units

4.4.1 This shall be located as centrally as possible to the conditioned area and contiguous to the corridors or other service areas for carrying air ducts in ceiling spaces.

4.4.2 In case of special and high-rise buildings, air handling units shall be provided in accordance with Part 4 'Fire and Life Safety' of the Code. Air handling unit rooms should preferably be located vertically one above the other.

4.4.3 Provision shall be made for the entry of outdoor ventilation air into air handling unit room. For energy conservation, it is desirable to install mechanism for modulating the outdoor air quantity based on demand.

4.4.4 Exterior openings for outdoor air intake and also exhaust outlets shall have louvers having rain protection profile, with volume control damper, pre-filter and bird screen.

4.4.5 In all cases, outdoor air intakes shall be so located as to avoid contamination from exhaust outlets and from the sources in concentration greater than normal in the locality in which the building is located. It is recommended to maintain minimum 8 m separation between outdoor air intake points and exhaust outlets.

4.4.6 Exhaust air from any dwelling unit shall not be circulated/ingress directly or indirectly to any other dwelling unit, to public corridor or into public stairway.

4.4.7 All air handling rooms should have floor drains and if possible, water supply connection. The trap in floor drain shall provide a water seal between the air conditioned space and the drain line.

4.4.8 Supply/return air duct serving other areas shall not be taken through fire exits.

4.4.9 Waterproofing of air handling unit rooms shall be carried out to prevent damage to floor below.

4.4.10 The floors should be finished smooth. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

4.4.11 Structural design should avoid beam obstruction to the passage of supply and return air ducts. Adequate ceiling space should be made available outside the air handling unit room to permit installation of supply and return air ducts and fire/smoke dampers at compartment wall crossings.

4.4.12 Appropriate sound insulation and noise control measures shall be taken in air handling unit rooms, if located in close proximity to occupied areas, as per Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code. The air handling unit rooms shall be acoustically treated in accordance with **12.1.9**, if located in close proximity to occupied areas.

4.4.13 Access door to air handling unit room shall be single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas. It is desired that access panels in air conditioned spaces should be provided with tight sealing, gaskets and self-closing devices for air conditioning to be effective.

4.4.14 It should be possible to isolate the air handling

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unit room in case of fire. The door shall be fire resistant (*see* Part 4 'Fire and Life Safety' of the Code) and fire/smoke dampers shall be provided in supply/return air duct at air handling unit room wall crossings. Annular space between the duct and the wall should be fire-sealed using appropriate fire resistance rated material.

4.4.15 Fire isolation shall be provided for vertical fresh air duct, connecting several floors.

4.4.16 It is desirable that individual air handling unit should be installed for each fire compartment, alternately, fire barrier should be provided at each fire separation for air handling units serving more than one compartment.

4.5 Pipe Shafts

4.5.1 The shafts carrying chilled water pipes should be located adjacent to air handling unit room or within the room.

4.5.2 Shaft carrying condensing water pipes to cooling towers located on terrace should be vertically aligned.

4.5.3 All shafts shall be provided with fire barrier at floor crossings (*see* Part 4 'Fire and Life Safety' of the Code).

4.5.4 Access to shaft shall be provided at every level, if there is any serviceable component in the shaft.

4.5.5 In case of tall buildings, care shall be taken for expansion/contraction of pipes while planning the supports.

4.6 Supply Air Ducts and Return Air Ducts

4.6.1 The duct supports shall be designed to handle the load and also to take into account seismic considerations. The support material should be galvanized steel/aluminium and facilitate ease of installation at site using alternatives such as fully threaded rod/angle section/wire support systems using stud anchors provided in the ceiling slab from drilled holes without damaging the slab or structural member.

4.6.2 If false ceiling is provided, the supports for the duct and the false ceiling, shall be independent. Collars for grilles and diffusers shall be taken out only after false ceiling/boxing framework is done and frames for fixing grilles and diffusers have been installed. Flexible ducts may be used for making the final connections.

4.6.3 Where a duct penetrates the masonry wall, it shall either be suitably covered on the outside to isolate it from masonry, or an air gap shall be left around it to prevent vibration transmission. Further, where a duct passes through a fire resisting compartment/barrier, the annular space shall be sealed with fire sealant to prevent smoke transmission (*see* Part 4 'Fire and Life Safety' of the Code).

4.7 Cooling Tower

4.7.1 Cooling towers are used to dissipate heat from water cooled refrigeration, air conditioning and industrial process systems to the atmosphere. Cooling is achieved by evaporating a small proportion of recirculating water into outdoor air stream. Cooling towers shall be installed at a place where free flow of atmospheric air is available.

4.7.2 Range of a cooling tower is defined as temperature difference between the entering and leaving water. Approach of the cooling tower is the difference between leaving water temperature and the ambient air wet-bulb temperature.

4.7.3 *Selection of Cooling Tower*

Following factors shall be considered for selection of cooling tower:

a) Design wet-bulb temperature and approach of cooling tower. The designer shall endeavour for reducing the approach for maximizing the energy conservation potential;
b) Height limitation and aesthetic requirement;
c) Location of cooling tower considering possibility of easy drain back from the system;
d) Placement with regard to adjacent walls, windows and other buildings, and effects on these from any water carried over by the air stream;
e) Vibration and noise levels, particularly during silent hours;
f) Material of construction for the tower;
g) Direction and flow of prevailing wind;
h) Quality of water used for make-up;
j) Maintenance and service space availability; and
k) Ambient air quality.

4.7.4 The recommended floor area requirement for various types of cooling tower is as given below:

a) Natural draft cooling tower : 0.15 to 0.20 m^2/TR
b) Mechanical draft cooling tower : 0.07 to 0.10 m^2/TR

4.7.5 Structural provision for the cooling tower shall be taken into account while designing the building. Vibration isolation shall be an important consideration in structural design.

4.7.6 Special care should be taken in design where noise transmitted to the adjoining building can be of serious concern. Special vibration control and sound attenuation devices may be required in that case. Appropriate sound insulation and noise control

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measures shall be taken in such cases in accordance with Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code.

4.7.7 Certain amount of water is lost from circulating water in the cooling tower, as given below:

a) *Evaporation loss* — It is usually about 1 percent of the rate of water circulation.
b) *Drift loss* —The drift loss shall be below 0.1 percent of rate of water circulation.
c) *Blow-down/bleed-off* —The amount of blow-down shall be below 0.8 percent of the total water circulation. If simple blow-down is inadequate to control scale formation, chemicals may be added to inhibit corrosion and limit microbiological growth.

Provision shall be made to make-up for the loss of circulating water.

4.7.8 Provision for make-up water tank to the cooling tower shall be made. Make-up water tank to the cooling tower shall be separate from the tank serving drinking water. Makeup water should be sourced from treated water from sewage treatment, waste water treatment plant, or from rain water harvesting.

Make-up water having contaminants or hardness, which can adversely affect the refrigeration plant life, shall be treated. Treated water where hardness as ppm of $CaCO_3$ is reduced to 50 ppm or below is recommended for air conditioning applications. Water with *p*H value less than 5 shall also need to be treated. For treatment of water for cooling towers, reference shall be made to the good practice [8-3(3)].

4.7.9 Cooling tower should be so located as to eliminate nuisance from drift to adjoining structures.

4.8 Building Envelope

The envelope of the building including wall, roof and fenestration shall be planned as per Part 11 'Approach to Sustainability' of the Code.

4.9 Fire Safety

For fire safety in case of special and high-rise buildings, provisions of Part 4 'Fire and Life Safety' of the Code shall be applicable.

4.10 Sound Insulation and Noise Control

Sound insulation and noise control measures for HVAC system shall be in accordance with Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code.

4.11 Energy Conservation

Designers shall aim for energy efficiency in buildings with the right blend of passive and active design strategies in accordance with Part 11 'Approach to Sustainability' of the Code, so as to minimise the energy use while ensuring comfort as per adaptive thermal comfort requirement given in **6**.

5 OUTDOOR DESIGN CONDITIONS

The outdoor design conditions shall be considered in accordance with Table 2. For cities not included in this table, it is recommended that extrapolation may be done, from the data of the nearby listed city, but keeping into consideration the specific topographical and climatic conditions of the concerned location. Values of ambient dry-bulb temperatures and wet-bulb temperatures, against the various annual percentiles, represent the value that is exceeded on average by the indicated percentage of the total number of hours. The 0.4 percent, 1.0 percent, 2.0 percent values are exceeded on average 35 h, 88 h and 175 h, respectively in a year. The 99.0 percent and 99.6 percent values are defined in the same way but are usually reckoned as the values for which the corresponding weather elements are less than the design conditions of 88 h and 35 h, respectively.

Mean coincidental values are the average of the indicated weather element occurring concurrently with the corresponding design value. After the calculation of design dry-bulb temperatures, the programme located the values of corresponding wet-bulb temperatures from the database for that particular station, the average of these values were computed, which were then called mean of coincidental wet-bulb temperature. In the same way, design wet-bulb temperatures and coincidental dry-bulb temperatures were evaluated.

The design values of 0.4 percent, 1.0 percent and 2.0 percent annual cumulative frequency of occurrence may be selected depending upon application of air conditioning system. For normal comfort conditions, values under 1.0 percent column should be used for cooling loads and 99 percent column for heating loads. For critical applications, values under 0.4 percent column should be used for cooling loads and 99.6 percent column for heating loads.

6 INDOOR DESIGN CONDITIONS

6.1 One of the primary objectives of designing indoor environment is to ensure thermal comfort of all occupants. Air conditioning, heating and mechanical ventilation (HVAC) system is employed to achieve thermal comfort inside building, when means to achieve the same only through building design is limited.

According to the internationally accepted definition, thermal comfort is that state of mind which expresses satisfaction with the indoor environment. The above

Table 2 Summary for Outdoor Design Conditions

(*Clause* 5.1)

Sl No.	Location Name	Cooling DB/MCWB						Evaporation WB/MCDB						Heating DB	
		0.4 Percent		1.0 Percent		2.0 Percent		0.4 Percent		1.0 Percent		2.0 Percent		99.6 Percent	99.0 Percent
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
1)	Ahmedabad	42.1	23.0	41.0	22.8	39.9	22.9	28.5	33.7	28.0	32.7	27.5	32.1	11.0	12.3
2)	Akola	43.2	22.0	42.0	21.7	40.9	21.5	26.8	34.3	26.2	32.1	25.7	31.0	12.9	14.1
3)	Allahabad	43.7	23.4	42.2	23.5	40.8	22.7	28.8	33.0	28.4	32.8	28.0	32.6	7.9	9.1
4)	Amritsar	42.2	23.8	40.9	23.6	39.2	23.5	29.1	33.9	28.7	33.6	28.3	33.2	2.0	3.2
5)	Aurangabad	40.2	22.6	39.2	22.7	38.2	22.4	26.6	35.2	25.7	33.1	25.1	31.7	10.6	12.0
6)	Barmer	43.1	24.2	42.0	23.6	41.0	23.3	28.5	37.9	27.8	35.3	27.2	33.3	9.5	10.7
7)	Belgaum	36.4	19.2	35.4	19.3	34.4	19.4	24.0	29.3	23.6	28.4	23.2	27.6	13.3	14.5
8)	Bengaluru	34.2	19.8	33.4	19.8	32.6	19.8	23.6	28.9	23.1	28.3	22.7	27.7	15.2	15.9
9)	Bhagalpur	42.4	26.8	40.7	27.4	38.9	25.6	30.0	37.1	29.6	36.4	29.2	35.2	11.4	12.6
10)	Bhopal-Bairagarh	41.8	21.6	40.6	21.4	39.4	21.3	26.2	31.5	25.8	30.7	25.4	30.0	10.0	11.2
11)	Bhubaneshwar	38.6	26.6	37.3	26.6	36.2	26.5	29.4	34.1	29.0	33.6	28.6	32.9	14.0	15.1
12)	Bhuj	41.0	23.9	39.7	23.8	38.5	23.9	28.8	34.8	28.3	33.8	27.8	32.9	8.0	9.8
13)	Bikaner	44.2	21.3	42.9	22.0	41.6	22.3	28.2	34.4	27.6	33.8	27.1	33.4	5.6	7.0
14)	Chennai-Minambakkam	38.7	25.9	37.2	25.8	36.2	25.8	28.4	33.1	28.0	32.3	27.6	31.9	19.9	20.8
15)	Chitradurga	36.2	20.8	35.4	20.8	34.6	20.9	25.5	31.4	24.7	30.4	24.1	29.5	15.8	17.0
16)	Dehradun	37.7	21.6	36.2	21.3	34.7	21.4	26.8	30.3	26.4	29.9	26	29.5	5.3	6.4
17)	Dibrugarh	34.0	27.0	33.2	26.8	32.3	26.7	28.3	32.6	27.8	31.8	27.4	31.3	7.5	8.7
18)	Gorakhpur	41.4	26.2	40.3	26.0	39.1	26.4	29.9	35.2	29.7	35.5	29.4	34.7	7.9	9.0
19)	Guwahati	34.5	26.5	33.6	26.5	32.8	26.5	28.7	32.7	28.2	31.9	27.9	31.3	10.8	11.8
20)	Gwalior	43.7	22.0	42.6	22.3	41.3	22.2	28.2	32.9	27.8	32.2	27.4	31.7	6.0	7.1
21)	Hissar	44.6	23.8	43.2	23.9	41.7	24.0	29.1	35.7	28.7	35.2	28.2	34.5	6.1	7.2
22)	Hyderabad	40.2	21.8	39.1	21.7	38.0	21.8	25.7	31.5	25.1	30.8	24.7	30.2	13.9	15.1
23)	Imphal	31.1	23.3	30.2	23.5	29.6	22.9	25.0	29.5	24.6	28.6	24.3	28.3	3.9	5.0
24)	Indore	40.8	19.7	39.6	19.8	38.4	19.7	25.6	30.3	29.6	25.1	24.7	29.0	9.1	10.4
25)	Jabalpur	42.4	20.7	41.1	20.7	39.7	21.0	26.7	31.4	26.2	30.4	25.7	29.6	8.4	9.6
26)	Jagdalpur	39.3	22.5	38.0	22.6	36.8	22.5	26.3	31.5	25.7	30.5	25.4	29.9	9.9	11.2
27)	Jaipur-Sanganer	42.5	21.3	41.2	21.3	40.0	21.3	27.5	31.2	27.0	30.9	26.6	30.5	7.2	8.6
28)	Jaisalmer	43.5	23.9	42.3	23.8	41.1	23.8	28.0	35.3	27.5	34.8	27.1	34.4	8.4	9.7
29)	Jamnagar	37.1	24.4	36.1	25.6	35.3	25.1	29.2	33.0	28.4	32.5	27.9	32.0	10.0	11.7
30)	Jodhpur	42.7	21.2	41.4	21.6	40.2	21.8	27.5	32.4	27.1	32.1	26.7	31.8	8.8	10.1
31)	Jorhat	34.4	28.2	33.6	27.7	32.9	27.3	28.7	32.7	28.3	32.7	28.0	31.8	9.6	10.6
32)	Kolkata-Dum-Dum	37.4	27.0	36.3	27.0	35.4	26.8	29.6	34.5	29.1	33.8	28.7	33.0	11.5	12.7
33)	Kota	43.5	23.0	42.4	22.6	41.2	22.6	27.3	35.2	26.8	33.0	26.5	31.8	9.9	10.8
34)	Kurnool	41.5	23.0	40.5	23.1	39.4	22.9	26.2	33.7	25.8	32.9	25.4	32.2	17.0	18.0

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Table 2 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
35)	Lucknow-Amausi	42.1	22.8	40.8	22.8	39.2	23.5	29.2	33.8	28.8	33.2	28.4	32.5	6.9	8.1
36)	Mangalore	34.3	24.9	33.8	24.9	33.2	24.7	27.1	31.3	26.7	30.8	26.5	30.5	20.6	21.4
37)	Mumbai-Santacruz	35.9	22.7	34.9	23.1	33.9	23.4	27.7	31.2	27.4	30.9	27.1	30.6	16.8	18.0
38)	Nagpur-Sonegaon	43.9	22.5	42.8	22.4	41.4	22.2	27.4	32.3	26.8	31.6	26.4	31.0	11.8	13.0
39)	Nellore	40.7	26.8	39.2	27.1	38.0	26.9	29.0	35.8	28.5	34.9	28.1	34.1	20.4	21.1
40)	New-Delhi-Safdarjung	42.2	22.7	40.7	22.9	39.4	23.1	28.7	34.0	28.2	33.4	27.9	32.9	6.2	7.2
41)	Panjim	34.1	25.6	33.5	25.6	33.0	25.5	28.2	31.9	27.7	31.3	27.4	30.9	19.7	20.4
42)	Patna	41.0	23.4	39.5	23.4	37.9	23.8	28.9	33.7	28.6	33.0	28.2	32.3	8.2	9.3
43)	Pune	38.1	19.7	37.1	19.6	36.0	19.7	24.6	29.8	24.2	29.0	23.7	28.3	9.7	10.9
44)	Raipur	43.6	23.3	42.2	23.3	40.8	23.0	27.1	31.8	26.8	32.0	26.5	31.2	11.3	12.6
45)	Rajkot	41.1	22.2	40.0	22.0	38.9	22.6	27.9	33.4	27.4	32.2	27.0	31.3	11.9	13.4
46)	Ramagundam	43.4	25.6	42.2	25.1	40.7	25.8	28.3	37.3	27.9	35.6	27.4	34.4	12.5	13.7
47)	Ranchi	38.9	22.1	37.7	21.8	36.4	21.5	26.2	31.7	25.6	30.4	25.2	29.2	9.1	10.4
48)	Ratnagiri	34.1	22.8	33.3	23.2	32.7	23.5	27.2	30.6	27.0	30.3	26.7	29.9	18.2	19.2
49)	Raxaul	38.6	23.1	36.9	24.5	35.5	24.6	28.9	33.0	28.4	32.0	28.1	31.8	7.5	8.5
50)	Saharanpur	41.3	23.8	39.6	24.6	38.1	24.0	28.5	33.6	28.1	32.9	27.8	32.5	1.7	3.0
51)	Shillong	24.2	19.7	23.5	19.4	22.8	18.9	20.7	23.3	20.3	22.7	19.9	22.2	-1.0	0.1
52)	Sholapur	41.1	22.2	40.1	22.5	39.0	22.3	26.6	33.1	25.9	32.1	25.4	31.4	15.9	17.1
53)	Surat	37.8	22.5	36.4	22.9	35.2	23.1	28.1	31.9	27.7	31.4	27.4	31.1	14.4	15.6
54)	Sundernagar	36.1	19.1	34.6	19.6	33.1	19.4	25.2	30.1	24.8	29.2	24.4	28.0	1.8	2.8
55)	Tezpur	34.2	27.4	33.3	26.5	32.5	27.1	28.9	32.8	28.4	31.8	28.0	31.4	10.5	11.4
56)	Thiruvananthapuram	33.8	25.8	33.2	25.7	32.8	25.6	27.6	31.7	27.2	31.2	26.9	30.8	22.1	22.7
57)	Tiruchchirapalli	39.0	25.8	38.1	25.7	37.3	25.5	27.8	35.0	27.2	34.1	26.9	33.5	20.0	20.8
58)	Varanasi	43.0	22.5	41.8	22.7	40.1	23.2	28.9	33.8	28.6	33.2	28.2	32.6	7.8	8.9
59)	Veraval	34.8	23.6	33.7	25.5	33.0	26.3	29.3	32.1	29.0	31.7	28.6	31.3	15.0	16.2
60)	Visakhapatnam	33.7	27.0	32.9	27.5	32.3	27.3	29.1	32.0	28.7	31.6	28.3	31.2	20.1	20.8

NOTE — Abbreviations used:
DB — Dry-bulb temperature.
WB — Wet-bulb temperature.
MCDB — Mean coincidental dry-bulb temperature.
MCWB— Mean coincidental wet-bulb temperature.

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definition clearly highlights the importance of both the psychological (mental) and physiological (physical) factors in determining acceptable thermal comfort conditions. The following four environmental parameters are important while designing the HVAC system because these are directly controllable by an HVAC system:

a) Air temperature (ºC),
b) Radiant temperature (ºC),
c) Air speed (m/s), and
d) Relative humidity (percent).

In addition to the above four environmental parameters, there are two personal or behavioural parameters that also affect thermal comfort but are not controllable by the HVAC system and they are as follows:

1) Activity rate (W/m^2), and
2) Clothing insulation (m^2.K/W).

There are number of secondary parameters also which are important to define thermal comfort conditions such as, radiative temperature asymmetry, temperature gradient, and draught rate.

6.2 Design of Indoor Conditions as per Adaptive Thermal Comfort Model

Air conditioning systems for interior spaces intended for human occupancy shall be sized for not more than 26°C for cooling and for not less than 18°C for heating at occupied level.

Design based on an adaptive thermal comfort model can play a major role in reducing energy use whilst maintaining the comfort, productivity and well-being of occupants. This approach recognizes that people's thermal comfort needs depend on their past and present context and that these needs vary with the outdoor environmental conditions of their location. People living year-round in air conditioned spaces are likely to develop high expectations for homogeneity and cool temperatures, and may become quite critical if thermal conditions deviate from the centre of the comfort zone they have come to expect. In contrast, people who live or work in naturally ventilated buildings, are able to control their immediate interior spaces, get accustomed to variable indoor thermal conditions that reflect local patterns of daily and seasonal climate changes. Their thermal perceptions, preferences as well as tolerances are likely to extend over a wider range of temperatures. It allows buildings to operate within broader temperature bands. The specification of a broader comfort band suited to the Indian context has the potential to reduce the use of energy intensive space cooling for buildings in India.

This Section deals with adaptive thermal comfort model which differentiates the thermal response of occupants in air conditioned and naturally ventilated buildings. It is imperative to specify indoor comfort conditions separately for buildings depending upon their operation, namely, air conditioned buildings as well as naturally ventilated buildings.

Operative temperature is more suitable index to measure thermal comfort in the building having low indoor air velocities, since the index also accounts for impact of building surface temperatures (radiant temperatures) on human comfort. Indoor operative temperature, for sedentary activities, can be approximated as an arithmetic mean of indoor air and radiant temperatures. For operating air conditioning system based on operative temperature, the prevalent conditions along with the historical outdoor trend can be used to derive suitable operative temperature limits. Typical climatic conditions of various Indian cities is in public domain.

In case of buildings having higher indoor air velocity (more than 0.5 m/s), effective temperature based approach is recommended since in addition to all factors considered in operative temperature, it also takes into account heat dissipation from human body through convective heat transfer. High air velocity can give opportunity of keeping higher air temperature without compromising thermal comfort. However, it is also suggested to keep under consideration noise and other effect of high indoor air velocity. For annual indoor design conditions as per adaptive model, for Indian cities, reference may be made to Annex A. These are indicative simplified values. They have been derived using typical weather files. It is recommended to practice sector specific adaptive thermal comfort model. More accurate design conditions can be derived using following equations. These equations are not applicable for outdoor running mean temperatures below 15°C.

a) *For naturally ventilated* (NV) *buildings*:

The following equation should be used for design and operation of naturally ventilated (NV) buildings. It indicates that occupants in NV buildings thermally adapt to the outdoor temperature of their location. It is based on the 30 day outdoor running mean temperature (in °C).

Indoor operative temperature = (0.54 × outdoor temperature) + 12.83

Where, indoor operative temperature (in °C) is neutral temperature, and outdoor temperature is the 30 day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the India specific adaptive models for naturally ventilated buildings is ±2.38°C.

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b) *For mixed-mode (*MM*) buildings*:

Mixed-mode buildings, where HVAC is operated only during extreme outdoor conditions, are becoming prevalent in India. The occupants in mixed-mode buildings are more adaptive when compared to those in air conditioned buildings and somewhat less adaptive compared to occupants in naturally ventilated buildings.

Indoor operative temperature = (0.28 × outdoor temperature) + 17.87

Where indoor operative temperature (in °C) is neutral temperature and outdoor temperature is the 30 day outdoor running mean air temperature (in °C).

The 90 percent acceptability range for the India specific adaptive models for mixed-mode buildings is ±3.46°C.

c) *For air conditioned (AC) buildings*:

Studies shows that static Predictive Mean Vote (PMV) model over-predicts the sensation on the warmer side of the 7 point sensation scale in air conditioned buildings. One of the two methods should be adopted while determining indoor conditions of fully air conditioned buildings. One of these methods is based on air temperature and the other is based on standard effective temperature (SET) which includes effect of body surface area, relative humidity (RH), air velocity (V_a), air temperature (T_a), radiant temperature (T_r), outdoor temperature (T_{out}), clothing insulation (*Clo*) and activity rate (MET).

1) *Air temperature based approach*:

   Indoor operative temperature =

   (0.078 × outdoor temperature) + 23.25

   Where indoor operative temperature (in °C) is neutral temperature and outdoor temperature is the 30 day outdoor running mean air temperature (in °C).

   The 90 percent acceptability range for the adaptive models for conditioned buildings is ±1.5°C.

2) *Standard effective temperature based approach*:

   Standard effective temperature =

   (0.014 × outdoor temperature) + 24.53

   Where standard effective temperature (in °C) is neutral temperature and outdoor temperature is the 30 day outdoor running mean air temperature (in °C).

   The 90 percent acceptability range for the adaptive models for conditioned buildings is ±1.0°C.

3) *Minimum outside fresh air:*

   Table 3 prescribes minimum supply rates of acceptable outdoor air required for acceptable indoor air quality. These requirements for ventilation of health care facilities (hospitals, nursing and convalescent homes) are separately covered in Table 4. These values have been prescribed to dilute human bio effluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels. The values prescribed in the table shall be used in conjunction with the accompanying notes.

Naturally ventilated spaces and mixed mode spaces, while getting operated in naturally ventilated mode, will have to rely on outdoor air using fenestration systems. The quantity and distribution of introduced fresh air should take into account the natural infiltration of the building.

The proportion of fresh air introduced into air conditioned building may be varied to achieve economical and efficient operation. When the fresh air can provide a useful cooling effect, the quantity shall be controlled through air side economizer to balance the cooling demand. However, when the air is too warm or humid the quantity may be reduced to a minimum to reduce the cooling load.

6.3 Indoor Air Quality (IAQ)

Indoor air quality is the quality of air which affects our comfort and health. This is most directly related to health and may result in sick building syndrome (SBS). Poor indoor air quality results in severe and recurring discomforts such as nausea, headaches, cold, dry mucous, inflamed membrane eye, nose and throat irritation, drowsiness, fatigue, dry skin and respiration problems.

6.3.1 *Measure of Indoor Air Quality (IAQ)*

Carbon dioxide is used as a surrogate ventilation index for diagnosing the ventilation efficiency in an air conditioned area. The measurement of carbon dioxide inside a conditioned area is an indicator of IAQ. Odour criteria are likely to satisfy, if ventilation rates are set so that 1 000 ppm CO_2 is not exceeded. However, in situations where outdoor conditions are not favourable, a difference of 700 ppm, where indoor ppm are less than outdoors, should be targeted. Building should meet accepted standards to avoid contamination through volatile organic compounds, microbial contamination (fungal and bacteria).

6.3.2 *Components of Acceptable Indoor Air Quality (IAQ)*

Acceptable IAQ is typically not achieved by addressing any one specific building product, system or procedure;

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Table 3 Minimum Ventilation Rates in Breathing Zone (*See* Notes 1 to 5)

[*Clause* 6.2(c)(3)]

(This table is not valid in isolation; it shall be used in conjunction with the accompanying notes.)

Sl No.	Occupancy Category	People Outdoor Air Rate, R_p		Area Outdoor Air Rate, R_a		Notes	Default Values			Air[1] Class
							Occupant Density (*see* Note 4)	Combined Outdoor Air Rate (*see* Note 4)		
		cfm/ person	l/s. person	cfm/ ft^2	l/s.m^2		Persons per 1 000 ft^2 or per 100 m^2	cfm/person	l/s.person	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	Correctional facilities:									
	a) Cell	5	2.5	0.12	0.6		25	10	4.9	2
	b) Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
	c) Guard Stations	5	2.5	0.06	0.3		15	9	4.5	1
	d) Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
ii)	Educational facilities:									
	a) Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
	b) Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
	c) Classrooms (ages 5-8)	10	5	0.12	0.6		25	15	7.4	1
	d) Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
	e) Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
	f) Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
	g) Art classroom	10	5	0.18	0.9		20	19	9.5	2
	h) Science laboratories	10	5	0.18	0.9		25	17	8.6	2
	j) University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
	k) Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
	m) Computer lab	10	5	0.12	0.6		25	15	7.4	1
	n) Media centre	10	5	0.12	0.6	*See* Note 6	25	15	7.4	1
	p) Music/theatre/dance	10	5	0.06	0.3		35	12	5.9	1
	q) Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
iii)	Food and beverage service:									
	a) Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
	b) Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
	c) Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
iv)	General:									
	a) Break rooms	5	2.5	0.06	0.3		25	10	5.1	1
	b) Coffee stations	5	2.5	0.06	0.3		20	11	5.5	1
	c) Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
	d) Corridors	—	—	0.06	0.3		—	—	—	1
	e) Storage rooms	—	—	0.12	0.6	*See* Note 7	—	—	—	1
v)	Hotels, motels, resorts, dormitories:									
	a) Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1
	b) Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
	c) Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
	d) Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
	e) Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
	f) Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1
vi)	Office buildings:									
	a) Office space	5	2.5	0.06	0.3		5	17	8.5	1
	b) Reception Areas	5	2.5	0.06	0.3		30	7	3.5	1
	c) Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
	d) Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
vii)	Miscellaneous spaces:									
	a) Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
	b) Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
	c) Electrical equipment rooms	—	—	0.06	0.3	*See* Note 7	—	—	—	1
	d) Elevator machine rooms	—	—	0.12	0.6	*See* Note 7	—	—	—	1
	e) Pharmacy (preparation area)	5	2.5	0.18	0.9		10	23	11.5	2
	f) Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
	g) Shipping/receiving	—	—	0.12	0.6	*See* Note 7	—	—	—	1
	h) Telephone closets	—	—	0.00	0.0		—	—	—	1
	j) Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
	k) Warehouses	—	—	0.06	0.3	*See* Note 7	—	—	—	2

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Table 3 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
viii)	Public assembly spaces:									
	a) Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
	b) Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
	c) Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
	d) Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
	e) Libraries	5	2.5	0.12	0.6		10	17	8.5	1
	f) Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
	g) Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
	h) Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
ix)	Residential:									
	a) Dwelling unit	5	2.5	0.06	0.3	*See* Notes 8 and 9	*See* Note 8	—	—	1
	b) Common corridors	—	—	0.06	0.3	—	—	—	—	1
x)	Retail:									
	a) Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
	b) Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
	c) Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
	d) Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
	e) Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
	f) Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
	g) Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2
xi)	Sports and entertainment:									
	a) Sports arena (play area)	—	—	0.30	1.5	*See* Note 10	—	—	—	1
	b) Gym, stadium (play area)	—	—	0.30	1.5		30	—	—	2
	c) Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
	d) Swimming (pool and deck)	—	—	0.48	2.4	*See* Note 11	—	—	—	2
	e) Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1
	f) Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
	g) Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
	h) Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
	j) Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
	k) Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
	m) Stages, studios	10	5	0.06	0.3	*See* Note 12	70	11	5.4	1

[1)]

Air Class	*Characteristic*
1	Air with low contaminant concentration, low sensory-irritation intensity, and inoffensive odour.
2	Air with moderate contaminant concentration, mild sensory-irritation intensity, or mildly offensive odours. Class 2 air also includes air that is not necessarily harmful or objectionable but that is inappropriate for transfer or recirculation to spaces used for different purposes.
3	Air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odour.
4	Air with highly objectionable fumes or gases or with potentially dangerous particles, bio aerosols, or gases, at concentrations high enough to be considered harmful.

NOTES

1 The rates in this table are based on all other applicable requirements being met.
2 This table applies to no-smoking areas only. Rates for smoking-permitted spaces shall be determined using other methods.
3 Volumetric airflow rates are based on an air density of 1.2 kgDA/m^3, which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 21°C. Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4 Actual occupant density should be considered, the default occupant density shall be used only when actual occupant density is not known. Default combined outdoor air (per person) rate is based on the default occupant density.
5 If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.
6 For high school and college libraries, use values shown for public assembly spaces- libraries.
7 The prescribed value may not be sufficient when stored materials include those having potentially harmful emissions.
8 Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
9 Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.
10 When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.
11 The prescribed value does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.
12 The prescribed value does not include special exhaust for stage effects, for example, dry ice vapours, smoke.

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Table 4 Outdoor Air Requirements for Ventilation of Health Care Facilities
[*Clause* 6.2(c)(3)]

Sl No.	Application	Estimated Maximum Occupancy[1)]	Outdoor Air Requirements		Remarks
		Persons/100 m²	l/s per Person	l/s per m²	
(1)	(2)	(3)	(4)	(5)	(6)
i)	Patient rooms	10	13	—	Special requirements and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates
ii)	Medical procedure	20	8	—	
iii)	Operating rooms	20	15	—	
iv)	Recovery and ICU	20	8	—	
v)	Autopsy rooms	20	—	2.5	Air shall not be recirculated into other spaces
vi)	Physical therapy	20	8	—	

[1)] Net occupiable space.

rather, it is the result of careful attention to each of the following fundamental elements:

a) Contamination source control;
b) Proper ventilation;
c) Humidity management; and
d) Adequate filtration.

Controlling the source of contaminants is fundamental to any IAQ strategy. Indoor contamination can also be in the form of particles or chemicals that may come from occupants and their activities. Contaminants from stationery local sources within the space should be controlled by collection as close to the source as practical and its removal from there itself. In some cases such as volatile organic compounds (VOCs), where collection close to sources is not possible, dilution with clean outdoor air should be adopted as the most practical and cost effective solution.

Microbial contamination (fungi and bacteria) can also be a major source of indoor contamination. When mold spores and other microbiological particles become airborne, occupants may experience allergic reactions; these result in offensive odours within the building. Proper design and selection of the air conditioning system should prevent the issues related to microbial contamination. Indoor humidity levels over 60 percent RH for periods as short as 24 h can support the growth of some forms of mold and fungi and should therefore be avoided.

6.3.3 *Subject to be managed at Contamination Source*

These should be managed by separate management system, as follows:

a) Depending upon size and capacity of photocopying machines, ammonia-printing machines, local exhaust system should be used to exhaust from such equipment.
b) Fibrous insulating material should not be used for internal lining and thermal insulation of ducts in health care facilities and food industries. For all other applications, it may be used with factory lamination back-up or suitable jacketing to avoid loose fibres getting into air stream.
c) Formaldehyde from reconstituted wood and other lingo-cellulosic products: Use of alternative materials may be considered.

6.3.4 *Subject to be Managed at Operation and Maintenance Stage*

a) It shall be ensured that the chilled water temperature is adequate or the refrigerant charge is adequate in the case of DX system. High humidity inside the conditioned area shall be avoided through proper dehumidification.
b) Mildew and mold spores from the damp corners or on false ceiling, damp carpeting and office furniture where there is water leakage from the air-conditioning units: it shall be ensured that there is no leakage from the drain pan of the units or no condensation on the chilled water/refrigerant pipes and valves by properly insulating the same.
c) Generation of fumes inside the conditioned area: ionizers shall be used.
d) Air handling unit rooms shall not be used as a storage space for storing files and waste materials.
e) Dirty supply air ducts, dirty false ceiling and return air space, dirty filters, dirty water accumulation or standing water in the drain pans, dirty cooling coils, dirty water in the air coolers and evaporative cooling plants, virus, bacteria, fungus from the air handling unit and drain pan of the air handling units, etc: Planned

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operation and preventive maintenance shall be implemented to avoid such issues.

6.3.5 *Pre-Occupancy Purge of Contamination*

Pre-occupancy purge shall be carried out to ensure that contaminants, that may build up during construction or during unoccupied periods, are removed prior to occupancy.

7 DESIGN OF AIR CONDITIONING

7.1 General

Systems for air conditioning need to control temperature, humidity and air quality within predetermined limits throughout the year. Systems for air conditioning may be grouped as all-air type, air and water type, all-water type and unitary type. Suitability of system type cannot be generalized; it needs to be building specific decision considering, initial cost, efficiency, maintenance, effect on building aesthetics, noise, service life and other factors. Lower operating cost, central maintenance and control are primary considerations. Designers may select centralized systems that comprise DX units or chillers and cooling towers (as applicable), all housed away from occupied spaces. This mitigates noise impacts. The heating application may require heat pumps or boilers.

These systems often require a greater initial cost than distributed systems but often result in annual energy savings because additional benefits also include the ability to reduce installed capacity by using load diversity. Centralized cooling systems usually prove to be more cost-effective when the total building load exceeds 100 TR, depending on climate and patterns of occupancy use. Central heating systems are desirable in heating applications in many building sizes since they can provide closer space control and can be used with many types of terminal units.

When low initial cost and simplicity are primary concerns, designers may select zone-by-zone distributed systems, incorporating either cooling or both heating and cooling facility. This approach tends to be used for smaller buildings as well as for larger buildings with multiple tenancy and sufficient roof area. Distributed equipment consists of fan, cooling coil, compressor and outdoor condenser. Examples of distributed systems include unitary air conditioners, packaged rooftop air conditioners, variable refrigerant flows (VRFs), heat pumps, as well as refrigerant-based split-system fan-coil units (single or multi-unit). Water-source heat pumps (WSHPs) are also distributed systems in which the compressor is located close to the occupied space, but they are collectively served by a centralized water system with auxiliary heat rejection devices.

7.2 Design Considerations

7.2.1 *System Analysis and Selection*

System selection for occupant comfort, as defined in **6**, for space cooling, heating and ventilation, shall be based on the following criteria:

1) Temperature and its acceptable variation,
2) Humidity and its acceptable variation,
3) Air movement,
4) Air purity or quality,
5) Air changes per hour,
6) Air and/or water velocity requirements,
7) Local climate,
8) Space pressure requirements,
9) Capacity requirements as per load calculation analysis,
10) Redundancy,
11) Spatial requirements,
12) Fire safety and security concerns,
13) Initial cost,
14) Operating cost, including energy and power costs,
15) Maintenance cost,
16) Reliability,
17) Flexibility,
18) Controllability,
19) Life-cycle analysis,
20) Sustainability characteristics,
21) Acoustics and vibration, and
22) Mold and mildew prevention.

7.2.1.1 *Types of systems*

Comparative advantages, disadvantages and constraints of each option should be carefully evaluated before zeroing down to final HVAC system selection. Table 5 lists out various system characteristics of different HVAC systems; the same may be used as a tool for system analysis and selection.

When accurate temperature control is needed, constant volume systems shall be used. Dehumidification arrangement and return air bye-pass shall be included while designing constant volume system. When using high velocity system, dual ducting shall be provided.

7.2.2 The requirements for various air conditioning equipment/system are given in **7.2.3** to **7.2.15.**

7.2.3 *Central Chilled Water System — Types and Components*

7.2.3.1 The central chilled water system equipment selection criteria shall be based on a comprehensive study to evaluate and define the lowest life-cycle cost

Table 5 HVAC System Analysis and Selection Matrix
(*Clause* 7.2.1.1)

Sl No.	System Characteristic	Fixed Speed Unitary Systems (Window ACs/Split ACs/ Package ACs)	Variable Speed/Flow/ Frequency/ Capacity Unitary Systems (Inverter Split ACs/Package ACs)	Variable Speed Multi or Modular Systems (VRF)	Central Systems
(1)	(2)	(3)	(4)	(5)	(6)
i)	Temperature	No uniform and effective control	Minimal uniform and effective control possible	Reasonably uniform and effective control possible	Uniform and effective control possible
ii)	Relative humidity	Effective control not possible	Effective control not possible	Effective control not possible	Effective control possible
iii)	Space pressure	Effective control not possible	Effective control not possible	Effective control not possible	Effective control possible
iv)	Capacity requirements	Capacity to suit zone peak, no diversity	Capacity to suit zone peak, no diversity	Capacity to suit zone peak, limited diversity can be considered	Allows the design engineer to consider HVAC load diversity factors, accordingly reduce installed equipment capacity
v)	Redundancy	Does not have the benefit of back-up or standby equipment	Does not have the benefit of back-up or standby equipment	It has the benefit of partial back-up or standby equipment	Back-up or standby equipment can easily be accommodated
vi)	Facility management	Allows minimal provision to maximize performance using good facility management techniques in operation	Allows minimal provision to maximize performance using good facility management techniques in operation	Limited possibilities to maximize performance using good facility management techniques in operation	Allows to maximize performance using good facility management techniques in operation
vii)	Spatial requirements	No plant/equipment room required. Compromises building elevation	No plant/equipment room required. Compromises building elevation	No plant/equipment room required. Outside units can be located on roof or on adjacent ground. Very small shaft desirable for refrigerant piping	Equipment rooms/spaces and accessible shaft required for chilled water piping
viii)	Electric supply	Distributed electric supply required	Distributed electric supply required	Zone-wise distributed electric supply required	Minimal distribution cost by centralized supply near the substation
ix)	Initial cost	Minimum initial cost	Initial cost marginally higher than fixed speed system	Moderate initial cost but marginally higher than variable speed unitary product	Even with HVAC diversity, a central system may not be less costly than decentralized HVAC systems
x)	Operating cost	Higher operating cost. Strategic scheduling of multiple pieces of equipment can save marginal operating cost, but equipment is less efficient	Strategic scheduling of multiple pieces of equipment can save reasonable operating cost, but higher peak energy requirement	Strategic scheduling of equipment can save operating cost better than unitary product, but higher peak energy requirement	More energy-efficient primary equipment and multiple pieces of HVAC equipment allow staging of operation to match building loads while maximizing operational efficiency
xi)	Maintenance cost	Comparatively less maintenance cost	Maintenance cost marginally higher than fixed speed	Maintenance cost higher than both fixed and variable speed unitary system but less than central system	Comparatively higher since centralized equipment room requires operator with no access to occupant workspace, but with fewer pieces of HVAC equipment to service
xii)	Reliability	Reliable equipment but low service life	Reliable equipment but low service life	Reliable equipment but moderate service life	Reliable equipment with much longer service life
xiii)	Flexibility	Has to be placed at fixed locations	Has to be placed at fixed locations	Can be placed at distributed locations	Flexibility available in terms of alternative locations
xiv)	Level of control	Limited control level available	Limited control level available	Moderate control level available	Close control level available
xv)	Noise and vibration	Noise and vibration within/adjacent to occupied spaces for unitary window type air conditioners which is substantially reduced in case of split system	It is generally available in split system only for which noise and vibration is substantially reduced in occupied and adjacent spaces as compared to a window type air conditioner	Noise and vibration on roof terrace or ground, away from occupied spaces; however the same can be reduced with good installation practices	Noise and vibration away from occupied spaces
xvi)	Constructability	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar-in-size equipment makes standardization a construction feature	Multiple and similar equipment makes standardization a construction feature	Require more coordinated installation with added benefit of consolidated primary equipment in a central location

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of the chilled water system. The study shall address system components and parameters, such as, chilled water leaving temperature, condenser water entering temperature, inlet/outlet chilled water and condenser water temperature differential, chilled/condenser water flow, pipe and pump sizes, etc.

While optimizing the chilled water system parameters, special consideration shall be given to the spaces requirements as given hereunder:

a) Space for chillers, pumps, and cooling towers should not only include installation footprints but should also account for adequate clearances to perform routine and major maintenance. A service clearance of 1.2 m or the manufacturer's recommended minimum clearance for the equipment, whichever is greater, shall be provided around equipment for operation, maintenance and service. For chillers, one end of the chiller barrels should be provided with free space, equivalent to the length of the evaporator and condenser barrels, to allow for tube pull-out. Designer may consider service bay roll-up doors or ventilation louvers for this tube access. Overhead service clearance height is also required, especially where chillers are installed. Where boiler installations as well as heating distribution equipment and appurtenances are required, the plant's physical size shall account for the type of boiler and the required exhaust emissions treatment. Good architectural planning requires that the location of all outdoor air intakes is kept preferably on opposite sides of exhaust and possible as far away as from contaminating sources like the exhaust outlets, loading docks and others. The final mechanical room size, orientation, and location shall be established after discussion with the architect and owner. The design engineer should keep the architect, owner, and facility engineer informed about the HVAC load analysis and system selection.

b) Winter time cooling requirement for applications like operating rooms, conference halls, high population density spaces like banquet halls and others, shall also be evaluated before finalizing system/equipment design.

c) All systems should be coordinated during the space-planning stage for safe and effective operation and maintenance of the central cooling and heating plant.

d) Large commercial developments, residential complexes and mixed use development projects generally provide a single central chilled water plant to serve multiple buildings. This allows the plant size to be reduced by taking into account diversity in loads for these buildings. The central plant for these applications should, generally, be placed on grade in an independent utility services block, which also houses most of the other high-side equipment like HT panel, transformers, DG sets, main LT panel, water storage tanks, water treatment plants, water supply pumps, fire water storage tanks, fire pumps and others.

e) Central plant catering to an individual building should, generally, be housed on the lowest basement floor slab resting on terra-firma. This inherently isolates noise and vibration transmission to the super-structure. However, the designer shall always ensure easy access for maintenance and replacement of the major components of the central plant.

The choice of refrigerant shall be based on guidelines specified in **3**.

7.2.3.2 *Central chilled water plant sizing*

The refrigeration/cooling plant size shall be optimized considering block load of the project, and the module selection shall be based on the optimal performance of chillers. However, the ancillary equipment like pumps, cooling tower, terminal units and other components shall be sized for the entire load profile of the project. The cooling load requirements for special applications where mandated dedicated chillers may be required, shall be met through full redundancy.

7.2.3.3 *Standby chiller capacity*

For new construction and major renovation projects, the central chilled water plant shall comprise number of chillers in operation to meet the total cooling demand. Only in critical operation projects, one standby chiller, equivalent to the largest capacity chiller, should be installed to provide 100 percent standby. However, in most of the commercial and residential projects, full load is encountered less than five percent of the time throughout the year; therefore, three chillers each of 40 percent of full load capacity, may generally be installed to provide part standby chiller capacity.

All other system components, namely, chilled water pumps, condenser water pumps, cooling towers and controls shall be sized and selected to match the installed chiller capacity including the standby machine.

7.2.3.4 *Liquid chilling machines*

Liquid chilling system may be based on chilled water,

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brine, or other secondary coolant for air conditioning or refrigeration. The most frequent application is water chilling for air conditioning, however, brine cooling for low temperature refrigeration and chilling fluids for thermal storage processes, are also becoming common.

The basic components of a vapour compression, liquid chilling system include a compressor, liquid cooler (evaporator), condenser, compressor drive, liquid refrigerant expansion or flow control device and control center; it may also include a receiver, economizer, expansion turbine and/or sub-cooler (*see* **7.2.3.5** for vapour compression water chiller). In addition, auxiliary components may be used, such as a lubricant cooler, lubricant separator, lubricant-return device, purge unit, lubricant pump, refrigerant transfer unit, refrigerant vents, and/or additional control valves. Liquid chilling units are also available with air cooled condensers.

7.2.3.5 *Vapour compression water chiller*

The unit shall be set down on to a solid foundation on resilient mountings. Pipe connections shall have flexible couplings; these should be considered in conjunction with the design of the pump mountings and the pipe supports.

Capacity control shall be capable to maintain an approximately constant temperature of the chilled water leaving the evaporator. This may be adequate for one or two chiller packages, but a more elaborate central control and plant optimization system is desirable for a large number of chillers. The design of the refrigeration control system should be integrated, or be compatible, with the control system for the heat transfer medium circulated within the cooler.

Multiple chiller configuration, same or different size and types shall be used to achieve the highest energy efficiency, and adequate system capacity availability at all conditions. System COP shall be the basis for design and selection of equipment**.**

Power consumption during operation should be reduced by taking advantage of a fall in the ambient dry-bulb and wet-bulb temperatures, which permit a corresponding increase in chilled water temperature and decrease in the condenser water temperature, and consequent considerable reduction in the compressor power consumption. It is important to optimize operating cost by optimum equipment selection and careful design of the automatic control system.

The water chilling packages are classified based on the type of compressor, as given below:

a) *Centrifugal compressor* — These compressors use impellers to impart pressure energy to the refrigerant. These may be modulated down to approximately 40 percent of full load capacity, with careful control of the condensing pressure. Part load operation of centrifugal compressor should be restricted to 40 percent or above in order to avoid surging of compressor that may damage it if continues to occur.

   In order to save energy, centrifugal compressors with variable speed drives (VFDs) should be preferred over fixed speed chillers. VFDs are used on chillers not only to enhance the part load performance but also to act as an alternate to auto-tap change starter for minimising the starting current for the compressor.

   Modern variable-speed oil-free centrifugal chillers have the shaft with impeller levitated during rotation, using digitally-controlled magnetic bearings. This unique feature reduces the friction and heat caused by conventional bearings, adding to the overall high efficiency. It also eliminates the need for lubricating oil and the ancillary components required to support the lubricating oil system, which further improves efficiency.

b) *Screw compressor* — Screw compressors are available in open and semi-hermetic form and are generally coupled directly to two-pole motors. The capacity of the compressor may be modulated down to 20 percent of full load capacity.

   Similar to centrifugal compressors, screw compressors with VFDs may be used as an effective way to enhance the part load performance and also minimise the starting current for the compressor.

   These are generally specified and used for capacities up to 400TR.

   In systems using a direct expansion evaporator (DX chiller), the oil is trapped in the evaporator and an oil recovery system is necessary.

   With some systems, oil cooler is required in the oil circulation system, to remove the heat gathered by oil during compression cycle.

c) *Scroll compressor* — Scroll compressors are generally used in residential and small/light commercial air-conditioning. Scroll chillers may be used in smaller sizes up to 120 TR.

d) *Reciprocating compressor* — Due to their relatively lower efficiency, reciprocating compressors are nearly phased out from the comfort air-conditioning application. However, for cold storage and other special purpose applications, these still have importance due to their capacity to offer high pressure ratio.

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7.2.3.6 *Absorption System*

The absorption cycle uses a solution which, by absorbing the refrigerant, replaces the function of the compressor. The absorbent/refrigerant mixture is then pumped to a higher pressure where the refrigerant is boiled off by the application of heat, and is subsequently condensed in the condenser.

Absorption machines are extensively used in liquid chilling applications. These are most suitable for applications where waste heat is readily available. Solar energy assisted air conditioning/cooling systems also use absorption systems.

7.2.3.6.1 *Indirect firing*

The lithium bromide/water absorption system can be powered by medium or high temperature hot water and low or medium pressure steam. Water is the refrigerant and lithium bromide, the absorbent. The four compartments enclosing the heat exchanger tube bundles for the condenser, evaporator, generator and absorber can be in a single or multiple pressure vessel arrangement. The whole assembly has to be maintained under a high vacuum, which is essential for the correct functioning of the unit. Water and absorbent solutions are circulated within the unit by electrically driven pumps.

Capacity control down to 10 percent of full load capacity is achieved by modulating the flow of the heating medium in relation to the cooling demand. There is some loss in performance at part load, which can be compensated by refinements in the system design and control.

7.2.3.6.2 *Direct firing*

Direct fired lithium bromide/water absorption plants have become common, by incorporating precise control of generator temperature necessary to avoid crystallization.

Ammonia/water systems are generally direct fired, but are rarely used for water chilling duties, except for small sized units, which are installed outside the building. There are two reasons for this; firstly capital costs are higher and secondly the danger to personnel in the event of leakage of the refrigerant.

Direct firing has the advantage that the losses in an indirect heating system are avoided, but in an air conditioning installation where a boiler system is installed to provide heating, the advantage is not of much concern.

7.2.3.7 *Chilled water system components*

7.2.3.7.1 *Chilled and condenser water pumps*

Radial flow centrifugal pumps are recommended for use in HVAC systems for circulation or transfer of water or water/glycol solutions. The choices available are single inlet/end suction or double suction type pump. In the end suction pump, liquid enters through a single inlet with end suction to impeller, while in double suction pump liquid enters on two sides of the impeller along the shaft. Double suction pumps are inherently self-balancing with reduced impact on bearings and on mechanical seal, when fluid enters the pump. This may be preferred for larger flow (> 63 litre per second) requirement. Some smaller end-suction pumps are direct-coupled, where the impeller mounts directly on the shaft of a face-mounted motor. A third popular HVAC pump is the in-line centrifugal, in which inlet and discharge piping are in line. Direct coupled pump assembly and inline pump may be used for smaller flow applications. Higher flow rate requiring motor size above 7.5 kW, pumps shall be coupled with high efficiency (Eff1) motors. Mono-block pumps are generally used up to 7.5 kW, but are not yet available with motor having Eff1 efficiency.

The split case horizontal pump shall be used in larger applications. These pumps cost more than other pumps, but are more efficient. Split casing also allows inspection and maintenance without disturbing the rotor, motor, or the connecting piping.

Centrifugal (horizontal or vertical split-case or vertical turbine) pumps mounted on base, are generally provided for chilled water and condenser water applications. In-line pumps may also be used for certain applications to minimise plant room space requirement.

Cavitation shall be avoided by selecting suitable location of pump with respect to the cooling tower, so as to always meet the net positive suction head (NPSH) requirement of condenser water pump.

Selection criteria and types of pumping system — Pump shall be selected to operate at lowest possible rpm to achieve energy efficiency. The operating point shall be selected at or near the highest efficiency and to the left side of the maximum efficiency point but not more than 5 percent from the maximum efficiency curve. The pump motor shall be non-overloading over the entire range of its operation and compatible with variable speed drive, where such applications are used. For water pumps, available net positive suction head (NPSH) shall exceed required NPSH to avoid pump cavitation.

The possible types of chilled water recirculation pumps are as given below:

a) Constant speed pumping system;
b) Variable speed pumping system (VSPS):
    1) Parallel VSPS configuration,
    2) Zoned VSPS configuration, and
    3) Primary secondary tertiary pumping system (P-S-T); and

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c) Primary only variable speed pumping system (PVF).

In order to improve energy efficiency of larger systems, where pumping energy amounts to 5 percent to 9 percent of total energy consumption in a building, glass flake coatings for large size pumps may be considered, based on life cycle cost assessment as it reduces friction and improves efficiency.

Chilled water circulation system having pump motor larger than 3.7 kW rating are generally designed for variable fluid flow to offer large savings in operating cost.

7.2.3.8 *Cooling tower*

7.2.3.8.1 Water is commonly used as a heat transfer medium to remove heat from the refrigerant vapour in condenser. Cooling tower is used to dissipate the heat from the air conditioning system. The water consumption rate for a cooling tower system is less than 5 percent of that for a once-through system, making it the least expensive system to operate with purchased water supplies. Additionally, the amount of heated water discharged (blow down) is very small, so the ecological effect is greatly reduced. Cooling tower can cool condenser water to within 2 to 3°C of the ambient wet-bulb temperature. Therefore, water cooled system operates at a condenser temperature in excess of 20°C lower than the corresponding air cooled system, resulting in considerably improved efficiency and significantly reduced energy consumption.

7.2.3.8.2 *Selection criteria*

Location of the cooling tower is usually determined by one or more of the following:

a) Architectural compatibility,
b) Rigging limitations,
c) Structural support requirements,
d) Cost of bringing auxiliary services to the cooling tower, and
e) Noise transmission, plume, and drift considerations.

These are best handled by proper site selection during the planning stage. Cooling tower shall be installed raised above the mounting surface by 450 - 1 250 mm to permit installation of pot strainer in condenser water line from cooling tower sump; also to provide easy drainage and maintenance of mounting surface as follows:

Minimum cooling tower efficiency shall be as follows:

1) 350 litre per minute/HP for 24×7 facilities, and
2) 300 litre per minute/HP for all others.

Cooling tower approach shall be as follows:

i) < 2.0°C approach for 24×7 plants, and
ii) < 3.0°C approach for all other applications.

Cooling tower accessories shall be project-specific and shall include such items as walking platform; stairs and ladder safety cage; bird screen; tower loading and supporting structure; and variable speed drive fan motor.

Cooling tower installation shall include installation of conductivity controller, flow meter on the makeup water line, overflow alarm and low level alarm.

7.2.3.8.3 *Scale control*

Water treatment is desirable to prevent scaling, corrosion, and biological fouling of the condenser and circulating system. Large system shall be provided with fixed continuous-feeding chemical treatment system in which chemicals, including acids for *p*H control, are diluted, blended and pumped into the condenser water system. Corrosion-resistant materials may be required for the treatment of system components that come in contact with these chemicals. In piping system design, provision for feeding the chemicals, blow down, drain, and on-line testing should be included. Treatment system design should incorporate main stream filtration without separate pumping system.

It is desirable that following methods are used to control scale formation:

a) Limit the concentration of scale-forming minerals by controlling cycles of concentration, or by removing the minerals before they enter the system. A cycle of concentration is the ratio of makeup water rate to the sum of blow down and drift rate. The cycle of concentration can be monitored by calculating the ratio of chloride ion, which is highly soluble in the system water, to that in the makeup water. Making mechanical changes in the system, like increasing water flow and providing exchanger with larger surface area, reduce the chances of scale formation.
b) Feed acid to keep the common scale forming minerals, like, calcium carbonate, in dissolved state.
c) Treat with chemicals designed to prevent scale.

For treatment of water for cooling towers, reference shall be made to the good practice [8-3(3)].

7.2.3.9 *Air handling unit* (*AHU*)

All-air system is commonly used for comfort applications.

7.2.3.9.1 *Selection criteria*

The designer shall select the air handling unit on the

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basis of supply air temperature and volume; outdoor air requirement; desired space pressure; heating and cooling coil capacity; humidification and dehumidification capacity; return, relief, and exhaust air volume requirement; filtration, and the corresponding pressure capability of the fan(s).

Air handling unit is of sectionalized construction, with each section depth limited to 1 m in order to facilitate its transportation to site, hoisting and placing in AHU room and assembling the sections in mounted position. The designer shall ensure that the AHU sections are accessible for easy maintenance. Control system shall not be overly complex in its arrangement to provide the required conditions. The AHU overall dimensions are decided by keeping the face velocity across filter and coil section less than 2.0 m/s.

7.2.3.9.2 *Fan*

Fan selection should be based on efficiency and sound power level throughout the anticipated range of operation, as well as on the ability of the fan to provide the required flow at the anticipated static pressure. For AHU fans requiring a shaft power of 2 kW or more, the fan efficiency grade (FEG rating) shall be FEG 71 or higher (*see* **11.7.1**). The operating total efficiency, in percent, at the selected point of operation for a given application shall be within 10 percent (absolute value) of FEG value. For example, for a fan of size 800 mm with a peak total efficiency of 75 percent (FEG 80), the operating total efficiency shall be between 65 and 75 percent.

7.2.3.9.3 *Cooling coil*

The cooling medium flowing through cooling coil can be either chilled water or refrigerant. In all finned coil, some air passes through without contacting the fins or tubes. The amount of this bypass can vary typically from 10 percent for a four-row coil at 2.0 m/s, to less than 2 percent for an eight-row coil at 1.5 m/s. The dew point of the air mixture leaving a four-row coil may satisfy a comfort installation with up to 25 percent outdoor air (10 percent for humid climates), a small internal latent load, and sensible temperature control only.

7.2.3.9.4 *Reheat coil*

Reheat coil is heating coil placed downstream of a cooling coil. Reheat system is strongly discouraged, unless recovered thermal energy is used. Reheat coil is used to provide precise humidity control, which is generally not required for comfort conditions in most applications. Either reheat or desiccant is usually required to dehumidify outdoor air. Reheating is necessary for laboratory, health care, or similar applications where temperature and relative humidity shall be controlled accurately. Hot-water coil, which provides a very controllable source of reheat energy, and thereby accurate relative humidity control is the preferred option for reheat coil. Condenser water recirculation through reheat coils may be considered for energy saving.

7.2.3.9.5 *Humidifier*

Humidifier shall be installed as part of the air handling unit only where close humidity control of selected spaces is required. For comfort installations requiring humidity control, moisture can be added to the air by mechanical atomizer or point-of-use electric or ultrasonic humidifier placed in the conditioned area.

7.2.3.9.6 *Air to air energy recovery device*

Energy recovery device is often used to precool the incoming hot and humid outdoor air, by the exhaust portion of the cool and dehumidified conditioned air. Sensible heat recovery device only exchanges sensible heat (temperature only) between the two streams of air, whereas energy recovery device, exchanges heat as well as moisture. In cases of high latent loads, energy recovery device should be used to save energy.

7.2.3.9.7 *Fan coil unit* (*FCU*)

Basic components of fan-coil unit are identical to those of the AHU, namely, the filter, cooling coil, fan, and temperature control device. Fan coil unit has draw-through configuration, therefore, filter is first encountered by conditioned air. Filter will be detachable for easy replacement and for cleaning by water spray. Fan recirculates air from the conditioned space through the coil, to cool/heat the air. The fan and motor assembly shall be arranged for quick removal for servicing. If the unit includes a cooling coil, it shall be equipped with an insulated stainless-steel drain pan. The casing shall be internally insulated for both thermal and acoustic considerations.

Fan motor control shall be provided with speed control for modulating air delivery, and as additional control over cooling and dehumidification. Coil's water-valve piping package shall include flow controls (manual or automatic), pressure-independent water balancing valves, strainer, unions, pressure-temperature ports, air vent, flexible connections and drain.

7.2.4 *Chilled Beam/Chilled Slab*

7.2.4.1 *Chilled beam*

Two types of chilled beams, passive and active, are in use. Passive chilled beam consists of a chilled water coil mounted inside a cabinet. Chilled water is piped to the convective coil at between 13°C and 17°C. In order to ensure proper dehumidification and adequate fresh air delivery to the spaces, passive chilled beam

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requires a separate ventilation system. If more ventilation air is needed to meet the space requirements, the volume of air can be split between the passive beam and high induction diffusers. Care shall be taken in selecting diffuser locations to coordinate well with the convective currents required by the chilled beam. Overcooling of chilled beam shall be avoided during cooling season, to prevent discomfort, condensation and microbial growth in spaces.

Active chilled beam operates with induction nozzles that entrain room air and mix it with the primary or ventilation air that is ducted to the beam. Chilled water is piped to the coil at between 13°C and 17°C. Primary air should be ducted to the beam at 13°C or lower to provide proper dehumidification. Active beams can have either a two or four-pipe distribution system. The two-pipe system may be cooling only or two-pipe changeover. Active beams may be designed to heat and cool the occupied space. In all chilled beam installations, flow control valves and chilled water supply temperature reset shall be provided. Vertical chilled beams shall be provided with condensate drain.

7.2.4.2 *Chilled slab/ceiling and radiant floor*

Radiant cooling and heating system provides an opportunity to achieve significant energy and peak demand savings, compared to conventional all-air system.

Radiant cooling systems can have circulation of water in pipes or tubes embedded in floor or ceiling or even on other surfaces such as walls. Chilled water is circulated through the floor/ceiling embedded pipes between 15°C and 17°C temperature for cooling applications and between 20°C and 35°C for heating applications depending upon the load conditions. Tubes can also be fitted in raised floor or suspended ceiling, with proper condensate drain, flow and temperature control. Looping of tubes/pipes shall be done for switching on/off cooling in particular area/pocket of the space as per the usage pattern.

Some low-energy cooling strategies such as displacement ventilation, natural ventilation, thermal mass, night ventilation shall be combined with radiant cooling to make it more effective.

Since the radiant cooling can take care of only sensible loads, parallel schemes are required for latent loads. These methods may form part of the ventilation strategy such as dedicated outdoor air system.

Operative temperature or effective temperature approach shall be used while designing these systems.

7.2.5 *Under Floor Air Conditioning*

Under floor air distribution (UFAD) is an alternate to ceiling/side based overhead air distribution system. UFAD system has several potential advantages over traditional overhead system, including improved thermal comfort, improved indoor air quality, and reduced energy use due to delivery of conditioned air right at the occupant level.

Under floor system is generally configured to have a relatively large number of smaller supply outlets, mostly in close proximity to the occupants, as compared to a conventional overhead system. Outlets may be floor diffusers, or desktop or partition outlets as part of a task/ambient conditioning (TAC) system. All these outlets are generally equipped with individual control. Air is returned from the room at ceiling level.

7.2.6 *Piping and Water Distribution System*

7.2.6.1 *Material*

Steel piping with welded or flanged/coupled joints should be used for water recirculation and distribution in central air conditioning system. Dielectric coupling shall be used to avoid corrosion when choosing different material combinations.

7.2.6.2 *Design principles*

The system design should achieve the following main objectives:

a) A good distribution of water to the various heat exchangers/cooling coils at all conditions of load, matching with temperature, humidity and pressure control strategies.
b) Adequate provision should be made for balancing, measuring flow rates and maintaining pressure differentials.
c) Pipe sizing shall be based on a balance between capital cost and operating cost.

Excessive water velocities should be avoided, as they lead to higher energy consumption and noise at pipe junctions and at bends.

In a large system when multiple water-chilling packages have to be used, control of the machines and the arrangement of the water circulation should be considered as an integrated whole.

Expansion tank shall be provided to cater for volume changes due to changes in temperature of the large volume of water filled within the system. System connection to expansion tank shall never be shut off. To maintain positive pressure during pump off situation, the open-type expansion tank shall be located at the highest point. Alternately, an inert gas pressurized closed expansion tank may be installed at a lower level. Air separator shall be provided in the chilled water system to improve the life and

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efficiency of chilled water piping and heat exchange equipment.

Soft water shall be used for central chilled water air conditioning system, as the heat transfer medium to convey heat from the air-handling units to the primary refrigerant in the evaporator. Special applications with temperature lower than 5°C shall be provided with additives to depress the freezing point and avoid freeze-up damage to the chiller.

Next generation fluids maybe considered to enhance heat exchange efficiency, based on nanotechnology, to reduce energy consumption.

7.2.6.3 *Piping design*

Water velocity shall be in the range of 1 m/s to 3 m/s. Main headers in the plant room shall be designed for velocity around 1 m/s. Velocity in excess of 4 m/s should be avoided for acoustic reasons and for erosion control.

Friction factor in piping should not exceed 5 m of water per 100 m of pipe length. System design shall be with high temperature differential and lower flow rate so as to reduce friction and thereby reduce energy consumption.

7.2.6.4 *Layout considerations*

The layout of the main pipe runs should be considered in relation to the building structure to support their weight when filled with water; also to cater to the imposed axial loads during circulation. The positioning of expansion joints should be considered in relation to the branches, to accommodate small movements. Pumps should not be subjected to excessive loads from the vertical columns of piping.

Automatic air vents shall be provided at all high points in the system.

Piping system should be designed to permit proper cleaning and flushing, and should also include suitable strainers and drain points at appropriate locations. Appropriate by pass arrangement/isolation points may be provided for ease of maintenance.

7.2.7 *Thermal Insulation*

7.2.7.1 Air conditioning and water distribution systems, carrying chilled or heated fluids/air shall be thermally insulated to prevent undue heat gain or loss and also to prevent internal and external condensation. Vapour seal shall be provided on chilled water pipes to avoid possibility of condensation.

7.2.7.2 The thermal insulation material shall be selected based on following physical characteristics:

a) *Fire properties* — Insulating materials shall be non-combustible and, in case of fire, shall not produce noxious smoke and toxic fumes. Materials and their finishes should inherently prohibit rotting, mould and fungal growth, attack by vermin, and should be non-hygroscopic.
b) Material should not give rise to objectionable odour at the temperature at which they are to be used.
c) It should not cause a known hazard to health during application, while in use, or on removal, either from particulate matter or from toxic fumes.
d) It should have a low thermal conductivity throughout the entire working temperature range.
e) It should have good mechanical strength and rigidity, otherwise it should be cladded for protection.

7.2.8 *Ductwork, Air Distribution and Fan System Interface*

7.2.8.1 *Material*

Ductwork is normally fabricated, erected and finished to the requirements in accordance with accepted standard [8-3(4)]. Designer should specify the requirements as appropriate for the velocity and pressure, and material to be employed. Ductwork is generally manufactured from galvanized steel sheet. Ductwork may also be manufactured from aluminium sheet for applications like operation theatres and intensive care units, where stringent cleanliness standards are a functional requirement. Special applications may warrant use of stainless steel or treated mild steel. Wherever, galvanized steel sheet, or aluminium sheet is used, the same shall conform to the accepted standard [8-3(5)] and [8-3(6)], respectively. Where building materials, such as concrete or brick, are used in the formation of airways, the interior surface should be fire resistant, smooth, airtight and not liable to erosion.

7.2.8.2 *Ductwork design*

Design calculations made to determine the size and configuration of ductwork in respect of pressure drop and noise generation, should conform to standard methods. The preferred duct profile is circular or elliptical to minimise the friction loss, however, ceiling space limitations invariably lead to rectangular duct. From aerodynamic principles, the aspect ratio of a rectangular duct, that is height to width ratio, should be kept within 1 : 3.

Ductwork design should also take into account the recommendations for fire protection (*see* Part 4 'Fire and Life Safety' of the Code) relating to the design of

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air handling system, for fire and smoke control in buildings.

7.2.8.3 *Layout consideration*

When designing ductwork, consideration should be given to,

a) co-ordination with building, architectural and structural requirements;
b) co-ordination with other services;
c) simplifying installation work;
d) providing facilities and access for commissioning and testing;
e) providing facilities and access for operation and maintenance of dampers;
f) meeting fire and smoke control requirement; and
g) prevention of vibration and noise transmission to the building and conditioned areas.

7.2.8.4 *Fan connection to duct system*

The performance of a fan when installed in a system, can be adversely affected by the flow conditions at fan inlet and outlet. Manufacturer's fan performance ratings are mostly based on optimum arrangement of fan inlet and outlet connections, to provide uniform straight flow conditions.

7.2.8.4.1 *Outlet duct*

A system designer shall closely examine the manufacturer's fan ratings to determine the conditions under which the fan has been tested. Fans intended for supply air applications are normally tested with an outlet duct. To achieve the rated performance for centrifugal fans, it is recommended to connect an outlet duct of one effective duct length (EDL), which is defined as a minimum of 2.5 equivalent duct diameters (EDD). Equivalent duct diameter for a rectangular duct is the diameter of a circular duct having the same cross-sectional area as the fan outlet. For fan outlet velocity higher than 12.5 m/s, additional length of one EDD, for each 5 m/s increment, should be added. The absence of an outlet duct in case of a tube axial fan does not result in any additional pressure losses. However, for a vane axial fan, a minimum of 50 percent EDL is required for them to perform as per the ratings.

7.2.8.4.2 *Outlet duct elbow*

Pressure loss in duct elbow is minimum when air approaching the elbow has uniform velocity profile. For centrifugal fan, elbow should be mounted after the outlet duct. In case of a tube-axial fan, outlet duct can be installed at fan outlet without causing additional loss. For vane-axial fans also, additional pressure loss can be made negligible by using a four piece mitre elbow, and placing it after a minimum of 12 percent EDL.

7.2.8.4.3 *Volume control damper* (*VCD*)

Manufacturer's pressure drop rating of wide open control damper is usually based on uniform approach velocity profile. To achieve this rating, VCD should be mounted after the outlet duct specified above.

7.2.8.4.4 *Inlet duct*

Non-uniform flow and swirl at fan inlet is the most common cause of deficient fan performance. The performance of a tube axial fan is severely compromised in the absence of an inlet duct. An inlet duct length equal to one impeller diameter, a bell mouth/ conical inlet, or a combination of the two, is recommended to minimise pressure loss and substantially enhance fan performance.

7.2.8.4.5 *Inlet duct elbow*

Elbows connected at or close to fan inlet make the approach velocity profile non-uniform. In addition they can cause pressure fluctuations, instability and excessive noise. It is strongly recommended that an inlet elbow be installed at least 3 inlet diameters away for an axial or centrifugal fan. The cross-sectional area of the inlet duct should be within -7.5 percent to +12.5 percent of the fan inlet area. A four piece mitre elbow is preferred over a two piece elbow.

7.2.8.5 *Cabinet effect*

Restricted fan inlet as in the case of inlet placed too close to a wall or inside a cabinet, adversely impacts fan performance. Fans inside plenum/cabinet, or next to walls, shall be placed so as to allow unobstructed air flow into fan inlet. A minimum distance of 75 percent of inlet diameter shall be provided between fan inlet and the wall. In case of two or more double inlet double width (DIDW) centrifugal fans placed side by side, a minimum separation of one inlet diameter shall be provided between the two adjacent inlets. The position of cabinet inlet should be symmetrical with the fan inlet to avoid uneven inlet flow or inlet spin.

7.2.9 *Geothermal Energy*

Ground source heat pump (GSHP) systems are largely based upon the fact that temperature of earth 3 m below the virgin ground level remains almost constant throughout the year, at annual mean temperature of that place. Such systems exchange heat with ground or with an aquifer inside the ground.

GSHP system consists of three parts, namely, ground heat exchanger, heat pump unit and air delivery system, that is, similar to any conventional air conditioning system.

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The ground heat exchanger can be a closed loop laid horizontal, vertical, immersed in pond, or in lake, or even in sewer line.

Decision about heat exchanger type shall be taken considering load, soil conditions, available land area and the local installation cost. The same loop works for both heating and cooling.

In cooling demand dominated climates, the depth of the horizontal loop should be at least 3 m to reduce efficiency losses in the late summer, due to drying of soil. In heating demand dominated areas, the depth may be reduced to 2 m. Antifreeze should be used in cold places. Antifreeze should be biodegradable and should present no hazard to the environment. All pipes should have the minimum cell classification number imprinted on the pipe. To create closed-loop systems, pipe and fittings shall be connected by butt or socket fusion (heat fusion) or stab fittings. Barbed fittings and clamps should not be used as they result in potential leaks and joint failure when used with high density polyethylene pipe. All pipes shall be pressure tested, then connected to the heat pump inside the building and trenches shall be backfilled.

For a vertical ground loop system, multiple boreholes shall be drilled 3 m to 5 m apart and 30 m to 120 m deep, depending on the thermal conductivity (TC) test. Two separate pipe lengths shall be connected with a U-bend to form a loop, then placed in each borehole and pressure tested. The borehole shall be backfilled with a grouting material and sealed off at the surface. Vertical loops shall be tied together with a system of horizontal piping laid in trenches, then connected to the heat pump in the building.

Pond/lake/sewer loops depend on the location of a pond or lake or sewer mains near the building. Loop coils should not be placed in a river or a body of water where fluctuating water levels or flood stage conditions can damage the pipe. Loop coil should be submerged in a fairly large body of water, at least 2.5 m deep, to prevent freezing in winter, and from exposing of tubes due to shortage of water in summer.

In an open-loop system, once the water has circulated through the heat pump, it is returned to the ground through one of the several methods, namely, a recharge well, a drain field or through surface discharge. This option should be used only where an adequate supply of water is available. About 15 litre per minute of water is required for each tonne of heating and cooling.

Thermal conductivity and thermal diffusivity (GHX TC) tests should be conducted before designing GSHP system:

a) *GHX TC test equipment* — Thermal conductivity test for vertical or horizontal borehole consists of,
   1) determining the ambient deep-earth-ground temperature,
   2) injecting heat into borehole at known rate (BTU/h or kW),
   3) determining the ΔT between fluid entering and leaving the GHX, and
   4) calculating thermal conductivity using the line-source method.

b) *Thermal conductivity test unit* — It shall consist of,
   1) circulation pump,
   2) electric elements,
   3) entering and leaving water temperature sensors,
   4) data logger, and
   5) power supply for electric elements.

c) *Typical TC test results* — A typical TC test report shows the entering and leaving water temperatures from the U-tube, as well as energy input. Data is typically logged in 1 to 5 min intervals, for the duration of the test. Standard method of testing shall be followed.

7.2.10 *District Cooling System*

7.2.10.1 District cooling system comprises of collective equipment to produce and distribute chilled water. Chilled water is produced by production plant and distributed by water pipes (the distribution network) to buildings equipped with energy transfer stations (sub-stations). Chilled water thus supplies some of its cooling to the building's installations. Such cooling system always operates in closed-circuit configuration and includes at least two water pipes; one of which carries the chilled water to the end user, and the other which carries it back towards the production plant.

In such a system, thermal energy produced at a central location is thus distributed to a set of consumers in commercial, residential and/or institutional buildings. This enables the consumer to air condition the building without having to install individual cooling (or heating) plant. Principle is similar to distribution of electricity to a number of consumers by an electrical distribution company. It is therefore the preferred air conditioning system for green-field cities and for large mixed-use development projects.

Some of the advantages of district cooling system are as follows:

a) Chilled water can be produced at one dedicated place, using large, highly efficient

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chillers. User buildings need to provide minimal space for the tertiary equipment, and for metering of chilled water or of cooling energy (BTU meter).

b) Total installed capacity and peak load of the air conditioning system get significantly reduced, due to large diversities in the cooling loads from diverse building usage pattern in the district.

c) Problems of plant operation and maintenance are confined to a centralized location, instead of distributing across the district.

d) Since air conditioning plant consumption is generally of the order of 40 percent of building energy consumption, power distribution system for the district will become lighter and cables sizes much smaller.

e) Problems of noise and vibration are confined to a place where it need not be objectionable.

7.2.10.2 Distribution of insulated chilled water pipes shall follow dedicated routes and adequate space for easy laying and maintenance. These are generally laid in trenches with removable covers and identifying markers. These trenches need to be integrated in the district planning.

7.2.10.3 *Cogeneration*

Cogeneration is the simultaneous production of electric power and thermal energy in a useful form such as steam, hot water and low temperature chilled water, all from a single energy source such as coal, oil or gas. Such systems are found useful in establishments where combined cooling/heating and power are simultaneously consumed. Good examples are, factory, hotel, hospital, etc, requiring cooling with chilled water; simultaneously with substantial electric power consumption. Cogeneration system presents a 50 percent to 70 percent more efficient utilization of the source of energy, that is, coal, oil or gas. Cogeneration is extensively used with district cooling systems.

7.2.11 *Window* (*Unitary*) *Air Conditioner*

7.2.11.1 Window (unitary) air conditioner is generally used for the following functions:

a) Cooling and general dehumidification, and

b) Cooling and heating by heat pump.

7.2.11.2 *Suitability*

Window (unitary) air conditioner is suitable for bedroom, office cabin, general office area, hotel room and similar applications, where normal comfort conditions are required to be maintained within a distance of 6 m from the window air conditioner.

7.2.11.3 *Noise level*

Noise level of window air conditioner inside the conditioned room should be as low as possible. It shall meet the requirements specified in the accepted standard [8-3(7)].

7.2.11.4 *Location*

Window (unitary) air conditioner should be mounted preferably at the window sill level on an external wall, where hot air from air-cooled condenser can be discharged without causing nuisance. There should not be any obstruction for the inlet air to, and discharge air from, the condenser. While deciding location of the window air conditioner, care shall be taken to ensure that the condensate drain water is piped to the ground level and does not drip, causing nuisance.

Window air conditioner is not recommended for special applications, like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired, nor in applications where high percentage of fresh air is desired and fire hazard exists, such as operation theatres depending on the type of anesthesia being used. It is also not suitable for areas that require close control of both the indoor temperature and relative humidity.

7.2.11.5 For detailed information regarding constructional and performance requirements and methods for establishing ratings of window (unitary) air conditioners, reference shall be made to the accepted standard [8-3 (7)].

7.2.12 *Split Air Conditioner*

7.2.12.1 It comprises of an indoor unit and an outdoor unit. The indoor unit may be mounted on floor or on wall, or at ceiling. The outdoor unit consists of compressor, heat exchanger, fan and motor; installed in a separate independent cabinet. The indoor unit is an air handling system, designed primarily to provide conditioned air to an enclosed space, room or zone (conditioned space). It includes a prime source of refrigeration for cooling and dehumidification/heating and means for the circulation and filtering of air.

Various types of split air conditioners may be categorized based on type of compressor for outdoor unit and air-distribution for indoor unit, as below:

a) *Outdoor unit with variable speed compressor* — It is also called an inverter AC or variable speed AC, which works on part load depending on the demand for the conditioned space. This uses a variable-frequency drive to control the frequency and thereby the speed of the compressor motor.

b) *Outdoor unit with fixed speed compressor*

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c) *Free-blow indoor unit* — It could be high wall mounted, ceiling suspended cassette (exposed type), or floor-mounted.

d) *Furred-in indoor unit (ceiling suspended)* — It is mounted in the ceiling and provided with a duct collar and grille.

e) *Ducted indoor unit* — It requires ducting for air distribution.

7.2.12.2 *Suitability*

Split air conditioner is suitable for wide range of applications including residences, small office, club, restaurant, showroom, departmental store, and others.

7.2.12.3 *Operating parameters*

In general, nominal capacity of the split air conditioner gets de-rated for the high ambient temperature (above 35°C) in summer months, in most of Indian cities. Also, generally a voltage stabilizer shall be required to get stabilized rated voltage as per specifications defined by manufacturer. For 3-phase unit, it is recommended to use phase reversal protection device in power supply to the outdoor unit.

7.2.12.4 *Location*

Split air conditioner indoor unit is mounted within the air conditioned space or above the false ceiling room from where the air distribution duct is taken to the conditioned space to distribute the conditioned supply air. When the indoor unit is mounted in the false ceiling, inspection panel shall be kept in the false ceiling to attend to the indoor unit, and periodic cleaning requirement of air filter. Outdoor unit is mounted at the nearest open area where unobstructed flow of outside air is available for the air cooled condenser.

7.2.12.5 *Installation*

Wall mounted unit and similar exposed indoor unit are provided with installation plate for ease in installation. Care shall be taken to ensure that enough clearance space is available below the ceiling in order to have free intake of return air.

Ceiling suspended indoor unit is provided with rubber grommets to minimise vibration transmission to the ceiling.

Outdoor unit is mounted on an epoxy-coated steel frame in an open area so that the fan of the air cooled condenser can discharge hot air to the atmosphere, without any obstruction. Care should be taken to ensure that free intake of air is also available to the outdoor air cooled condenser. Also precaution should be taken that hot air from any one outdoor unit does not mix with the outdoor air intake of any other air cooled condenser.

Service valves are to be provided for proper pressure testing of the system for leaks, for evacuation of moisture and air from the system, and to carry out predetermined gas quantity charge into the system. Also in case of maintenance of any part, these valves can be used to isolate and to store the entire refrigerant charge within the outdoor unit by pumping down, thus saving the entire charge of refrigerant.

Split units shall be installed as per the procedure given in **12.2**.

7.2.12.6 *Limitations*

Split air conditioner is generally not recommended for,

a) where distance between indoor unit exceeds beyond the maximum of 30 m (or higher as per the recommendation of the manufacturer) from the outdoor unit for units up to 17 500W (5 TR). The horizontal distance between the indoor unit and outdoor unit should not exceed 10 m for reciprocating compressor, nor for scroll compressor. The vertical distance between the indoor unit and the outdoor unit should not exceed 10 m for units with reciprocating compressor, and 25 m for unit with rotary/scroll compressor.

b) area requiring close control of both the indoor temperature and relative humidity.

c) sound recording rooms where criteria for acoustics are stringent.

d) special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired.

e) large multistoreyed buildings where multiplicity of compressors may entail subsequent maintenance problems.

7.2.12.7 For detailed information regarding constructional and performance requirements and methods for establishing ratings of split type room air conditioners, reference shall be made to the accepted standard [8-3(8)].

7.2.13 *Packaged Air Conditioner*

7.2.13.1 Packaged air conditioner is a self-contained unit suitable for floor mounting, designed to provide conditioned air to moderate sized conditioned spaces. It includes prime source of refrigeration for cooling and dehumidification, distinct facility for drawing of fresh air and mixing with return air, means for cleaning of mixed return and fresh air, and generally provision for external air distribution ducting for uniform air distribution in the conditioned spaces. It may also include winter heating package and humidification package for winter operation. The machine is equipped with compressor, evaporator, expansion device and

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remote air cooled condenser or water cooled condenser with interconnected copper refrigerant piping.

Water-cooled condenser packaged unit gives higher capacity at lower power consumption as compared to an air-cooled condenser packaged unit which gets considerably de-rated in capacity for high ambient temperature (beyond 35°C) in summer months for most of the cities in India. Air cooled package unit consequently also consumes more power in peak summer months. On the other hand, water-cooled condenser unit requires cooling tower with necessary piping and pump sets for circulating condenser-cooling water, but is far more energy efficient due to our low ambient wet-bulb temperatures in summer months.

Packaged units are generally available with vertical air discharge; however, horizontal air discharge unit may also be procured but heat island effect should be avoided.

7.2.13.2 *Suitability*

Packaged unit is suitable for wide range of applications including office, club, restaurant, showroom, departmental store, banquet halls and others.

7.2.13.3 *Location*

Packaged unit can be mounted within the air conditioned space with discharge air plenum or in a separate room from where the air distribution duct is taken to the conditioned space. While deciding location for the packaged unit, provision shall be kept for ease of servicing of the unit.

7.2.13.4 *Installation*

Packaged unit is normally mounted on resilient pads which prevent vibration of the unit from being transmitted to the floor.

7.2.13.5 *Limitations*

Packaged air conditioner is generally not recommended for,

a) large multi-storeyed buildings, where multiplicity of compressors may entail subsequent maintenance problems.
b) where the length of air distribution ducting may exceed approximately 30 m. However, duct length limitation depends upon permissible external static pressure specified by the manufacturer.
c) where the vertical distance of air-cooled condenser from the packaged unit exceeds about 20 m. The sum of horizontal and vertical distance should generally be kept within 25 m.
d) special applications like sterile rooms for hospitals and clean room applications where high filtration efficiency is desired. For these applications, special packaged units are available with high micron efficiency filters.
e) applications, such as, operation theatres where high percentage of fresh air is needed and fire hazard exists depending on the type of anesthesia being used.

7.2.13.6 For detailed information regarding constructional and performance requirements and methods for establishing rating of packaged air conditioner, reference shall be made to the accepted standard [8-3(9)].

7.2.14 *Variable Refrigerant Flow* (*VRF*) *System*

7.2.14.1 Variable refrigerant flow (VRF) system is a direct expansion (DX) multi-split system with variable speed compressor, capable of delivering capacity according to variable load requirement. By operating at variable speeds, VRF unit delivers required capacity allowing for substantial energy savings at partial-load conditions. VRF system has each outdoor unit connected with multiple number of indoor units *via* refrigerant piping, an attribute that distinguishes VRF system from other DX systems. Other advantages of VRF system are its scalability, variable capacity, distributed temperature control, and the standards cooling/heating mode application.

VRF system achieves temperature control on a zone by zone basis primarily by using refrigerant side control. As compared to DX system, VRF indoor unit has an additional electronic expansion device to control refrigerant flow passing through evaporator coil, to control indoor temperature precisely, based on the instantaneous load requirement.

VRF system is available with a dedicated air handling unit for supply of tempered fresh air (TFA). In order to cater to fresh air needs, VRF system outdoor unit should be connected with TFA-AHU. A control box equipped with electronic expansion device and communication printed circuit board (PCB) is needed for TFA-AHU so that it can communicate seamlessly with the VRF system outdoor unit.

VRF technology comes in two pipe or three pipe system. In a 2-pipe heat pump system, all of the zones shall either be in cooling mode or in heating mode. Application requiring simultaneous heating and cooling should have 3-pipe systems for enabling heat recovery.

7.2.14.2 *Configuration*

VRF system is available with air cooled or water cooled condenser.

Outdoor unit in VRF system can have multiple compressors, with one or more compressor provided

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with variable speed control. Generally for air cooled VRF system, outdoor unit is available both with top discharge and with side discharge.

7.2.14.3 *Suitability*

VRF system is suitable for wide range of applications including residence, apartment, villa, small and big office, club, restaurant, showroom, departmental store, healthcare facility, hospitality, cultural facility, educational facility and industrial facility.

In VRF system, depending on application, same or different types of indoor units can be connected to a single outdoor unit or to multiple outdoor units. VRF indoor units and air handling units for fresh air or for special treatment of re-circulated air, can be connected to the same refrigerant line, to facilitate more flexible system design, in mid and large size applications. However, usage of bigger AHU in VRF systems may have evident effect on the part load energy efficiency advantage of the system.

7.2.14.4 *Controls*

VRF system usually has factory-packaged integral controls in each component; these communicate through their system specific protocol, to ensure that all system components operate collectively. VRF indoor and outdoor units include refrigerant and air side sensing and control devices which allow the system to optimize its output (compressor speed, discharge temperature, fan speed) based on inputs from controllers. Depending on the application and design, a VRF system is able to operate with many levels of controls. Different types of controllers are available to cater to various requirements, as given below:

a) Individual/group controller,
b) Centralized controller with remote monitoring and control, and
c) Interface with building management system.

7.2.14.4.1 *Individual/group controller*

VRF indoor units can be controlled individually with wired or wireless individual remote controller. Control options include, 'ON/OFF', temperature change, mode change, and fan speed change. Applications such as a large common area in which multiple indoor units are running simultaneously, at the same condition, can be controlled by a single remote controller by combining these indoor units as a group. All setting conditions remain same for all indoor units connected in the group. Each of the grouped indoor unit may operate according to the sensed return air temperature.

7.2.14.4.2 *Centralized controller with remote monitoring and control*

Centralized controller allows users to operate and monitor multiple indoor units centrally. Besides having all functions of individual remote controller, centralized controller has the additional facility of scheduling energy saving by operation restrictions and web monitoring. In some applications, single outdoor unit is used by different tenants connected to different indoor units. In such cases, centralized controller offers facility of tenant billing through software application, depending on individual usage through proportional power distribution.

Some manufacturers offer smart phone application as it provides easy access and human interface for the VRF system user giving flexibility to operate and monitor the system remotely.

7.2.14.4.3 *Interface with building management system*

VRF system should be integrated with building management system if available, with the use of different interface gateways that communicate with different protocols. With this interfacing, it is easy to operate and monitor air conditioning with user's building management system.

7.2.15 *Evaporative Cooling — Indirect Direct Cooling System*

7.2.15.1 The various components of the indirect-direct cooling system are as follows:

a) Filters;
b) Cooling coil/heat exchanger [for indirect cooling (sensible heat exchanger)];
c) Cellulose pads [for evaporative (direct or adiabatic) cooling];
d) Fan section with enclosure for fan, filters, heat exchanger, cellulose pads with piping, moisture eliminators and dampers;
e) Cooling tower;
f) Pumps for heat exchanger and cellulose pads; and
g) Piping with valves and fittings.

7.2.15.2 The indirect cooling can be done by using following systems for dissipating the heat at air cooling coil/heat exchanger:

a) Through water in open cooling tower;
b) Through liquid in closed loop cooling tower;
c) Through liquid in closed loop geothermal system;
d) Through water in open loop — lake or pond geothermal system;
e) Through specially designed plate type heat exchanger; and
f) Through refrigerant circulating in cooling coil of the refrigeration system.

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7.2.15.3 This system is more useful in areas having moderate ambient temperature and especially low wet-bulb temperature. The system can be used using both stage of cooling during peak summer conditions giving outlet dry-bulb lower than ambient wet-bulb temperature. In monsoon, only indirect cooling can be used where the moisture is not added in the already moist ambient air.

7.2.15.4 It is good practice to have 100 percent fresh air system for evaporative cooling. During summers in the dry climates, outlet temperature is much lower; it can reduce the amount of air required to dissipate or remove the heat from the enclosed area, especially in industrial applications or applications where only comfortable temperature range is acceptable.

7.2.15.5 The air velocity across cooling surface is recommended between 2 and 2.5 m/s. Heat exchange is better at the lower face velocity while with higher face velocity, heat exchange is compromised.

7.2.15.6 Saturation efficiency of these indirect/direct coolers are normally in excess of 100 percent, making these a very effective solution for comfort applications in dry climates.

7.2.15.7 For detailed information regarding air capacity, constructional features, performance requirements and methods of testing of evaporative air cooler, reference shall be made to the accepted standard [8-3(10)].

7.3 Factors to be Considered for Different Applications

The general guidance, for various selected applications, for the factors that usually influence the selection of the type, design and layout of the air conditioning or ventilating system, to be used are given in **7.3.1** to **7.3.6**. The primary objective of these is to define the special provisions required for the air conditioning system, to ensure comfort conditions for occupants in the respective applications.

7.3.1 *Office Building*

Office building may include both the outer and inner zones. The outer zone may be considered as extending from approximately 4 m to 6 m inwards from the outer wall of the building, and is generally subjected to wide load variation owing to daily and annual changes in outside temperature and solar radiation. Ideally, the system(s) selected to serve an outer zone should be able to provide summer cooling and winter heating. During intermediate seasons the outer zone of one side of the building may require cooling and at same time the outer zone on another side of the building may require heating. The main factors affecting load are usually window area and choice of shading devices. The other important factors are the internal gain owing to people, light and office equipment. Choice of system may be affected by requirements to counteract down-draughts and chilling effect due to radiation associated with single glazing during winter. Cooling load for inner zone is generally entirely from the heat gain from people, lights and office equipment, which is generally fairly uniform throughout the year.

Other important considerations in office building application may include requirements for individual room control, partitioning flexibility serving multiple tenants, and requirement of operating selected areas outside of normal office hours. Areas such as conference room, board room, canteens, etc, will often require independent system. For outer building zone with large glass area, for example, greater than 60 percent of the external facade, the air-water type of system, such as induction or fan coil is generally economical than all-air system and has lower space requirement. For outer zones with small glass area, an all-air system, such as variable volume, may be the best selection. For building with average glass area, other factors may determine the choice of system. For inner zone, a separate all-air system with volume control may be the best choice. System employing reheat or air mixing, while technically satisfactory, is generally poor as regards energy conservation.

Each system or each zone within a system shall be provided with not less than one thermostat capable of being set from 15°C to 30°C and capable of operating the system's cooling and heating. The thermostat or control system, or both, shall have an adjustable dead band, the range of which includes a setting of 12°C between heating and cooling where automatic changeover is provided. Wall mounted temperature control shall be mounted preferably on an inside wall and shall meet the requirements given in **13** and Annex B of Part 3 'Development Control Rules and General Building Requirements' of the Code for universal accessibility.

7.3.2 *Hotel Guest Rooms*

Each guest room or each zone shall be provided with not less than one thermostat capable of being set from 15°C to 30°C and capable of operating the system's cooling and heating. The thermostat or control system, or both, shall have an adjustable dead band, the range of which includes a setting of 12°C between cooling and heating, where automatic changeover is provided. Wall mounted temperature control shall be mounted preferably on an inside wall and shall meet the requirements given in **13** and Annex B of Part 3 'Development Control Rules and General Building Requirements' of the Code for universal accessibility.

Guest room systems are required to be available for

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operation on a continuous basis. The room may be unoccupied for most of the day and therefore provision for operating at reduced capacity, or switching off, is essential. Low operating noise level, reliability and ease of maintenance are essential. Treated fresh air (TFA) is introduced through an independent TFA system, it is generally balanced with the bathroom extract ventilation, to ensure air circulation into the bathroom. Fan coil unit is generally found to be the most suitable for this kind of application with speed control for fan and motorized/modulating valve for chilled water control for cooling.

7.3.3 *Restaurant, Cafeteria, Bar and Night Club*

Such applications have several factors in common; highly variable loads, with high latent gains (low sensible heat factor) from occupants and meals, and high odour concentrations (body, food and tobacco smoke odours) requiring adequate control of fresh air extract volumes, direction of air movement for avoidance of draughts and make up air requirement for associated kitchens to ensure an uncontaminated supply.

This type of application is generally best served by the all-air type of system preferably with some reheat or return air bypass control, to limit relative humidity. Either self-contained packaged unit or split system, or air handling unit served from a central chilled system, may be used. Sufficient control flexibility to handle adequately the complete range of anticipated loads, is essential.

7.3.4 *Department Store/Shop*

For small shop and store, unitary split type air conditioning system offers many advantages, including low initial cost, minimum space requirement and ease of installation. For large department store a very careful analysis of the location and requirement of individual department is essential as these may vary widely, for example, for lighting department, food halls, restaurants, etc. Some system flexibility to accommodate future changes may be required.

Generally, internal loads from lighting and people predominate. Important considerations include initial and operating costs, system space requirements, ease of maintenance and type of operating personnel who will operate the system.

The all-air type of system, with variable volume distribution from local air handling unit, may be the most economical option. Facilities to take all outside air, for 'free-cooling' under favourable conditions, should be provided.

7.3.5 *Theatre/Auditorium*

Characteristics of this type of application are buildings generally large in size, with high ceiling, low external load, and high occupancy producing a high latent gain and having low sensible heat factor. These give rise to the requirement of large fresh air quantities and low operating noise levels. Theatre and auditorium may be in use only a few hours a day.

Movie theatre design considerations shall be based upon timing of usage, low occupancy level and low sensible load. Special care shall be taken to ensure proper relative humidity level without overcooling the space. System design shall meet the required noise criteria. The lobby and exit passageways in a multiplex which are seldom densely occupied, although some light to moderate congestion can be expected for short times, shall be separately treated.

Stage in auditorium shall be specially treated because of heavy mobile lighting load and performance considerations.

7.3.6 *Educational Institute*

Special attention for the design of the HVAC systems shall be paid to meet the needs of every age group. The equipment should be easy to operate and maintain and the design should provide no drafts. These facilities have two distinct occupant zones: (a) the floor level, where younger children play, and (b) normal adult height, for the teachers. The administrative and teachers offices shall be considered as a separate zone.

Special consideration shall be given to operating schedule for setback. Supply air outlets should be positioned to avoid drafts. Proper ventilation and exhaust shall be provided for controlling odours and to prevent the spread of diseases.

University and college campus having large diversity in cooling/heating loads, should be provided with large central utility plant or smaller mechanical rooms serving a cluster of buildings. The central utility plant may supply chilled/hot water. The designer should consider site constraints, including geographic location. In addition to accommodating the mechanical and electrical equipment, central utility plant may also house engineering, operation and maintenance personnel. A central control room shall be provided for energy monitoring.

7.4 Buildings, in which the HVAC planning and design requirements vary from a normal comfort application, such as, data centers, hospitals and underground metro stations, etc, are covered in **8**.

8 SPECIALIZED APPLICATION

8.1 There are many buildings with specialized application, like, data center, hospital and underground metro station; where requirement for these varies from

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a normal comfort application and hence these need to be treated differently. The requirements for such specialized applications have been given below:

a) *Health care facility/Hospital* — Some of the spaces in health care facilities require specific conditions of temperature, relative humidity, pressure differential with respect to adjacent spaces and cleanliness levels as well as low noise. When lower temperatures are desired in comparison to general areas, multiple design philosophies are available.

b) *Data centres* — The occupant load in data centres is nearly 1 or 2 percent of total load, rest is primarily server/equipment load. Therefore, in this type of building, the majority of load is sensible load. It is critical to maintain the operating conditions of server/equipment for their safe and consistent operation at lowest operating cost. Design needs should be identified after working closely with architect, equipment/server manufacturer and HVAC consultant.

c) *Underground metro station* — There are two challenges to be dealt with at underground metro station:
   1) Tunnel air temperature which increases due to the movement of metro train in tunnel.
   2) Comfort condition at platform and concourse due to sudden high passengers load and metro movement (equipment load).

Both the above may be handled differently by different designers.

The methodology which may be adopted for addressing the specific requirements of above applications are given in **8.1.1** to **8.1.3**.

8.1.1 *Health Care Facility*

Patient therapy shall be the prime consideration while air conditioning or ventilating a health care facility. While planning the air conditioning and ventilation of the health care facility, the plan shall include the clinical services to be provided in each space, equipment to be used with in the space and requirement of temperature, humidity, air flow pattern and pressure gradient with respect to adjacent spaces.

Following are the parameters which shall be taken into consideration while designing HVAC system for health care facilities:

a) Temperature and humidity requirements of various spaces;
b) Ventilation and filtration requirements for contamination control;
c) Restriction on air movement between adjoining spaces;
d) Permitted tolerance on environmental conditions;
e) System reliability and maintainability; and
f) Adaptability of the system for fire emergency and for smoke management.

Guidelines for the above parameters for various functional spaces in a health care facility are given in Table 6 and Table 7.

8.1.1.1 *Air distribution system*

Air distribution systems in a health care facility shall provide ventilation to dilute and remove contaminants and assist in controlling transmission of air borne infections besides maintaining the desired temperature and humidity. Design of the air distribution system shall be such that air movement is from clean to less clean areas. Recirculation of air should be avoided in critical care areas.

For critical care areas, constant volume systems shall be used to maintain proper pressure relations and ventilation. Critical areas in general are operating theatres, ICUs, isolation rooms, sterile areas, post-operative patient care; any place which houses medical surgical procedures and some of the laboratories.

For patient rooms and non-critical areas, variable air volume system shall be considered for energy conservation. However when variable air volume systems are used, care should be taken to ensure that minimum ventilation requirements are not compromised and pressure balance is maintained even at minimum flow.

Active smoke control systems shall be used along with fire and smoke partitions to limit the spread of smoke in the event of fire. Smoke and fire management shall be done in accordance with Part 4 'Fire and Life Safety' of the Code. For health care facilities which provide ambulatory care to patients, safety from fire and smoke is a paramount design consideration and shall be provided in accordance with Part 4 'Fire and Life Safety' of the Code.

A separate exhaust system shall be provided for removal of anesthetic gases from the operation theatre. Alternatively, proper isolation dampers may be provided in the air circulation system for removal of anesthetic gases or fumigation effect.

Air handling devices shall be designed to prevent water intrusion and permit access for inspection and maintenance.

When humidifiers are provided, they shall be located within the air handling unit or duct work in such a way

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Table 6 Guidelines for Parameters to be Considered for HVAC System Design for Health Care Facilities
(*Clause* 8.1.1)

Sl No.	Area/Functional Space	Temperature °C	Relative Humidity Percent	Minimum Total Air Changes per Hour	Minimum Air Changes of Outdoor Air per Hour	Air Pressure in Relation to Surrounding Area
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Operating theatres	18-24	45-55	25	5	Positive
ii)	Cath labs	20-22	30-60	15	3	Positive
iii)	Delivery rooms	20-22	30-60	25	5	Positive
iv)	Recovery room, ICU, Treatment rooms	20-24	30-60	6	2	Equal
v)	Endoscopy, Bronchoscopy	20-24	30-60	12	2	Negative
vi)	Patient rooms	24±1	30-60	6	2	Equal
vii)	Toilets	—	—	—	10	Negative
viii)	Protective environment rooms (Immuno suppressed patients)	24±1	30-60	12	2	Positive
ix)	Isolation room (for patients with infectious disease)	24±1	30-60	12	2	Negative
x)	Corridors	—	—	2	2	Negative
xi)	X-ray/Radiology	20-24	30-60	15	3	Positive
xii)	Laboratories (Other than biochemistry and serology)	22-24	30-60	6	2	Negative
xiii)	Biochemistry and serology labs and pharmacy	22-24	30-60	6	2	Positive
xiv)	Admission/Waiting rooms	22-24	30-60	6	2	Negative
xv)	Diagnostic/Treatment OPD	22-24	30-60	12	2	Negative
xvi)	Sterilizer room	22-26	30-60	10	—	Negative
xvii)	Sterilizer storage	22-26	30-50	4	2	Positive

Table 7 Guidelines for Filter Efficiency Requirement in Health Care Facilities
(*Clause* 8.1.1)

Sl No.	Category	Area/Designation	Filter Efficiency	
			Filter Bed 1	Filter Bed 2
(1)	(2)	(3)	(4)	(5)
i)	Category 1	a) Orthopaedic OT b) Bone marrow transplant OT c) Organ transplant OT	3 to 10 micron particles 70 percent efficiency	0.3 to 1 micron particles 95 percent efficiency (HEPA at outlets)
ii)	Category 2	a) General OT delivery rooms b) ICU, patient care rooms c) Treatment rooms d) Diagnostic areas	3 to 10 micron particles 70 percent efficiency	0.3 to 1 micron particles 85 percent efficiency
iii)	Category 3	a) Laboratories b) Sterile storage	0.3 to 1 micron particles 75 percent efficiency	Not required
iv)	Category 4	a) Food preparation b) Laundry c) Admin, etc	3 to 10 micron particles 70 percent efficiency	Not required

that moisture accumulation on downstream components do not take place. Evaporative pan type humidifiers shall not be used.

Fibrous acoustic insulating material shall not be used as duct lining for critical spaces unless downstream terminal filters are provided. Supply air ducts shall be externally insulated as required.

Multiple direct drive plenum fans may be used in air handling units serving critical areas. This provides redundancy and minimises shut down of critical areas in case of single fan failure.

For critical areas, both supply air and return air shall be ducted. Ducts shall be sized for medium velocity and medium pressure drop (12 m/s and 4 mm for 10 m *Max*). For applications like operation theatres and intensive care units, the preferred material for ductwork should be aluminium sheet.

Ultraviolet germicidal irradiation is recommended for air handling units serving health care facilities. Lamps may be installed either upstream or downstream of the evaporator coil but away from the filter media.

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8.1.1.2 *Air flow and filtration*

Outside air intakes shall be located at least 8 m away from exhaust stacks, cooling tower and/or any other polluting source. Bottom of an outside air intake shall not be located less than 2 m above ground level and 1m above any roof terrace level.

Exhaust outlets shall be located at a minimum height of 3 m away from ground level and away from doors, occupied areas and operable windows. Locating exhaust outlets above the roof, projecting upwards, is preferred.

While installing filters, care shall be taken to see that there is no scope for leakage between frame and filters and between filter segments.

All openings in ducting/diffusers collars shall be sealed to prevent infusion of dust and dirt.

All slab openings shall be terminated in enclosed rooms and airflow systems shall be designed and balanced to create positive or negative air pressure with-in specified areas.

It is recommended that supply air outlets shall be located at or near the ceiling and return/exhaust is collected near the floor level. This is to ensure that clean conditioned air moves through breathing and working space to the floor area, for return/exhaust.

For operating room and procedure room, where patients are highly susceptible to infection, such as orthopedic and cardiac operating theatres, laminar air flow system shall be considered. A unidirectional air flow pattern at a velocity of 0.45 ± 0.10 m/s should be aimed for. A vertical laminar flow system which will wash the patient on the operating table and flow downwards, to be collected near floor level, shall be chosen for such rooms. The area of laminar flow grid shall extend by a minimum of 450 mm beyond the foot print of the operating table on all sides. If required, additional supply diffusers may be provided for achievement of required temperature and humidity.

Exhaust grilles (minimum two) shall be provided at opposite corners of the room at approximately 200 mm above the floor level.

8.1.1.3 *Pressure differential*

Operating rooms where highly infectious patients are treated and isolation is required, an anteroom shall be provided between the operating room and external area. Anteroom shall be maintained at positive pressure with respect to both the operating room and the surrounding areas.

All air from operating rooms and from all airborne infection isolation rooms, shall be exhausted directly to outdoors and if this is not practical, the room shall be ventilated with re-circulated air supplied through high-efficiency particulate arrestance (HEPA) filters. Such rooms shall be maintained at a minimum negative pressure of 2.5 N/m^2 with respect to surrounding areas.

Protective environment rooms, such as, bone marrow transplants and organ transplants, shall be maintained at a positive pressure of 2.5 N/m^2 with respect to surrounding spaces.

8.1.1.4 *Conditioning equipment*

Cooling equipment can be central or local chilled water systems, direct expansion type condensing units or variable refrigerant flow systems. Indirect cooling systems using chilled water are preferred and, if direct cooling systems are used, required safety measures should be adopted.

Heating equipment shall include heat pumps, boilers and heat exchangers.

Sizing and arrangement shall give adequate consideration to minimum loading and standby facility for critical areas. It shall be possible for the facility to operate even when one of the systems is under break down or maintenance.

Where specific areas are to be maintained at a low temperature coupled with low humidity, an additional direct expansion coil may be introduced downstream of the regular evaporator coil. In such cases, the control strategy shall ensure that the DX coil is energized only after the main evaporator coil is at full load.

When variable refrigerant flow systems are used, care shall be taken to see that minimum air change and pressure differential considerations are not compromised.

8.1.1.5 *Installation and maintenance*

The air distribution system shall be provided with access panels to allow inspection and cleaning. Duct systems shall be cleaned of construction debris before commissioning.

Surfaces of air terminals shall be suitable for cleaning.

Access to equipment rooms shall be planned so as to avoid intrusion of maintenance personnel into critical care areas. Equipment room layout shall allow easy access to equipment for its operation and maintenance.

Operation and maintenance records shall include indoor temperature and pressure requirements as well as permitted tolerances for all spaces. It shall also include standard operating procedures for emergencies, such as power failure, equipment breakdown and fire situation.

Pressure differentials of operating rooms, protective

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environment rooms, and air borne infection isolation rooms with respect to surrounding areas, shall be verified and recorded semiannually.

HEPA filters shall be replaced periodically based on pressure drop. Filters of fan coil units and air handling units (AHU) shall be cleaned according to a regular maintenance schedule. AHU/Fan coil drain pans shall be of stainless steel construction and shall be cleaned monthly.

Supply and return air ducts for critical areas shall be tested for air leakage and an air blow down process shall be undertaken before loading of filters. All areas served by the AHU shall be cleaned and mopped before the AHU is started. Filters shall be loaded in sequence. Pre-filters shall be loaded first followed by microvee filters and finally HEPA filters. AHU shall be run with each set of filters for 24 h and the conditioned area shall be cleaned and mopped each time before the next set of filters is loaded.

After air balancing, and adjusting of air quantity, a validation process shall be carried out by recording temperature, humidity and pressure differentials. For critical areas, validation process shall be repeated and recorded at least once every year.

8.1.2 *Data Centre*

8.1.2.1 Data centre is a technological facility which houses electronic equipment used for data processing, storing and networking (datacom equipment). The design requirement for cooling of such technological facility differs significantly from comfort air conditioners.

Such facility has a little or no requirement of occupancy as the facility becomes complete automatic barring interventions for maintenance. The major contributing heat is from electronic equipment which is sensible in nature and hence cooling equipment needs to be designed with a high sensible factor. Main focus is equipment cooling rather than comfort conditions for space.

The facility generally works for all day and all night (continuously 24×7). High reliability and redundancy is an important criteria as any loss of data may contribute to huge financial loss. The components to be selected for cooling datacom equipment need to be highly reliable besides being energy efficient.

8.1.2.2 *Inside conditions/thermal guidelines*

Inside temperature within the facility may vary depending on whether dehumidified conditioned air is supplied on inlet side or exhaust side of the equipment. Presently the best practice of facility design for datacom equipment placement in the rack is based on hot and cold aisle air arrangement. In such configuration, front of the datacom equipment cabinet/rack should face cold aisle, where the dehumidified conditioned air from cooling equipment is supplied either through floor grilles or through overhead ducts.

The allowable envelope is where information technology (IT) manufactures test their equipment in order to verify that the equipment will function within these envelope boundaries.

Prolonged exposure of IT equipment to conditions outside its recommended range, especially approaching the extremes of the allowable environment, can result in decreased equipment reliability and shorter life span. However, occasional short time excursions outside the allowable envelope, may be acceptable.

Facilities should be designed and operated to target the recommended range. The present recommended range is:

a) Low end temperature : 18°C (64.4°F)
b) High end temperature : 27°C (80.6°F)
c) Low end moisture : 5.5°CDP (41.9°FDP)
d) High end moisture : 60 percent RH and 15°CDP (59°FDP)

8.1.3 *Underground Metro Station*

The underground metro station is provided with environment control system (ECS). The ECS system shall serve following function:

a) Station public area and ancillary room air conditioning,
b) Mechanical ventilation of plant rooms, and
c) Smoke management system.

8.1.3.1 *Station public area and ancillary room air conditioning*

8.1.3.1.1 *Station air conditioning design philosophy*

The underground stations of the metro corridor are built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. It is therefore, essential to provide forced ventilation in the stations for the purpose of,

a) supplying fresh air for the physiological needs of passengers and the authority's staff;
b) removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
c) preventing concentration of moisture generated by body sweat and seepage of water in the sub-way; and
d) removing large quantity of heat dissipated by the train equipment like traction motors,

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braking units, compressors mounted below the under-frame, lights and fans inside the coaches and the air conditioning units.

8.1.3.1.2 *Station heat load*

The station heat loads are a combination of the unsteady train heat loads, passenger heat load, lighting, equipment, miscellaneous equipment and fresh air loads, as given below:

a) *Unsteady heat load due to train movement* — The major source of heat for the station is from the train air conditioning systems and the train traction and braking systems.

The heat developed inside the tunnel during normal operation mixes with station air due to piston effect caused by train movement. This increases heat load of the station. This heat load is unsteady and needs special software for its estimation. These software model the complete metro network of tunnels and underground station and take train operation, rolling stock physical parameter, tunnel structure parameters, tunnel gradient and alignment, station architecture, etc, as input data. Such software takes into account the heat load of tunnel airflow generated by the train movement and the heat of trains dwelling at station as per the planned headway of train operation. These values do not include the fresh air heat loads or the steady heat loads from station, such as passengers, lighting, escalator and other equipment.

The unsteady heat load is obtained from the software at simultaneous and staggered headway for summer and monsoon condition, and the system is designed for the highest heat load.

b) *Steady heat load:*

1) *Passenger heat load* — The passenger occupancy at station is taken from Peak Hour Peak Direction Traffic (PHPDT) data given in detail project report (DPR). Passenger heat gain shall be computed from the above data.

2) *Lighting and miscellaneous equipment load* — It is based on lighting in public area and equipment like lifts, escalators and AFC Gates contributing to the heat load.

3) *Fresh air loads* — Fresh air is supplied to the platform and concourse to meet the physiological requirements of the passengers. Fresh air quantity is considered as 10 percent of supply air quantity, or at the rate of 0.005 $m^3/s.m^2$, whichever is higher.

8.1.3.1.3 *Design criteria*

Since the passengers stay in the stations only for a short period, a reasonable degree of comfort conditions, just short of discomfort conditions are considered appropriate. Station air conditioning system shall be designed to maintain specific design conditions.

Station air conditioning system design conditions are:

a) Platform, concourse : 27°C at 55 percent relative humidity

b) Outdoor monsoon : Summer and condition as per location

8.1.3.1.4 *System description*

The station environment control shall be by a central air conditioning system. Station shall have provision of fresh air intake and exhaust shaft. The station shall be supplied with conditioned air *via* ductwork from air handling unit (AHU) located in plant room. AHU shall be supplied with chilled water from water cooled chillers and its associated pumping system.

To extract the return air, trackway exhaust system shall be installed in the trainways of each station to capture both excessive tunnel airflows and the heat rejected by the vehicle propulsion/braking/air-conditioning systems as the train dwells in the station. An under platform exhaust (UPE) duct is often utilized to capture heat from the trains undercarriage heat sources. An overtrack exhaust duct is normally utilized to capture heat that is rejected from the above car area of dwelling trains. The overhead trackway exhaust (OTE) duct may be required if the railcars have rooftop mounted air-conditioning units. Openings in the OTE and UPE shall be located so as to be near the heat generating sources on the train.

8.1.3.1.5 *Modes of operation*

a) *Open mode operation* — In open mode, 100 percent outside air is circulated in the stations. It is an economical mode of operation when the outside air temperature is relatively low. AHU shall draw the air directly from outside *via* fresh air shaft and deliver the air at platform level and concourse level. Trackway exhaust fans (TEF) shall extract the air from OTE and UPE and discharge it outside directly *via* exhaust shaft. The water cooled chillers units shall remain shut down in this mode. This mode is generally used during winter season.

b) *Closed mode operation* — In close mode, air

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is extracted from the public areas of the station and returned to the air handling units to be cooled and delivered back to the platform and concourse. Closed mode operation is proposed when the outside air temperature and humidity are high. In this operation, AHU shall recirculate the air of OTE and UPE with the addition of 10 percent fresh air, brought in by fresh air fans (FAF). The TEF will take the exhaust from OTE and UPE and deliver to return air plenum where 10 percent fresh air is also mixed with the return air. This mode is generally used during summer and monsoon season.

8.1.3.2 *Ancillary area air conditioning*

Air conditioning of ancillary areas, that are occupied by staff and non-travelling persons, who are going to stay in these areas for considerable duration, is carried out by system similar to that for normal buildings.

8.1.3.3 *Mechanical ventilation*

The backs of house area rooms are provided with mechanical ventilation supply, ventilation exhaust or both according to their use and particular requirements.

8.1.3.4 *Smoke management system*

The smoke extract fans (SEF) and trackway exhaust fans (TEF) are used respectively for concourse and platform smoke extraction. The smoke extraction fans and other system components like duct, dampers, attenuators, etc, shall have suitable fire rating. Smoke extraction fans with related equipment shall be installed in the ECS plant rooms provided at concourse level at each end of the station. Where smoke extract ducting passes through protected areas, it shall be rated to the same fire resistance as the walls of the compartments. Flow switches shall be provided for exhaust. Station smoke removal fans to provide a positive indication of the fan operation at the station control rooms (SCR) as well as operations control center (OCC).

8.1.3.5 *Staircase pressurization*

Pressurization of exits shall be done in accordance with Part 4 'Fire and Life Safety' of the Code.

9 REFRIGERATION FOR COLD STORES

Cold store plays a major and critical role in cold chain. Apart from required temperature and relative humidity management, better air movement around the produce, proper arrangement of stacking, inspecting for any defectives are also important to maintain the produce quality in cold storage. The two basic product groups on cold storage of perishable food stuffs are chilled food and frozen food. The material of the equipment/ machineries used in cold stores should be corrosion resistant property and easily accessible for maintenance.

9.1 Key Elements and Components of Cold Room

9.1.1 *Product Quality*

Refrigeration cannot improve the quality of products. It does slow down the processes of microbial, chemical or enzymatic deterioration that occur in them. The more advanced these processes are, the more difficult it is to slow them down. Good results can, therefore be, expected only with clean, wholesome products which are free of any bruises, contamination or physiological disorders, and which have a normal microbial population for the products.

Storing products which do not have these qualities can harm those that do, when they are stored in the same room. They can also contaminate the rooms in which they are put together, through odours, dispersal of mold spores, etc. It shall be kept in mind that harmful micro-organism development can begin after a certain length of time and then speed up considerably. It is often very useful to know exactly where the product has come from and its history, in order to better evaluate its long term keeping quality, from both a qualitative and a commercial point of view.

Cold treatment should come quickly; that is, it should be done as soon as possible after the raw products have been harvested. Any delay in storing a product reduces the amount of time it can be stored, either because it has already deteriorated, or because it has already been transformed, and putting it into cold storage may not keep it from deteriorating further. Refrigeration should be continuous.

9.1.2 *Temperature of Cold Room*

During the entire storage period, the temperature should remain as constant as possible. Some products are particularly sensitive to temperature variations, which can reduce the shelf life of some fruits.

One shall avoid putting into a room a large amount of goods at a temperature too different from that of goods already in the room. The cold-production equipment should be checked to make sure it can handle this extra load. Within one room the temperature should be as uniform as possible, as this affects not just products that are sensitive to temperature variations, but also those with recommended temperatures near 0°C. These optimum conditions shall be approachable without risk of freezing.

Heat coming in through the floor and the walls can upset this uniformity of temperature in the room. However, the inside temperature can be made uniform through

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forced air circulation. Dead zones and regular drafts shall be avoided. The range of temperature given in chilling is generally meant as acceptable tolerance for each food. Storage temperature shall in any case be kept as constant as possible. Temperature sensors should be placed around the room on the basis of the accuracy, as indicated by the manufacturer, of the automatic devices. Cold store temperature can be either recorded or read at regular intervals. Thermometers should be protected from impact and yet be easily accessible. Temperature should be read at more than one location. Moreover, the temperature of the products themselves should be taken.

9.1.3 *Measurement of Temperature of Food*

A thermometer/temperature measurement device that can measure the internal temperature of food, like one with a probe that can be inserted into the food is required. Food internal temperature needs to be measured as the surface temperature may be warmer or cooler than the temperature of the rest of the food. The thermometer shall be accurate to ±0.5°C. The thermometer/temperature measurement device should be cleaned and sanitized before inserting it into food. The probe should be washed in warm water and detergent, sanitized according to the sanitizer instructions or the instructions that thermometer accompanies, and the probe should be allowed to air dry or thoroughly dried with a disposable towel.

9.2 Typical Design Inputs for a Standard Cold Room

The criteria involved in designing a cold room are similar to any warehouse, that is, storage capacity, facilities for receiving and dispatching goods, interior operating space, location of cold room, selection and location of refrigeration units. While designing cold room, the difference between room temperature and product temperature should be kept at a minimum value.

9.3 Importance of Heat Loads

Refrigeration load includes,

a) transmission load, which is heat transferred into the refrigerated space through its surfaces;
b) product load, which is heat removed from and produced by products when these are brought into and kept in the refrigerated space;
c) internal load, which is heat produced by internal sources (for example, lights, electric motors, defrost mechanism and people working in the space);
d) infiltration air load, which is heat gain associated with air entering the refrigerated space; and
e) equipment related load.

The first four segments of load constitute the net heat load for which a refrigeration system is to be provided; the fifth segment consists of all heat gains created by the refrigerating equipment itself.

Thus, net heat load plus equipment heat load is the total refrigeration load for which a compressor shall be selected.

While other loads are quite similar to loads in regular HVAC system design, the product load includes the primary refrigeration loads from products brought into and kept in the refrigerated space, which includes,

1) heat that shall be removed to bring products to storage temperature, and
2) heat generated by products (mainly fruits and vegetables) in storage.

In addition, another new aspect in heat load is the heat from defrosting where the refrigeration coil operates at a temperature below freezing and shall be defrosted periodically, regardless of the room temperature.

In order to avoid system oversizing, and to take full advantage of load diversity, it is recommended to use the hour-by-hour load calculation or simulation method.

9.4 Considerations for Cold Room Selection

The conditions within a closed refrigerated chamber shall be maintained to preserve the stored product. This refers particularly to seasonal, short shelf life, and long-term storage.

The four major concerns for product compatibility are temperature, moisture, ethylene, and odour.

Specific considerations include,

a) uniform temperatures as much as possible in empty condition as well as with product loaded condition;
b) length of air blow and impingement on stored product;
c) effect of relative humidity;
d) effect of air movement on employees working in cold store;
e) controlled ventilation, if necessary;
f) product entering temperature;
g) expected duration of storage;
h) required product shipping temperature when leaving cold store;
j) traffic in and out of storage area;
k) design of storage bins; and
m) size of food product ($L \times W \times H$) or volume.

Rack systems are mostly related to retail store

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refrigeration and are not considered as part of building system.

9.5 Installation and Maintenance of Cold Room — Key Aspects

9.5.1 The conventional construction in cold stores is the insulation on walls and ceilings, and finishing with cement sand plaster. The latest trend is to use sheet metal cladding. The cladding materials are aluminium sheet or pre-coated galvanized steel sheet.

The development of pre-insulated panels has brought in a change in cold storage construction. Polyurethane foam (PUF) panels using polyurethane as insulation material foamed between two metal skins, are structurally strong and have a better insulation value as compared to expanded polystyrene (EPS) panels for a given thickness. All panels for thermal insulation of cold storage shall be selected and designed in accordance with the good practice [8-3(11)].

The highlights of prefab panel's construction are:

a) Greater flexibility and faster construction due to reduced site work;
b) Better thermal efficiency due to better isolation between outside and inside surfaces;
c) Less moisture load due to good vapour barrier by PUF and sheet skin;
d) Prefab panels serve as walls and ceilings, eliminating brick walls, thereby increasing the cold store volume on a given floor area;
e) Modular construction is flexible and offers advantages of modular addition or expansion as per requirement; and
f) Increased hygienic quality of the structures. Panels can have a finish as per user's specification and are easy to clean and maintain.

9.5.2 Refrigeration system has to be assembled as per proper specifications to ensure that refrigerant leakage does not occur. It is essential to have proper emergency measures in case of any accidental leaks. The building structure has to be designed with adequate safety factors and the thermal insulation has to be protected properly from any possible occurrence of fire. Emergency alarms should be provided in the cold store with switches in each chamber.

Safety is critical in the design, construction and operation of refrigeration systems for cold storage, especially with ammonia systems. Refrigeration system's safety standards shall meet requirements relating to safe design, construction, installation, and operation of refrigeration systems by establishing safeguards for life, limb, heath and property as per the applicable safety standards. This includes, but is not limited to, occupancy classification, restriction on refrigerant use, installation restrictions, design and construction of equipment and systems, and operation and testing. Equipment selection and their placement should be such so as to ensure safe and easy maintenance. A safety review of the engineered design and equipment layout is recommended with participation from the owner's site operations and maintenance (O&M) team. Personnel safety measures are required as part of the facility design. The designer should prepare a system safety plan with full hazard analysis.

9.6 Cold Room Safety

The cold temperatures inside a low temperature cold room can cause increase in blood viscosity and risk to life unless proper precautions are taken. A hooter should be installed outside the cold room, powered through a UPS and the switch should be fixed prominently and within reach, inside the cold room. This will help any person trapped inside to alert those outside, for help.

9.6.1 The following safety provisions should be kept/ taken care of, at the cold room site:

a) Fire fighting equipment,
b) Safe handling of refrigerant leaks,
c) Safety devices, controls and alarm systems,
d) Emergency lighting in the cold chambers,
e) Lightning arrestor,
f) First-aid kit,
g) Air filters/breathers,
h) Emergency assembly points,
j) Regular safety drills and training,
k) Water shower in ammonia plants, and
m) Avoiding ramps as they become slippery when wet or frozen.

9.6.2 *Precautions against Getting Trapped in Freezing Room*

In order to facilitate getting out of a person who may accidentally get locked in a cold room, emergency exits shall be provided. These shall have facility to be opened from inside, even when they are locked from the outside. In all cases, following shall be installed in the freezing room:

a) Doors which can open manually both from the inside and the outside (for functioning during power shortages, etc). In case of rooms with large dimensions say more than 25 m, it is advisable to provide emergency doors with

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UPS/battery lit exit sign at both ends of the freezing room for easy exit.

b) A signage system outside the freezing room with a steady or blinking light, and a siren or buzzer, activated from the inside by pressing a UPS-lit button. This button should also be connected to the caretaker's apartment, where a monitoring board shows where the button has been pressed. These visible and audible alarms should always be connected to a self-contained electric circuit, operated with a permanently charged battery. The same circuit should also connect to an independent, battery operated emergency lighting system or a phosphorescent signalling system, all the way to the nearest emergency exit from the area.

c) Electric or pneumatic sliding doors, capable of being operated both from outside and inside by push button or pull cords, easily accessible, in case of large freezing rooms, to the persons inside/outside.

9.6.3 *Precautions Against Refrigerant Leaks*

Safety measures should be taken against leak of liquid or gaseous refrigerant. Consideration should also be given to installing gas detectors and shut-off valves. The safety of the people should be considered by installing in traffic and public areas with which the refrigerant supply can be cut long before the refrigerant concentration reaches the level which would affect the people or the stored products. The gaskets around the cold storage door should be periodically inspected and corrected for any damage.

In refrigeration applications with ammonia, there is a risk of a high concentration accumulating in an enclosed room. With 15 to 28 percent by volume, and an ignition source (of 582°C), it is possible to create a fast burning process which could be something like an explosion. So a rapid dilution/containment system or an expulsion system should be installed.

Self-contained breathing apparatuses and protective clothing are essential for entsering a building with a concentration of ammonia greater than 50 ppm. Ammonia clouds can be neutralized with dry ice (CO_2) or transformed by fog nozzle, but there is then a risk of water pollution. For safety requirements for cold stores as also for refrigerant gas related safety, relevant standards shall be followed.

9.7 Cold Room in Various Segments and Requirements

The recommended temperature ranges for various applications/product categories to be stored in modular cold rooms are given below:

Application/Product category	*Recommended Temperature Range*
Horticulture (fruits and vegetables)	+2 to +8°C
Floriculture	+2 to +6°C
Hotels, restaurants, fast food chains	+2 to +6°C
Pharmaceuticals	+8 to –25°C
Dairy	+8 to –25°C
Ice cream	–20 to –25°C
Ripening	+12 to +20°C
Controlled atmosphere	+1 to +3°C

requirements and other conditions. The relative humidity in most of the cases are above 90 percent except pharmaceuticals, seeds and frozen products, or as required for a specific case by the user.

10 HEATING

10.1 The installations for air conditioning system may be used advantageously for the central heating system with additions such as a hot water and hot water coil or a strip heater bank. Electrical heating may be actively discouraged and instead heating through superheat of cooling unit, heat pump, reverse cycle operation of unitary system and solar hot water systems are highly desirable; these result in a greener environment and lower carbon foot print.

While the efficiency of a heating equipment can never be more than 100 percent, a refrigeration system for heating usage can have the coefficient of performance (COP) of more than 4.5. Therefore, compared to electrical heating or thermal heating through boiler, preference should be for the systems working on refrigeration principle. Some examples are heat pump, VEF system, air cooled package unit, split air conditioner (in reverse cycle mode), and even window air-conditioner (in reverse cycle mode). Any of these refrigeration system can result in considerable energy saving and lesser carbon print. Hence while purchasing an air conditioner, a better choice can be for models with both cooling-heating modes.

10.2 Various heating equipment/systems are described under **10.2.1** to **10.2.6**.

10.2.1 *Hot Water Heated Coils*

Central heating systems using hot water usually require not more than one or two rows of tubes in the direction of air flow, in order to produce the desired heating capacity. To achieve high efficiency without excessive water pressure drop through the coil, various circuit arrangements are adopted.

Generally, the resistance to the hot water flow through the heating coil should not exceed 4 kPa in low pressure

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hot water heating installations. In high pressure hot water installations, the resistance to the water flow will probably be determined by other factors, for example, the need to balance circuits.

The hot water heating coil should be served from hot water supply and return mains with sufficient connections to each row, or bank of tubes, or sections, to give uniform distribution of the heating medium.

The hot water supply connection to the heating coil should generally be arranged at the lowest point, and the return connections at the highest, to aid venting. The expansion of the tubes when the heating coil is in operation should be considered, and necessary arrangement made to accommodate expansion and contraction.

Thermometer wells should be fitted in the pipes near the inlet and outlet of the coil so that the temperature drop through the heating coil can be readily observed.

10.2.2 *Electric Heating*

Air velocity through electric heating element should be sufficient to permit the absorption of the rated output of the finned tube heaters within its range of safe temperatures. Exact velocity determined in conjunction with the manufacturers of the heating elements. Electrical load should be balanced across the three phases of the power supply.

Where automatic temperature control is required, the electric heating element should be divided into a number of sections, depending upon the degree of control to be effected.

Each section of the heating element, which may be two rows of elements, should have its own bus bar and connections. Each section should be capable of withdrawal from the casing, thus enabling parts of the elements to be cleaned or repaired, whilst the remaining elements continue in operation. Each section should be capable of being isolated electrically before being withdrawn from the casing.

All electric heating elements should be electrically interlocked with the fan motor(s), so that the electric supply to the heating elements gets switched off when the fan is stopped, or when air velocity is reduced to a level below that for which the heating element has been designed.

The air velocity over the face of the heating element is of particular importance in the design of electric heating, and the manufacturer should be given details of the maximum and minimum air velocities likely to occur.

With all electric heating, care should be taken to preclude the risk of fire under abnormal conditions of operation, by the use of a suitably positioned temperature sensitive trip of the manual reset type, to cut off the electric supply in case of temperature rise beyond the specified limit.

10.2.3 *Solar Water Heating* (*SWH*) *System*

SWH is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. In a close-coupled SWH system, the hot water storage tank is horizontally mounted immediately above the solar collectors on the roof. No pumping is required as the hot water naturally rises into the tank through thermal siphon flow. In a pump circulated system, the storage tank is ground or floor mounted and is below the level of the collectors; a circulating pump moves water or heat transfer fluid between the tank and the collectors.

SWH systems are designed to deliver hot water for most times of the year. However, in winter, sometimes there may not be sufficient solar heat gain to deliver sufficient hot water. Therefore, a gas or electric booster is used to heat the water.

Residential solar thermal installations fall into two groups; passive systems (sometimes called compact) and active systems (sometimes called pumped). Both typically include an auxiliary energy source (electric heating element or gas connection for the hot water storage tank, or fuel oil fired central heating system) which is activated when the water in the tank falls below a minimum temperature setting such as 55°C. Hence, hot water is always available. The combination of solar water heating and using the back-up heat from boiler to heat water can enable a hot water system to work all year round in cooler climates.

The amount of heat delivered by a solar water heating system depends primarily on the amount of heat delivered by the sun at a particular place, that is, the insolation. In tropical places, the insolation can be relatively high, for example, 7 kWh/m^2 per day, whereas the insolation can be much lower in temperate areas where the days are shorter in winter, for example, 3.2 kWh/m^2 per day. Even at the same latitude the average insolation can vary a great deal from location to location due to differences in local weather patterns and the amount of overcast.

The design, installation and performance evaluation of solar heating systems shall be in accordance with the good practice [8-3(12)].

10.2.4 *Condenser Heat Recovery System*

Condenser heat recovery system captures energy that would otherwise be wasted to the atmosphere and converts this energy into useful heat. It is possible to capture this heat from the condenser and use it to

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generate hot water. By capturing this heat, overall system efficiency is considerably improved. Such a system should be used, wherever there is heating requirement concurrent with cooling demand.

10.2.5 *Heat Pump*

Heat pump can provide year round climate control by supplying heat in the winter and cooling it in the summer. Some types can also heat water. A heat pump is an electrical device that extracts heat from one place and transfers it to another. Air sourced heat pumps draw heat from the outside air during the winter heating season, and rejects heat outside during the summer cooling season. There are two types of air source heat pumps. The most common is the air-to-air heat pump. It extracts heat from the air and then transfers heat to either the inside or outside depending on the season. The other type is the air-to-water heat pump, which is used with hydronic heat distribution systems. During heating, in the winter season, the heat pump takes heat from the outside air and then transfers it to the water in the hydronic distribution system. During cooling, in the summer season, the process is reversed: heat pump extracts heat from water in the home's distribution system and pumps it outside to cool. Electricity is used to pump a refrigerant around the system, which picks up heat from the air and transfers it to the water/air.

Efficiency of heat pump is significantly higher as compared to gas or electric heater and when used in the right environment, results in energy saving, economy and also reduce greenhouse gas emissions

A heat pump uses electricity to drive the compressor and the fan instead of using electricity to heat the water directly. The amount of heat transferred depends on the ambient temperature. For example, when air temperature is 15°C and the desired water temperature is 55 to 60°C, the heat transferred into the water is typically around 3 times as much as the electrical energy used. Heat pumps may require an electric booster, if operated in regions where it is cold. The electric boost turns on once the entering water temperature drops below a certain point (normally below 15°C).

Selection of heat pump as a heating system over all other available options, would depend on the particular circumstances. In addition, placement and manner of installation of the hot water appliance can have a significant effect on the running costs and life span of the system. The important considerations to be kept in view while selecting a heat pump hot water heater are given hereunder.

Heat pump works most efficiently in warm, humid climates. It can work effectively during the night and in wet weather provided the air temperature is sufficient. Some models can continue to operate to temperatures below 0°C, though they will not achieve a very high level of efficiency. Heat pumps operate most efficiently at higher air temperatures. Heat pumps can be a better choice than solar water heaters for locations with limited sunshine, provided that the temperatures are not consistently low. In locations with good year round sunshine, a solar water heater that requires little boosting could use less energy.

10.2.6 *Ground Source Heat Pump*

Ground source heat pump uses the earth, or ground water, or both as the source of heat in the winter, and as the sink for heat removed from the conditioned areas in the summer. Heat is removed from the earth by using groundwater or an antifreeze solution; the liquid's temperature is raised by the heat pump; and the heat is transferred to indoor air. For year round air conditioning, the process is reversed during summer months, heat is taken from indoor air and transferred to the earth, by the ground water.

11 MECHANICAL VENTILATION

11.1 Objective and Options

Ventilation is the process of changing air in an enclosed space. A portion of the air in the space should be continuously withdrawn and replaced by fresh air drawn from outside to maintain the required level of air purity, health, comfort and safety of building occupants. Ventilation is required to control the following:

a) *Oxygen content* — Prevent depletion of the oxygen content of the air;

b) *Carbon dioxide and moisture* — To prevent undue accumulation;

c) *Other hazardous gases, such as, CO, NO*x, SO_2, *etc* — To eliminate;

d) *Odours and contaminants* — To prevent undue rise in concentration of body and other odours and contaminants (chemical, VOCs, tobacco smoke, etc);

e) *Bacteria* — To oxidize colonies of bacteria and fungi to prevent their proliferation; and

f) *Heat* — To remove body heat and heat dissipated by electrical or mechanical equipment, and solar heat gains.

Ventilation may include either mechanical exhaust system or exhaust can occur through natural means. Mechanical ventilation is one of the forms of ventilation option available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. Natural ventilation and natural exhaust, which are another option for ventilation, are covered in Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the

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Code. The scope of this Section is therefore restricted to mechanical ventilation.

Following considerations affect the type of ventilation system selected for a particular application and sizing of the ventilation plant:

a) The climatic zone in which the building is located is a major consideration. An important distinction that shall be made is between hot-dry and warm-moist conditions. In an industrial environment, hot dry conditions occur around furnaces, forges, metal extruding and rolling mills, glass forming machines, and so forth.

   Typical warm moist conditions are found in textile mills, laundries, dye houses, and deep mines where water is used extensively for dust control. Warm-moist conditions are more hazardous than hot-dry conditions.

b) Siting (and orientation) of a building is also an important factor. Solar heat gain and high outside temperature can add significant heat load, in addition to the internal heat gains from occupants, equipment and processes.

c) The comfort level required is another consideration. In many industrial applications, comfort levels as understood in the context of residential buildings, commercial blocks or office establishments cannot be achieved and therefore, what is often aimed in industrial application is 'acceptable working conditions' rather than 'comfort'.

There are many options available in mechanical ventilation, such as, spot cooling, local exhaust, changes in work pattern, for achieving the desired acceptable working conditions. The options available may need to be extended to evaporative cooling in order to achieve more acceptable working conditions when confronted with more hostile environmental conditions. For meeting heat stress standards, radiation shielding in addition to ventilation control measures described above may become necessary.

As a general rule, in complex and harsher environmental situations, mechanical systems should be the preferred alternative to achieve acceptable working conditions.

11.2 Industrial Ventilation

Industrial buildings find a major application of mechanical ventilation. Industrial processes may use chemical compounds and toxic substances which may cause particulates, gases and mists in the work zone air in concentrations that cross the prescribed safe limits. Thus in industrial buildings, ventilation is needed not only to provide oxygen rich fresh air normally required for health and hygiene and to mitigate against thermal loads due to equipment, people and building heat gains, but also to remove and maintain the hazardous industrial pollutants within safe limits.

11.2.1 *Basic Ventilation Strategies*

11.2.1.1 *Mechanical extract/natural supply*

This is the simplest form of extract strategy comprising one or more exhaust fans, usually of the propeller, axial flow or mixed flow type, installed on outside wall or on the roof. The discharge should terminate in louvers or cowls or a combination of both.

Alternatively, the system may comprise of ductwork arranged for general extraction of the vitiated air or for extraction from localized sources of heat, moisture, odours, fumes and dust. Such duct work may be connected to centrifugal or axial flow fan which discharge through the wall or roof, terminating in louvers or cowls or a combination of both.

It is essential that provision for make-up air is made and that consideration is given to the location and size of inlet. Inlet should not be located in the vicinity of exhaust fan. This strategy creates negative pressurization in the building and is not suitable for dusty ambient environment, nor when dust free environment needs to be maintained indoors.

11.2.1.2 *Mechanical supply/natural extract*

This strategy is similar in form to the extract strategy but arranged so that one or more fans supply fresh air into the enclosed space. Such a system necessitates the discharge of vitiated air by natural means through open doors, windows, other building openings and cracks. This ventilation strategy creates positive pressurization in the enclosed space which is essential to maintain a clean interior environment. For relatively closed spaces, positive pressurization levels can be controlled by providing balanced pressure relief dampers at selected discharge zones.

The points of delivery of fresh air supply can be controlled by incorporating a system of supply ducts and discharge diffusers. The desired level of air quality in the supply air can be maintained by providing suitable filters in the supply fan systems.

11.2.1.3 *Mechanical supply/mechanical extract*

This strategy is a combination of the above two strategies and consists of two independent systems — a mechanical supply system and a mechanical extract system with or without their respective duct system.

This strategy provides the best opportunity for control of ventilation parameters, such as, indoor air quality,

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air distribution, movement and pressurization, but with additional system cost and complexity.

In the interest of efficient use of energy and comfort to the occupants, it is imperative that all ventilation strategies should be considered in relation to the thermal characteristics of the building, ambient environment and the nature of processes inside.

Reference shall be made to the good practice [8-3(13)] for basic requirements regarding safe design, installation, operation, testing and maintenance of ventilating system with respect to general ventilation and wherever applicable dilution ventilation for industrial processes. Measures to reduce heat hazards due to industrial processes are also briefly described therein. The information contained in this section should be considered complimentary to the good practice and shall not supersede the provisions of the same.

11.2.2 *Ventilation for Heat Control*

Ventilation for heat control measures normally includes cooler replacement air, an evaporative or mechanically cooled source, velocity cooling method or combination thereof. The required ventilation flow rate should be calculated both for the sensible and latent heat load. The required ventilation rate is the larger of the two volumetric flows.

In majority of cases the sensible heat load far exceeds the latent heat load, so the design rate usually can be calculated on the basis of sensible heat alone. The sensible heat load includes solar heat gain, occupancy, lighting load, equipment load as well as other particular sources, if any.

The ventilation flow rate can be calculated using the following equation:

$$Q_s = 3.462 \times \frac{H_s}{\Delta T}$$

where

Q_s = air volume flow rate, in m^3/h;

H_s = sensible heat load, in kcal/h; and

ΔT = allowable temperature rise, in °C.

The allowable temperature-rise values are specified in Table 2 of the good practice [8-3(13)]. Ventilation system should be designed for air to flow through the hot environment in a manner that will effectively control the excess heat.

11.2.3 *General* (*Dilution*) *Ventilation Versus Local Exhaust Ventilation*

General exhaust ventilation (dilution ventilation) is appropriate when,

a) emission sources contain materials of relatively low hazard (*see* Note);

b) emission sources are primarily vapours or gases, or small, respirable size aerosols (those not likely to settle);

c) emissions occur uniformly;

d) emissions are widely dispersed;

e) moderate climatic conditions prevail;

f) heat is to be removed from the space by flushing it with outside air;

g) concentrations of vapours are to be reduced in an enclosure; and

h) portable or mobile emission sources are to be controlled.

NOTE — The degree of hazard is related to toxicity, dose rate, and individual susceptibility.

Local exhaust ventilation is appropriate when,

1) emission sources contain materials of relatively high hazard;

2) emitted materials are primarily larger diameter particulates (likely to settle);

3) emissions vary over time;

4) emission sources consist of point sources;

5) employees work in the immediate vicinity of the emission source;

6) the plant is located in a severe climate; and

7) minimising air turnover is necessary.

Local exhaust ventilation normally requires lower air flows than general (dilution) ventilation.

Dilution ventilation is used to reduce the concentration of vapours from a given liquid solvent in the air to a safe level known as the threshold limit value (TLV) of the solvent expressed in ppm (parts per million). For a given solvent, the volume of air required to dilute its vapour concentration to below TLV can be calculated by the following equation:

$$\text{Air volume, in } m^3 \text{ per kg of evaporation} = \frac{\left(24 \times 10^6 \times k\right)}{\left(m \times TLV\right)}$$

where

k = constant varying from 3 to 10 depending on the solvent, uniformity of air distribution, dilution of vapours in air and location of exhaust hood; and

m = molecular weight of the solvent.

A local exhaust ventilation system normally consists of a hood, a duct system, air cleaner, a fan and an exhaust stack. Such a system captures the contaminants at the point of generation through a properly mounted exhaust hood. The exhaust flow rate is determined from the area of the hood opening and capture velocity sufficient to prevent outward escapement of the

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contaminant. Table 8 lists the recommended range of capture velocity for various types of industrial contaminants.

Table 8 Recommended Capture Velocities for Industrial Contaminants
(*Clause* 11.2.3)

Sl No.	Condition of Dispersion of Contaminant	Process Example	Recommended Capture Velocity m/s
(1)	(2)	(3)	(4)
i)	Released with practically zero velocity into still air	Evaporation from pickling tank, degreasing tank	0.25-0.5
ii)	Released at low velocity into moderately still air	Spray booth, intermittent container filling, welding, plating, low speed conveyor transfer	0.5-1.0
iii)	Active generation into zone of rapid air motion	Spray painting in shallow booth, barrel filling, conveyor loading, crushers	1.0-2.5
iv)	Released at high initial velocities into zone of very rapid air motion	Grinding, abrasive blasting, tumbling	2.5-10

From the range of capture velocities shown in the above table, the proper choice of capture velocity may be made based on the factors described in Table 9.

Table 9 Factors Affecting the Choice of Capture Velocity within a Range
(*Clause* 11.2.3)

Sl No.	Lower End of Range	Upper End of Range
(1)	(2)	(3)
i)	Minimum air currents favourable to capture	High room air currents
ii)	Minimum toxicity of the contaminants	High toxic contaminant
iii)	Intermittent/low production	High production/heavy use
iv)	Large hood, large air mass in motion	Small hood, local control only

The sizing of the ducts shall be determined considering the volume of air required and recommended duct velocity necessary to convey the contaminants with minimum possible pressure drop keeping in mind economics of installation and operation. Recommended duct velocity for exhaust ventilation system is given in Table 10.

The selection, installation and operation of fan should be in conformity with the nature of contaminants and should be capable of overcoming the total system pressure drop and deliver the required flow rate. For dust and other industrial contaminant laden air, the drive arrangement (motor, belts and pulleys) should be kept outside the air stream.

Table 10 Recommended Duct Velocity for Exhaust Ventilation Systems
(*Clause*11.2.3)

Sl No.	Nature of Contaminants	Examples	Recommended Duct Velocity m/s
(1)	(2)	(3)	(4)
i)	Vapours, gases, smoke	All vapours, gases and smoke	5 - 10
ii)	Fumes	Welding	10 - 12.5
iii)	Air laden with very fine dusts	Litho powder, wood flour, cotton lint	12.5 - 15
iv)	Dry dust and powders	Fine rubber dust, moulding powder dust, cotton dust, jute lint, soap dust, leather shaving	15 - 20
v)	Average industrial dusts	Grinding dust, general material handling, clay dust, brick cutting, lime stone dust, asbestos dust in textile industry, dry buffing lint, granite dust, silica flour, shoe dust	17.5 - 20
vi)	Heavy dusts	Metal turnings, saw dust, sand blast dust, C.I. boring dust, lead dust, foundry tumbling barrels and shakeout	20 - 22.5
vii)	Heavy and moist dusts	Lead dust with small clips, moist cement dust, sticky buffing lint, quick lime dust	22.5 and above

11.2.4 *Humidification for Industrial Processes*

Evaporative cooling should generally be used, where humidification is necessary to meet the requirements of manufacturing processes in factories, as for instance, in a cotton mill to keep the textile fibres pliable and strong, in rubber factories to prevent static electricity in processes using volatile and inflammable solvents, and in painting and lithographic works to maintain accurately the size of the paper and other materials. Evaporative cooling shall be done in accordance with **7.2.15**.

11.3 General Ventilation Rate for Non Air Conditioned Areas

The rate of air circulation recommended for different general areas is as given in Table 11.

11.4 Commercial Kitchen Ventilation

The basic purpose of a kitchen ventilation system (KVS) is to provide a comfortable environment in the kitchen and to ensure the safety of the people working in the kitchen and other building occupants, by effective removal of effluents which may include gaseous, liquid and solid contaminants produced by the cooking process and products of fuel and food combustion.

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Table 11 Recommended Rate of Air Circulation for Different Areas
(*Clause* 11.3)

Sl No. (1)	Application (2)	Air Change per Hour (3)
1)	Assembly rooms	4-8
2)	Bakeries	20-30
3)	Banks/building societies	4-8
4)	Bathrooms	6-10
5)	Bedrooms	2-4
6)	Billiard rooms	6-8
7)	Boiler rooms	*see* **11.2.2**
8)	Cafes and coffee bars	10-12
9)	Canteens	8-12
10)	Cellars	3-10
11)	Changing rooms	6-10
12)	Churches	1-3
13)	Cinemas and theatres	10-15
14)	Club rooms	12, *Min*
15)	Compressor rooms	10-12
16)	Conference rooms	8-12
17)	Corridors	5-10
18)	Dairies	8-12
19)	Dance halls	12, *Min*
20)	Dye works	20-30
21)	Electroplating shops	10-12
22)	Engine rooms/DG rooms/GG rooms	*see* **11.2.2**
23)	Entrance halls	3-5
24)	Factories and work shops	8-10
25)	Foundries	15-30
26)	Garages	6-8
27)	Glass houses	25-60
28)	Gymnasium	6, *Min*
29)	Hair dressing saloon	10-15
30)	Hospitals-sterilising	15-25
31)	Hospital-wards	6-8
32)	Hospital domestic	15-20
33)	Laboratories	6-15
34)	Launderettes	10-15
35)	Laundries	10-30
36)	Lavatories	6 -15
37)	Lecture theatres	5-8
38)	Libraries	3-5
39)	Lift cars	20, *Min*
40)	Living rooms	3-6
41)	Mushroom houses	6-10
42)	Offices	6-10
43)	Paint shops(not cellulose)	10-20
44)	Photo and X-ray dark room	10-15
45)	Public house bars	12, *Min*
46)	Recording control rooms	15-25
47)	Recording studios	10-12
48)	Restaurants	8-12
49)	Schoolrooms	5-7
50)	Shops and supermarkets	8-15
51)	Shower baths	15-20
52)	Stores and warehouses	3-6
53)	STP rooms	30, *Min*
54)	Squash courts	4, *Min*
55)	Swimming baths	10-15
56)	Toilets	6-10
57)	Underground vehicle parking	6, *Min*
58)	Utility rooms	15-30
59)	Welding shops	15-30

Heat is the primary ingredient of kitchen effluents. 50-90 percent of the appliance energy input is released in the form of a rising convective thermal plume above the cooking surface; balance is released into the surrounding space through radiation. The thermal plume also contains most of the food and fuel generated effluents. In the absence of cross drafts, the hot convective plume above a cooking surface rises vertically, entraining ambient air which enlarges the plume, cools it and slows it down. This hot plume can be conveniently captured by placing an exhaust hood over the cooking surface. The hood shall be of sufficient size and placed at proper height to encompass the whole plume. The hood exhaust flow rate should be slightly higher than the plume flow rate. Extra exhaust capacity may be required to resist cross drafts.

From a system design perspective, grease is the most important constituent of effluent generation in a commercial kitchen. Grease generation is a function of both what is being cooked and on what type of appliance it is being cooked. The amount of grease in vapour phase is significant and varies from 30 percent to 90 percent by mass. This is an important factor in designing the grease removal system. Carbon monoxide (CO), carbon dioxide (CO_2) and oxides of nitrogen (NO_X) are present in combustion processes in gas appliances and not in electrical appliances.

11.4.1 *Hood Exhaust Flow Rate*

Kitchen hoods have been classified as two types, Type I and Type II. Type I hoods are used to collect and remove grease, smoke, steam and heat. Type II hoods only remove steam and heat. Thus, Type I hoods are fitted with some kind of grease collection device such as grease filters, baffles and a fire suppression system but a Type II hood typically does not have these devices. Appliances such as cooking ranges, fryers, broilers and griddles require Type I hoods whereas ovens, steamers and dishwashers can work with Type II hoods.

The most commonly used Type I hoods are available in four basic styles:

a) Wall mounted canopy;
b) Single island;
c) Double island; and
d) Back shelf or proximity.

The upward velocity of the effluent thermal currents over the hot cooking surface is mainly a function of the temperature of the cooking surface and varies from 0.08 m/s over steam equipment to 0.8 m/s over charcoal broilers. Higher the effluent velocity, higher will be the flow required. Thus for a particular hood style, the exhaust flow rate is primarily determined by the appliance surface temperature (type of appliance), in addition to an allowance for preventing cross drafts.

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Recommended hood exhaust flow rates for different types of cooking equipment and exhaust hoods per linear metre of hood length should be as per Table 12.

If more than one duty category appliance is placed under one hood, the hood exhaust flow should be calculated on the basis of the heaviest duty appliance.

For Type II hoods, the recommended exhaust flow rates are from 150 to 460 litre per second per linear metre of hood length for oven hoods, and 460 to 770 litre per second for condensate hoods.

11.4.2 *Good Hood Design and Installation Practices*

Following are good hood design and installation practices:

a) Increasing hood overhang increases capture volume which aids capture and prevents spillage. A minimum overhang of 150 mm on all open sides for all canopy hoods is recommended. Increasing front overhang and use of inclined side panels (instead of side overhang) significantly reduces capture flow rates.

b) Deployment of side panels improves hood performance significantly. Side panels prevent the plume from spilling at the side, prevent cross drafts and increase velocity at the hood front.

c) Under a wall canopy hood, pushing the appliance towards the back wall significantly improves hood performance in two ways, increased front overhang and reduction in gap between the appliance and the back wall.

d) When using multiple duty category appliances in line under a single hood, the lowest capture rates are achieved when light duty appliance are at the end of the line. Therefore, hood performance is best when heavy duty appliances are placed in the middle of the line.

e) Hood should be mounted at as low a height as practical above the appliance surface.

11.4.3 *Oil/Grease Removal*

The removal of oil/grease from the exhaust airflow is a very important part of commercial kitchen operation. In absence of proper filtration, grease will,

a) collect in the exhaust plenum and ducts resulting in,
   1) a fire hazard, and
   2) an increase in the frequency of costly duct cleaning;
b) collect on the fan, causing it to become unbalanced which leads to premature failure;
c) create odours in or near the restaurant;
d) collect on the rooftop creating safety/ environmental hazard; and
e) collect on the rooftop equipment and cooling coils.

These problems can be greatly reduced through the use of proper filtration device in the hood exhaust system. The design and selection of proper filtration device should ensure that the exhaust air is clean and conforms to the applicable pollution control norms.

11.4.4 *Recommended Exhaust Duct Design, Installation and Maintenance Practices*

Kitchen exhaust ductwork carries hot grease laden air. The following general guidelines should be followed in their design, installation and maintenance:

Table 12 Appliance Category and their Recommended Hood Exhaust Flow Rates
(*Clause* 11.4.1)

Sl No.	Appliance Category ⟶ / Surface Temperature °C ⟶	Light 200°C	Medium 200°C	Heavy 315°C	Extra Heavy 370°C
(1)	(2)	(3)	(4)	(5)	(6)
i)	Cooking equipment	a) Electric/gas ovens b) Electric/gas steamers c) Cheese melters d) Pizza ovens e) Food warmers	a) Hot top/element ranges b) Griddles c) Fryers d) Pasta cookers e) Conveyor ovens f) Grill g) Rotisseries	a) Open burner ranges b) Broiler c) Wok ranges	Appliances using solid fuels for example, wood, charcoal briquettes
ii)	Plume velocity (m/s)	0.25	0.43	0.75	0.93
iii)	Hood type	Hood exhaust flow rates per linear metre of hood length litre per second			
	a) Wall mounted canopy	309	463	618	850
	b) Single island	618	772	927	1 080
	c) Double island (per side)	386	463	618	850
	d) Back shelf	463	463	618	—

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a) Ducts should be round or rectangular.
b) Ducts shall be grease tight and should be free of traps that can hold grease.
c) Minimum sheet gauge should be 16 gauge mild steel or 18 gauge stainless steel.
d) All joints and seams shall be fully welded and made grease tight.
e) Ductwork shall lead directly to building exterior and should not be interconnected with any other type of building ductwork.
f) Horizontal duct runs should be minimised and pitch towards the hood or an approved reservoir for continuous drainage of liquid grease and condensate. The slope should be 2 percent for runs under 23 m. For horizontal runs greater than 23 m, 8 percent slope should be provided. A grease drain outlet shall be provided in form of a leg under a vertical riser.
g) Maximum velocities are limited by pressure drop and noise and should normally not exceed 12.5 m/s.
h) The minimum air velocity for exhaust ducts should be 2.5 m/s.
j) For new single speed fan system, a design duct velocity of 7.5 m/s to 9 m/s is appropriate.
k) Ducts shall conform to requirements given in Part 4 'Fire and Life Safety' of the Code.
m) Access doors duly nut bolted with lead/fire rated gasket shall be provided for scavenging/ grease removal during maintenance. This should be marked/provided in drawings as well as in actual duct work, so that nothing is built to block access to them.
n) It is recommended that duct cleaning at regular intervals be carried out so that the grease film thickness inside ducts (measured with a wet film thickness gauge or equivalent device) does not exceed 180 microns. This will avoid accidental grease sparks and fire.

11.4.5 *Fan for Kitchen Exhaust*

Kitchen exhaust consists of hot, grease laden air with some solid particulate matter also. Fan shall be capable of handling this air and the motor and the drive train (shaft, bearings, belts, etc) shall be kept outside the air stream. The recommended kitchen exhaust fan should consist of a backward type impeller. A forward curved centrifugal fan is not recommended for kitchen exhaust.

11.4.6 *Terminations of Kitchen Exhaust System*

Kitchen exhaust systems should be terminated so that,

a) discharge direction should be such as to minimise re-entry into fresh air intake. This not only requires a minimum separation between exhaust and fresh air intake but also knowledge of prevailing winds.
b) grease should be collected and drained into a closed container (a fire safety precaution).
c) rainwater should be kept out of the grease container.
d) grease should not be allowed to drain down the side of the building.
e) discharge should not be directed downward or towards pedestrian areas.
f) roof top discharge should be released a minimum 4 m above the roof surface.
g) for discharge from building sides, it should be ensured that the discharge air is clean, free from odours and conform to applicable pollution control norms.

11.4.7 *Replacement (Make-up) Air Considerations*

The air exhausted through a kitchen hood shall be replaced 100 percent with clean outside air. Kitchen room pressure should be maintained slightly lower than the adjoining building space (for example, dining room) to allow conditioned air to transfer into the kitchen and to contain heat and odours within the kitchen. For kitchens adjacent to a building exterior wall, the kitchen pressure should be slightly higher than the ambient to prevent ingress of dust, heat and insects.

Replacement air in air conditioned kitchens should be supplied as close to the hood as possible and this can be best achieved by the use of compensating exhaust hoods, with supply air forming an integral part of the hood.

11.4.8 *Energy Management Considerations*

Hood exhaust flows can result in twenty or more air changes per hour. Installing a variable volume system is the first step towards energy conservation to allow for the exhaust and supply units to ramp up and down depending on the cooking load. Varying both the exhaust and the supply will vary the amount of air that needs to be conditioned. In some cases, a variable system can reduce the costs associated with conditioning make-up air by up to 50 percent.

Exhaust and supply air flow rates should be controlled by installing variable frequency drives (VFD) on the fan motors. The VFDs are controlled by a temperature sensor mounted in duct collar. The control system varies the frequency of the motor drives and thus fan speed, according to the temperature seen in the duct collar. The VFD system varies the flow continuously as per the cooking requirement, as opposed to the high, medium and low speed settings on the motor controlled manually. The energy savings using VFDs result from the fact that the fan power, W is proportional to the third power of speed, N, that is, $W \propto N^3$.

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11.5 Underground Car Park Ventilation

11.5.1 *Requirement*

Ventilation is essential in enclosed car parking areas to dilute the level of toxic gases such as carbon monoxide (CO), oxides of nitrogen (NOx), presence of petrol/diesel fumes and smoke from engine exhaust. Carbon monoxide is a colourless, odourless and highly poisonous gas. Even dilute concentrations of CO in air can cause nausea, headache and vertigo. The undesirable health and fire hazard of the above contaminants can be contained if their levels are maintained within permissible limits by ventilation.

The ventilation rate required to maintain the concentration of toxic gases within safe limits for an enclosed parking facility depends primarily on four factors:

a) Numbers of cars in operation during peak usage (N),

b) *Length of time of operation* — The length of time a car remains in operation in a parking garage (T_m),which further depends on the size and layout of the garage and the number of cars trying to enter or exit. The time taken can vary from 60 s to 600 s, but on average ranges from 60 s to 180 s.

c) *Car emission rate* — The operation of a car in a parking garage differs considerably as compared to the car on the road or even in a road tunnel, because most of the operation of the car in and around the garage takes place at low gear. A car entering the garage is at slow speed but the engine is usually hot. A car exiting the garage has a cold engine with rich fuel mixture. Emissions from a cold start are generally much higher, so the distinction between a hot and cold start plays a critical role in determining the ventilation rate. Typical CO emissions (E) within parking garages can vary from 113 g/h (gram/hour) in summers to 202 g/h in extreme winters with hot engines. With cold start engines, the rates go up to 220 g/h in summers to as high as 1 130 g/h in winters. These rates are at an assumed vehicle speed of 8 km/h.

d) *Contaminant level criteria* — The recommended ventilation rate will ensure that the CO level is maintained within 40 mg/m^3 (35 ppm) for 1 h exposure, with a maximum of 29 mg/m^3 (25 ppm) for an 8 h exposure.

For a maximum permissible CO concentration of 29 mg/m^3, the required ventilation rate, Q, in m^3/h, for a given car park with number of cars in peak usage, N, may be calculated from the following equation:

$$Q = \frac{0.25N \times E \times T_m}{26.7}$$

where

N = number of cars in peak usage;

E = average CO emission per car, in g/h; and

T_m = average time a car remains operating in the car park, in s.

For a parking garage of area, A, in m^2, and height, H, in m, the resulting air changes per hour (ACPH) may be calculated as under:

$$ACPH = \frac{Q}{(A \times H)}$$

11.5.2 *Ventilation Rate Requirement of Mechanically Ventilated Underground Car Parks*

For enclosed underground car parks without provision for natural ventilation, a minimum ventilation rate of 6 air changes per hour shall be provided to keep contaminants within acceptable hygiene limits. In large basements, each compartment shall be independently ventilated at the minimum rate of 6 ACPH.

11.5.3 *System Requirement*

The underground car park ventilation system can be classified as supply-only, exhaust-only or a combination of the two. A system of ducts or impulse fans (jet fans) may also be used for proper distribution of air in the car park. Regardless of which system is used, the following elements should be considered in planning the system:

a) Accounting for the contaminant level of outside air drawn in for ventilation.

b) Avoiding short circuiting supply air.

c) Avoiding a long flow field that allows contaminants to exceed acceptable levels at the end of the flow field.

d) Providing short flow fields in areas of high contaminant emission, thereby limiting the extent of mixing.

e) Providing efficient, adequate airflow throughout the structure.

f) Accounting for stratification of engine exhaust gases when stationary cars are running in enclosed facilities, for example near entry and exit.

For underground car parking, the fans and the ventilation system used for normal CO level ventilation are also used for smoke ventilation during a fire. The extraction fans, ancillaries and the system should therefore be rated for high temperature operation including air changes per hour requirement, as specified in Part 4 'Fire and Life Safety' of the Code.

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11.5.4 *Demand Control Ventilation Based on CO Level*

The ventilation air flow rate can be varied according to CO level in order to conserve energy during off peak hours when vehicular movements is much lower than during peak hours. Since the flow rate of a fan is directly proportional to its speed, this can be achieved with multiple fans in an 'ON/OFF' mode, with dual speed motors or motors connected to variable speed drive (VFD). In multilevel basements as well as in large single level structures, independent fan system with individual control is required. This is to take care of fire compartmentation requirements (*see also* Part 4 'Fire and Life Safety' of the Code).

Significant energy savings are possible with demand control ventilation (DCV), which varies the fan speed to regulate CO levels below the maximum permissible level. The power consumed by a fan is proportional to the third power of its speed $\left(W \propto N^3\right)$. This means that even, if larger fans are installed to meet code requirements, power consumption will not necessarily increase as long as demand control ventilation is used.

11.5.4.1 *Location of sensors*

The sensors for demand control ventilation shall be placed in the following manner:

a) Maximum distance of any corner in the car park to the nearest sensor should be less than 25 m.
b) Sensors should be grouped according to the zone covered by the exhaust fan. The coverage area of each sensor should typically be 500 m^2.
c) Sensors should ideally be located between 0.9 m and 1.8 m above floor level. However, for practical reasons (in order to avoid vandalism), the sensors may be installed at just above 1.8 m height from floor.

11.6 Tunnel Ventilation System

11.6.1 *General*

The tunnel ventilation system (TVS) for underground metro station tunnel is intended to provide,

a) an acceptable environment in the tunnel and station trackway for the operation of trains;
b) pressure relief during normal operation;
c) heat removal during congested/maintenance operation; and
d) an effective means of controlling smoke flows during emergency conditions.

11.6.2 *Operation Philosophies*

There are three design operating conditions for the tunnel ventilation system, normal, congested and emergency.

During normal operation, the main source of ventilation for the tunnel is piston generated airflow produced by moving train. In congested operation, the tunnel ventilation fans (TVFs) are activated for preventing the accumulation of warm tunnel air around idling train in the affected ventilation zone. The tunnel ventilation design condition for congested train operation is maximum stratified tunnel air temperature of 46°C or 50°C (depends on the design of the rolling stock). In emergency operation, the TVS is set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for fire fighting purposes. The ventilation system is operated in a 'push-pull' supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction. A typical ventilation system in tunnel during fire on a train is shown in Fig. 1.

11.6.3 *System Description*

The tunnel ventilation system (TVS) consists of tunnel ventilation fans (TVFs), trackway exhaust fans (TEFs), tunnel booster fans (TBFs), tunnel ventilation dampers (TVDs), nozzles and sound attenuators provided in the tunnel ventilation plant rooms at each end of the station and connected to both trackways and to outdoors through ventilation shafts.

Each tunnel ventilation installation has two fully reversible tunnel ventilation fans with fan isolation dampers. These dampers are closed when the fan is not in operation. In addition, there is a bypass duct around the fan room, which acts as a pressure relief shaft when open during normal conditions, and enables the flow of air to bypass the TVFs, allowing air exchange between tunnel with flows generated by train movement. Dampers are also used to close the connections to tunnel and nozzles when under different operating conditions. The tunnel booster fans are installed at the crossover locations to direct the flow in desired direction during congestion and emergency ventilation. The trackway exhaust fans are located in separate plant rooms at each end of the station and connected to station trackway through under platform exhaust and over track exhaust ducts and to the outdoors through exhaust ventilation shafts, to enable independent ventilation of station trackway. The specialized software tools are used to derive the TVF airflow rate, TBF thrust and location and operation philosophy to be adopted to meet the design criteria of the above mentioned scenario. In addition to this, 3D modelling tools are used to study the temperature stratification in congestion mode.

A typical schematic of the TVS system installed at Delhi metro station at platform level is shown in Fig. 2.

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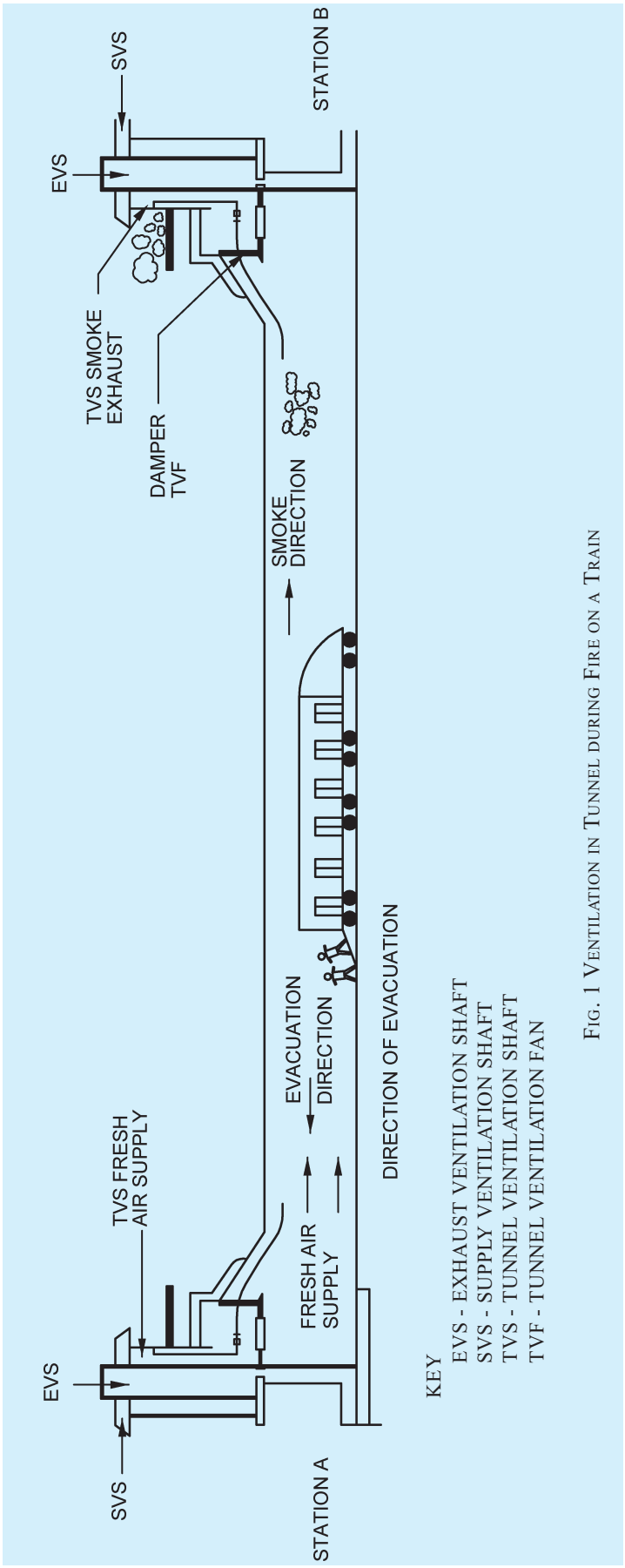


FIG. 1 VENTILATION IN TUNNEL DURING FIRE ON A TRAIN

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11.6.4 *Control and Monitoring of TVS*

The TVS system shall be equipped with provisions for automatic, manual, local and remote controls so that the fans and motors can be operated from a station control room (SCR) or from the operations control centre (OCC). At OCC, an integrated supervisory control and data acquisition system (SCADA), should be employed to control and monitor the TVS plant in each station, as the same are generally not attended locally.

11.7 Selection of Fan for Mechanical Ventilation

Fan consumes most of the energy in a mechanical ventilation system. Various type of fans are available for ventilation applications, for example, forward and backward curved centrifugal fan, tube axial/vane axial fan, mixed flow fan, roof ventilator and in-line fans. Proper selection and application of fan for a given application results in the most economic and energy efficient operation.

The primary factors that govern the size and type of fan are the required flow, system pressure drop and acceptable noise levels. The size of the fan and its operating speed should be selected on the basis of the fan operating efficiency criterion. A fan should be selected so that its efficiency at the required point of operation is the highest possible from a range of selections. This will not only ensure minimum motor power and low energy cost but will also normally result in the quietest operation. This is because most fans emit minimum sound levels in the vicinity of the maximum efficiency operating point.

11.7.1 *Fan Efficiency Requirement*

Fan total efficiency is defined as under:

$$\text{Fan total efficiency} = \frac{\text{Flow rate } (\text{m}^3/\text{s}) \times \text{Fan total pressure (Pa)}}{\text{Fan shaft power (W)}}$$

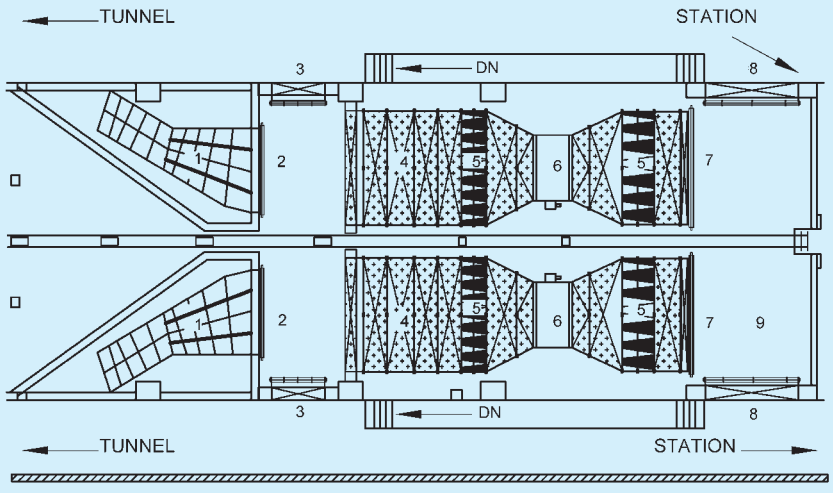
Fans are classified under various efficiency grade (FEG) based on their peak efficiency (*see* Fig. 3). The FEG grading is representative of the fact that larger size fan is inherently more efficient than geometrically similar smaller fan. The following selection criterion should be used to select fan for various type of mechanical ventilation applications for a new building:

a) For axial fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 60 or more.
b) For centrifugal fans requiring a shaft power of 2.5 kW or more, the fan efficiency grade shall be FEG 71 or more.

The minimum operating total efficiency of the selected fan at the desired point of operation for a given application shall be within 10 percentage points of its peak total efficiency value.

11.7.2 *Other Fan Selection Parameters*

In addition to the size and operating speed, the choice of a fan and its drive arrangement also depends on the



KEY

1 - NOZZLE
2 - NOZZLE DAMPER
3 - TUNNEL VENTILATION DAMPER
4 - DUCT
5 - ATTENUATOR
6 - TUNNEL VENTILATION FAN
7 - FAN ISOLATION DAMPER
8 - DRAFT RELIEF DAMPER
9 - SHAFT DAMPER

FIG. 2 TYPICAL SCHEMATIC OF THE TVS PLANT ROOM AT PLATFORM LEVEL

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nature of air to be handled and the type of application. If the fan has to handle dust laden or contaminated air, for example, industrial exhaust or kitchen exhaust, the fan drive arrangement (motor, pulleys, bearing and belts) shall be kept outside the air stream. The same applies to the temperature of air to be handled. For higher than normal air temperatures, for example, smoke ventilation, the fan shall be rated for high temperature application.

Because belt drives incur additional transmission losses, consideration should also be given to direct driven fan in conjunction with variable speed drive (VFD) to adjust fan speeds.

12 INSTALLATION OF HVAC SYSTEM

12.1 Installation of Air Conditioning System

12.1.1 *Installation of Chiller*

The chiller shall be mounted on a reinforced cement concrete/structural foundation and shall be adequately isolated as per manufacturer's recommendations against transmission of vibration to the building structure.

For open type, special attention shall be paid to the alignment of the drive and driven shaft; final alignment shall be checked at site in presence of the contractor, using a dial indicator.

Compressor and motor sole plates, anchor bolts, sleeves and necessary vibration isolation pads shall be provided with the chiller.

All controls and switch gear shall be tested for proper functioning and set at design values. These shall be mounted within a panel, installed so as to permit enough space to move around the machine, and to freely operate the door of panel.

12.1.2 *Installation of Pump*

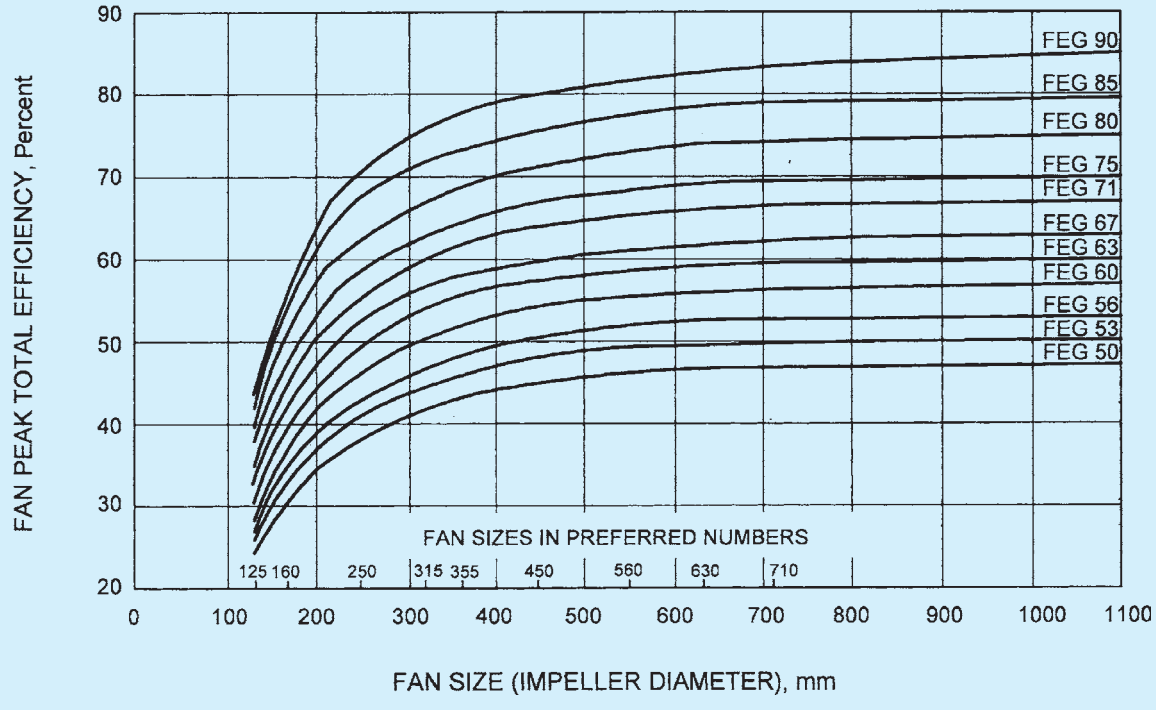
The pump base frame shall be mounted on concrete block which in turn shall be mounted on machinery isolation cork or any other equivalent isolation material. More than one pump set shall not be installed on a single base or on a single cement concrete block.

Foundation bolts where required, shall be embedded correctly. Before the bolts are grouted and the coupling bolted, the base frame level shall be checked before proceeding with work.

The pump motor shall then be mounted on base frame, alignment checked, and shall then be connected to the pump with flexible coupling and with guard, both for the condenser and chilled water pumps.

The insulation for chilled water pump shall be carried out in a manner so that it allow maintenance of the pump without causing damage to the insulation.

After installation of the complete system and before



NOTE — Beyond 1100mm diameter size, the FEG lines are horizontal.

FIG. 3 FEG RATING OF FANS FOR VARIOUS IMPELLER DIAMETERS

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testing, the pump shall be lubricated in strict accordance with the manufacturer's instructions.

12.1.3 *Installation of Cooling Tower*

The cooling tower shall be mounted on a set of four or six numbers of reinforced cement concrete pillars (structural foundation) as per manufacturer's recommendations. Height of these pillars shall be not less than 1 000 mm, actual height is decided at site as per space required to install a pot strainer below the water level in cooling tower sump, drain pipe and valve for complete drainage of sump, and to permit maintenance of slab upon which structural foundation is installed.

Cooling tower should be located at a well-ventilated place, preferably on the terrace of the building, in consultation with the structural consultant. Dynamic structural loading on the terrace shall be considered. Cooling tower shall be installed in such a way that its dynamic load is transferred directly to the building structural columns, for which necessary mild steel I-section may have to be provided. Epoxy coating is required for these mild steel I-sections. Suitable thickness of vibration isolation pads shall be placed between the tower and the I-sections to avoid transfer of vibration to building structure. Sufficient space shall be left all around the cooling tower support structure for efficient operation of the cooling tower.

When cooling tower is installed at ground level, contiguous to the utility services block, great care has to be exercised to prevent users and visitors from coming in close proximity to the cooling tower. This is necessary to avoid their exposure to legionellae bacteria which can hibernate in the cooling tower sump, if operator does not follow strict instructions for regular bleed-off and chemical treatment of condenser water.

12.1.4 *Installation of Air Handling Unit* (*AHU*)

12.1.4.1 Floor mounted air handling unit is generally installed on a set of precast PCC blocks to raise it off the mounting surface to permit easy drainage of the AHU drain pan and cleaning of the mounting surface. A set of 4 or 6 numbers of 200 mm × 200 mm × 200 mm blocks are generally used for AHUs up to capacity of 10 000 m^3/h air-flow, and 6 or more 300 mm × 300 mm × 300 mm blocks for higher capacity AHU.

It is essential to provide floor trap in the AHU room for disposal of condensate which accumulates in the drain pan during operation of AHU. AHU room floor should slope in the direction of floor trap to avoid the accumulation of water in AHU room. Also the slope of the drain pan should be checked in the direction of drain pipe connection, to ensure zero retention in the drain pan, precluding possibility of legionellae bacteria hibernation. The condensate drain piping shall be connected with U-trap of the floor drain to avoid odour carry over with the return air.

AHU location shall be marked on the AHU floor as per approved shop drawings/manufacturer's details. Co-ordination with contractors for civil works and other services shall be checked prior to installation. AHU shall be assembled at site and installed on vibration isolation pad placed upon each PCC block, as per manufacturer's recommendations against transmission of vibration from AHU to the building structure (*see also* **12.6**).

Easy accesses and sufficient clearance shall be ensured for servicing and maintenance, that is, for cleaning of filters, maintenance of strainer/valve packages, tightening of fan belts, and repair as well as possible replacement of fan motor.

Duct flexible connection made of fire-proof canvas, shall be fixed on air outlet of the AHU, and if possible also in perpendicular direction in main ducts within AHU room, to avoid vibration transmission along the ducts beyond the AHU room.

The valve package and piping connections shall be completed as per approved shop drawings.

12.1.4.2 Installation of ceiling suspended air handling unit shall be done with rod and fasteners as per the procedure stated above, barring the PCC blocks required for floor mounted AHU, and that insulated condensate drain pipe shall be laid in slope within ceiling space terminating into the U-trap of the nearest floor drain.

12.1.4.3 Since the AHUs have the tendency to vibrate, both floor mounted and ceiling suspended AHUs shall be isolated from the structure by suitable rubber or spring based isolators (*see* **12.6**).

12.1.5 *Installation of Air Washer Unit (AWU)*

Air washer unit (AWU) components are similar to those of AHU, except for water spray section with in-line recirculation pump, which replaces the cooling coil. Installation of AWU shall follow the same steps as described above for AHU. Ceiling suspended AWU is not recommended.

12.1.6 *Installation of Axial Fan*

Axial fan is manufactured in vane-axial and tube-axial configuration, and is generally mounted in-line, suspended from ceiling. Special care is required for its mounting to minimize noise and vibration transmission to the structure and also to the connecting duct work. The fan is generally mounted on two

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numbers of mild steel channels of size 100 mm × 50 mm × 5 mm, welded onto mild steel plate of 6 mm thickness, finished with 2 coats of red oxide and one coat of epoxy based enamel paint. Support rods for hanging the plate shall be cut and trimmed after finalizing the levels; extra length of 25 mm of support rods should be left for final adjustments. Burrs and sharp edges should be removed before applying finishing coat of paint.

All necessary accessories, as below, shall be provided for proper installation:

a) Vibration isolators for the axial fans;
b) Double canvas connection (of fire retardant material) at the outlets of each fan;
c) Acoustic silencers at inlet and outlet of the fan as per manufacturer's instructions; and
d) Bird screen for the protection from extraneous elements, specially at fresh air intake and at exhaust outlet to outdoor.

Axial fan shall be installed in a manner so as to allow easy maintenance of the fan, its accessories, and easy service and possible replacement of fan motor. Field balancing shall be done.

Upon completion of installation, capacity of axial fan shall be measured by an anemometer. Power consumption shall be computed from measurements of incoming voltage and input current. Measured values shall conform to the data given by the vendor in technical submittal.

12.1.7 *Installation of Ducting Works*

The material and constructional requirements for ducts shall conform to the accepted standard [8-3(4)]. The installation of sheet metal duct work for air distribution and also its associated items, such as, air outlets and inlets, fresh air intake and smoke/fire dampers are covered in **12.1.7.1** to **12.1.7.3**.

12.1.7.1 *Duct support and hangers*

Supporting details for low pressure rectangular ducting system are given below:

Larger Side of Duct	*Supporting Angle*	*Vertical Rod Diameter*	*Maximum Spacing between Supports*
mm	mm	mm	mm
Up to 900	40 × 40 × 5	8	2 400
901 to 1 500	40 × 40 × 5	8	2 400
1 501 to 2 400	40 × 40 × 5	10	2 400
2 401 and above	65 × 65 × 5	12	2 400

Supporting details for high pressure rectangular ducting system are given below:

Larger Side of Duct	*Supporting Angle*	*Vertical Rod Diameter*	*Maximum Spacing between Supports*
mm	mm	mm	mm
Up to 1 250	50 × 50 × 5	12	2 400
1 251 to 2 100	65 × 65 × 5	12	2 400
2 101 and above	75 × 75 × 5	15	2 400

Installation of other types of ducts and supports may be decided in consultation with the specialist structural designers. However, all safety and performance criteria in accordance with this Section shall be complied with in all cases.

12.1.7.2 *Damper*

Volume control damper shall be provided at the junction of each branch duct with main duct. Dampers shall be 2 gauge heavier than the gauge of large duct but should not be less than 20 gauge, and shall be rigid in construction so as not to flutter with the passage of air.

12.1.7.3 *Access door*

Access door shall be provided in duct before and after any equipment like in-line fan installed in duct. Access door shall also be provided before every smoke/fire damper locations. Access door shall be fabricated of the same material as the duct work and shall have minimum two hinges. Hinges shall be zinc plated and pins shall be of brass. Access doors shall be of minimum 305 mm × 305 mm size. At least two heavy solid fasteners and a brass handle shall be provided for each door. A continuous neoprene rubber gasket shall be fixed with adhesive to the opening frame.

12.1.8 *Installation of Piping Works*

Design, choice of materials, and the installation of chilled water/condenser water/drain water pipes, pipe fittings and valves shall conformed to relevant Indian Standards and shall meet the requirements of pressure rating for the system.

Chilled/condenser/hot water pipes of sizes up to 150 mm shall be heavy class, ERW mild steel black pipes conforming to the accepted standard [8-3(14)] and those of sizes above 150 mm shall be ERW/SAW pipes of Grade 330 conforming to the accepted standard [8-3(15)].

Piping shall be properly supported on, or suspended from, stands, clamps, springs, hangers, as required at site. Design of all the brackets, saddles, anchors, clamps and hangers shall be as per requirement identified by the system designer.

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All pipes within HVAC plant room shall be supported off the floor of the plant room, and rest from the ceiling, with engineered support structures made of pipes and channels, with pipe always resting on the necessary high density PUF/wooden haunches. Minimum requirements in respect of support details, for horizontal and vertical chilled water pipes with mild steel channel and angle sections, are given in Table 13.

The recommended spacing between supports for various pipe sizes are given below:

Pipe Size mm	*Spacing Between Supports* m
Up to 12	1.5
15 to 25	2.0
30 to 250	2.0
Above 250	2.5

All pipe supports shall be of steel, coated with two coats of anti-corrosive paint and finally finished with epoxy paint. Where pipe and clamps are of dissimilar materials, a gasket shall be provided in between.

Vertical pipes passing through floors shall be parallel to wall and should be straight to wall duly checked with plumb line.

Wherever pipes pass through the brick or masonry/slab openings, the gaps shall be properly sealed as per the provisions given in Part 4 'Fire and Life Safety' of the Code.

Wherever insulated pipes are installed, pipes should be supported in such a way that no undue pressure is exerted on the insulation material.

Piping layout shall take due care of expansion and contraction in pipes, and shall include expansion joints, where required.

All pipes shall be accurately cut to the required size in accordance with relevant Indian Standards, edges beveled and burrs removed before laying. Open ends of the piping section shall be closed as the pipe is installed to avoid entrance of foreign matter. Where reducers are to be made in horizontal runs, eccentric reducers shall be used for the piping to drain freely. In other locations, concentric reducers may be used.

Auto purge valves shall be provided at all highest points in the piping system for venting air. Air valves shall be 15 mm pipe size with screwed joints. Discharge from the air valves shall be piped through an equal sized mild steel or galvanized steel pipe to the nearest drain or sump. These pipes shall be pitched towards drain points.

Drain pipes shall be provided at all the lowest points in the system, as well as at equipment where leakage of water is likely to occur, also to remove condensate and water from pump glands. The drain pipe work can be carried out with threaded joints or simply welded.

12.1.9 *Installation of Insulation Works*

Fixing of thermal/acoustic insulation of ducts, pipes with valves and equipment room shall be done in accordance with **12.1.9.1** to **12.1.9.4**.

12.1.9.1 *Material*

Selection of material shall be as per design requirement, such as,fibre glass, closed cell flexible elastomeric foams, expanded/extruded polystyrene (EPS/XPS) and polyurethane foam (PUF). The guidelines for insulating with fibre glass are given below; for other insulation materials, manufacturers' recommendations for installation should be followed.

12.1.9.2 *Thermal insulation of duct*

Surface of duct, on which the external thermal insulation is to be provided, shall be thoroughly cleaned with wire brush and rendered free from all dust and grease. Then, two coat of cold-setting adhesive compound (environment friendly), should be applied over the duct surface.

Table 13 Support Details for Chilled Water Pipe

(*Clause* 12.1.8)

All dimensions in millimetres.

Sl No. (1)	Pipe Size (2)	Ceiling Support (3)	Base Support (4)	MS Plate Size (5)	Fastener Size (6)
i)	Horizontal chilled water pipe support (for one pipe):				
a)	Up to 50	40 × 40 × 5 thick angle	40 × 40 × 5 thick angle	Cleat ISA 75 × 75 × 5	M10 × 2 numbers
b)	65 to 125	50 × 50 × 6 thick angle	75 × 40 MS channel	250 × 250 × 8 thick	M10 × 4 numbers
c)	150 to 250	75 × 40 MS channel	100 × 50 MS channel	250 × 250 × 8 thick	M10 × 4 numbers
d)	300 to 350	100 × 50 MS channel	150 × 75 MS channel	300 × 300 × 10 thick	M12 × 4 numbers
e)	400 to 500	100 × 100 × 6 MS channel box	150 × 150 × 6 MS channel box	400 × 400 × 10 thick	M16 × 4 numbers
f)	600 to 700	150 × 150 × 6 MS channel box	150 × 150 × 6 MS channel box	400 × 400 × 12 thick	M16 × 4 numbers
ii)	Vertical chilled water pipe support (for one pipe):				
a)	65 to 125	—	75 × 40 MS channel	250 × 250 × 8 thick	M10 × 4 numbers
b)	150 to 250	—	100 × 50 MS channel	250 × 250 × 8 thick	M10 × 4 numbers

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The thermal insulation material should then be wrapped around the duct with aluminium facing on outer side. Joints of insulation should be properly sealed with either same type of material or aluminium tape of 50 mm width on all longitudinal/transverse joints. Finally PVC straps should be fixed at suitable interval to ensure that the insulation is properly fixed with the ducts.

The insulation should then be covered with 0.63 mm × 19 mm galvanized iron (GI) wire mesh netting on the outside of the duct, where it is exposed to the weather and should be additionally covered with either a layer of tar-felt, or two coats of 10 mm thick sand cement plaster.

12.1.9.3 *Acoustic lining of duct*

Acoustic lining of duct should be carried out as follows:

a) The inside surface of duct on which the acoustic lining is to be provided should be thoroughly cleaned with wire brush and rendered free from all dust and grease.
b) The material to be used for duct lining should be 12/25 mm thick resin bonded fibre glass rigid board having a density of 48 kg/m^3. The board should be fixed inside the duct using suitable adhesive and covered with fibre glass tissue paper.
c) The insulation board should then be covered with 0.5 mm thick perforated aluminium sheet with at least 20 to 40 percent perforation.
d) The insulation board and aluminium sheet should be secured with cadmium coated bolts, nuts and cup washers/steel screws.
e) Finally the ends should be sealed completely, so that no lining material is exposed.

The lining of initial length of the duct may have to be done as per the requirement at site.

Alternatively, open cell flexible elastomeric foams or fire retarding foam board panels, specially formulated to attenuate noise may also be used. These should be fixed inside the duct with special eco-friendly cold-setting adhesive compound.

12.1.9.4 *Acoustic lining in equipment room*

Acoustic treatment in equipment room to prevent noise transmission to adjacent occupied areas should be provided on the walls and ceiling of equipment room with acoustic lining of thermal insulation material. The process should be as below:

a) Wall/roof surface should be thoroughly cleaned with wire brush.
b) A 610 mm × 610 mm frame work of 25 mm × 50 mm × 25 mm or 50 mm × 50 mm × 50 mm 'U' shape channel, for 25 mm or 50 mm thick acoustic lining respectively, made of 0.6 mm thick galvanized steel sheet should be fixed on to walls leaving 610 mm gap above floor (to prevent damage from flooding) by means of wall plug/screw anchors in walls. Similar frame work should also be fixed on ceiling by means of dash fasteners.
c) Resin bonded glass wool/mineral wool as specified, cut to size should be fitted in the frame work and covered with fibre glass tissue paper.
d) Surfaces should be finished by covering with 0.5 mm thick perforated aluminium sheet having perforation 20 to 40 percent with brass screws.
e) All horizontal and vertical joints should be covered with at least 25 mm wide, 1 mm aluminium strips held in position by steel or brass screws.

12.1.9.5 *Insulation of CHW/HW refrigerant pipes*

Pipe insulation material should be EPS/XPS/PUF/ closed cell flexible elastomeric foam/fibre glass as per requirement, specified with suitable density and thickness. Adhesive used for setting the insulation should be non-flammable, vapour proof, cold-setting, eco-friendly compound. Generally, pipe insulation material is available in pre-moulded pipe insulation sections, which should be applied to the pipe surface and sealed as described below:

a) The pipe to be insulated should be cleaned thoroughly with steel brush for removing dirt, rust and grease.
b) A coat of zinc chromate primer and two coats of cold setting adhesive compound should be applied on pipes.
c) Insulation of specified thickness should be fixed tightly and all joints should be sealed with adhesive compound.

The insulation should then be finished as per the specific requirement of the site, as given below:

1) *Inside the building* — Insulation over the pipe work exposed in the building should be finished with specified thickness of aluminium sheet cladding, over a vapour barrier, with 50 mm overlap and tied down with lacing wire.
2) *Outside the building* — Insulation over the pipe work exposed to weather should be finished with vapour barrier, and 12 mm thick cement-sand plaster in two layers of 6mm thick each, followed by curing of minimum 48 h.
3) *Buried pipe insulation* — For pipes outside the building and laid underground, the insulation should be covered with suitable

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gauge polythene faced hessian, (the polythene facing outward), with 50 mm overlap. All joints should be sealed with bitumen. A layer of 0.50 mm × 20 mm GI wire mesh netting should be provided over it butting all joint, and it should be laced down with GI wire. A 20 mm thick cement-sand plaster (1 : 4) should be provided in 2 layers of 10 mm thickness each and should be water proofed by applying hot bitumen and fixing tar-felt over the plaster. It should be finally finished with a coat of hot bitumen.

4) *Pump insulation* — Chilled water pump should be insulated to the same thickness as the pipe to which they are connected and application should be same as above. Care should be taken to apply insulation in a manner as to allow the dismantling of pumps without damaging the insulation.

5) *Insulation of valves and fittings in chilled water line* — All valves, fittings, strainers, etc, should be insulated to the same thickness and in the same manner as for the respective piping, taking care to allow operation of valves without damaging the insulation.

12.2 Installation of Split Air Conditioners

Split air conditioners shall be installed as per the procedure given below:

a) The outside unit shall be installed on a place solid enough to bear the weight and vibration of the unit, where the operation sounds will not be amplified. The location shall be such that the hot air discharged from the unit or the operation sounds may not disturb the surroundings.

b) All piping, fittings, and insulation shall then be installed as per manufacturer's requirements. The units shall be installed in level and plumb. Evaporator-fan components shall be installed using manufacturer's standard mounting devices securely fastened to building structure. Refrigerant tubing and fittings shall then be installed and connected.

c) The clearance for maintenance shall be maintained while selecting the location. Sufficient space for air passage around the unit for air inlet and the air outlet shall be provided. The site shall be free from the possibility of flammable gas leakage in a nearby place. The inside and outside unit's power cords and inter-unit wire shall preferably be kept at least 3 m away from television and radio sets to avoid interference to images and sounds.

d) After piping has been completed, the refrigerant piping system shall be pressure tested at a pressure of 21 kg/cm² on the high side and 10 kg/cm² on the low side. The pressure shall be maintained on the system for a minimum of 12 h. The system shall be evacuated when the surrounding ambient air is not less than 16°C. A minimum vacuum of 500 microns of Hg shall be pulled on the system and maintained for 12 h. The system shall be charged as recommended by the equipment manufacturer.

e) *Start-up* — Manufacturer or factory-authorized service representative shall be engaged to perform start-up service. Manufacturer shall provide on-site start-up and commissioning assistance through job completion. Installation and start-up checks shall be completed according to manufacturer's written instructions.

12.3 Installation of VRF Systems

VRF systems shall be installed as per the procedure given below:

a) All piping, fittings, and insulation shall be installed to meet manufacturer's requirements. Units shall be installed in level and plumb. Evaporator-fan components shall be installed using manufacturer's standard mounting devices securely fastened to building structure. Refrigerant tubing and fittings shall then be install and connected.

b) Installer shall supply isolation ball valves for zoned refrigerant isolation. Installer shall supply isolation ball valves with Schrader connection for isolating refrigerant charge and evacuation at each connected inside unit and condensing unit. Isolation ball valves, with Schrader connection, are required for instances of inside unit isolation for troubleshooting, repair, or replacement without affecting the remainder of the system. These are also required at condensing unit connection to isolate unit for troubleshooting, repair or replacement and as required to provide partial capacity heating/cooling in the instance of a failure of one of the multiple outdoor unit (condensing unit) compressors.

c) During brazing an inert gas (such as nitrogen) shall be continuously passed through the system at a rate sufficient to maintain an oxygen free environment to prevent the formation of copper oxide scale. After piping has been completed, the refrigerant piping system shall be pressure tested at a pressure of 21 kg/cm² on the high

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side and 10 kg/cm² on the low side. The pressure shall be maintained on the system for a minimum of 12 h. The system shall be evacuated when the surrounding ambient air is not less than 16°C. A minimum vacuum of 500 microns of Hg shall be pulled on the system and maintained for 12 h. The vacuum pump displacement shall be not less than 4 CMH for up to 15 t. The system shall be charged as recommended by the equipment manufacturer.

d) Electrical wiring, both high and low voltage, shall comply with the requirements laid down in Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

e) *Start-up* — Manufacturer or factory-authorized service representative shall be engaged to perform start-up service. Manufacturer shall provide on-site start-up and commissioning assistance through job completion. Installation and start-up checks shall be completed according to manufacturer's written instructions. This shall include a factory start-up for factory provided control devices as well as configuring control points for other devices. Service representative shall completely configure all control devices.

f) *Demonstration* — Manufacturer or factory-authorized service representative shall also be engaged to train owner's maintenance personnel to adjust, operate and maintain individual units and complete system. This shall include training of the owner's energy management department representatives.

g) The indoor units and outside condensing units shall be installed in accordance with the manufacturer's recommendations and as shown on the shop drawings.

12.4 Installation of Mechanical Ventilation System

12.4.1 *Installation of Equipment*

12.4.1.1 In selecting the location of equipment room, aspects of efficiency, economy and good practice should be considered and wherever possible, it shall be made contiguous with the building. This room shall be located as centrally as possible with respect to the area served and shall be free from obstructing columns. Equipment room should preferably be located adjacent to external wall to facilitate equipment movement and ventilation. It should also be close to main electrical panel of the building, if possible, in order to avoid large cable lengths.

12.4.1.2 Location and dimensions of shafts and openings in walls, slabs and roof for ducting, cables, pipes, air intakes and exhaust (if envisaged) should be planned at the concept stage itself. Shafts should be located adjacent to the equipment or within the room itself.

Evaporative cooling units (air washers) should be located preferably on summer-windward side. They should be painted white or with reflective coating or thermally insulated, so as to minimise solar heat absorption.

In locating the units, care should be taken to ensure that their noise level is not objectionable to the neighbours.

Exhaust air devices, preferably on leeward and overhead side may be provided for effective movement of air.

The equipment room should be adequately dimensioned keeping in view the need to provide required movement space for personnel, space for entry and exit of ducts, the need to accommodate air intakes and discharge, operation, maintenance and service requirements. In case the equipment is located in basement, equipment movement route shall be planned to facilitate future replacement and maintenance. Service ramps or hatch in ground floor slab should be provided in such cases. Also, arrangements for floor draining should be provided.

In the case of large installations, it is advisable to have a separate isolated utility services block.

12.4.1.3 The floor of the equipment room should be light coloured and finished smooth with epoxy coating. For floor loading, the air conditioning engineer should be consulted (*see also* Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code).

Arrangements for draining the floors shall be provided. The trap in floor drain shall provide a water seal between the equipment room and the drain line. Water proofing shall be provided for floor slab of evaporative cooling unit room, AHU room and AWU room.

12.4.1.4 Supporting of water pipe within equipment room spaces should be normally from the floor. However, outside equipment room area, structural provisions shall be made for supporting the water pipes from the floor/ceiling slab. All floor and ceiling supports, make-up and drain connection pipes, ducting cables/cable trays, etc, shall be isolated from the structure to prevent transmission of vibrations.

12.4.1.5 Plant machinery in the plant room shall be placed on plain/reinforced cement concrete foundation and provided with anti-vibratory supports. All foundations should be protected from damage by providing epoxy coated angle nosing. Seismic restraints requirement may also be considered.

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12.4.1.6 Wherever necessary, acoustic treatment should be provided in plant room space to prevent noise transmission to adjacent occupied areas.

12.4.1.7 In case of large and multistoried buildings, independent ventilation/air washer units should be provided for each floor. The area to be served by the ventilation system should be decided depending upon the provision of fire protection measures adopted. All such units should preferably be located vertically one above the other to simplify location of pipe shafts, cable shafts and drain risers.

12.4.1.8 Openings of adequate size should be provided for intake of fresh air. Fresh air intake shall have louvers having rain protection profile, with volume control damper and bird screen. Outdoor air intakes and exhaust outlets shall be effectively shielded from weather and insects. Minimum distance of air intakes from exhaust outlets or from sources whose contamination concentration levels are greater than normal in the locality in which the building is located, shall be so as to avoid short circuiting of air.

12.4.1.9 Access doors to equipment rooms should be through single/double leaf type, air tight, opening outwards and should have a sill to prevent flooding of adjacent occupied areas.

12.4.1.10 It should be possible to isolate the equipment room in case of fire. The door shall be fire resistant. Smoke damper shall be provided in each supply/return air duct at fan room, air handling unit room and air washer unit room wall crossings. The annular space between the duct and the wall should be fire sealed using appropriate fire resistance rated material. Fire-rated access panel shall be provided in the supply and return air ducts, within equipment room, to inspect the smoke damper at wall crossings.

12.4.2 *Energy Efficient Installation of Ventilation Fans*

The performance of a fan when installed in a system can be adversely affected by the flow conditions at fan inlet and outlet. Manufacturers' fan performance ratings are mostly based on optimum arrangements of fan inlet and outlet connections to provide uniform straight flow condition. Any deviation from this will result in additional pressure losses known as fan system effects and therefore cause deficient fan performance. Provisions in **7.2.8.4** and **7.2.8.5** should be followed to minimise fan system effects and ensure efficient fan performance.

12.4.3 *Safe Installation Practices for Fans*

Same installation practices for fans as given below shall be followed:

a) *Centrifugal fans:*
   1) The concrete foundation for the fans, wherever required, shall be prepared and shall have the foundation bolts and base plates. Foundation bolts and base plates should be placed securely in proper position while the foundation is cast. Else the fan shall be mounted on suitable channel frame.
   2) Vibration isolation base for both fan and motor should be built as an integral part and be mounted on concrete foundation through anti-vibration isolator having an efficiency of 90 percent.
   3) Fan outlet connections should be by means of flexible fire retardant canvas connections.
   4) At the free suction side, safety screen shall be provided.
   5) For belt driven fans, removable belt guard should be provided.
   6) For direct driven fans, removable coupling guard should be provided.

b) *Axial flow fans:*
   1) Removable safety screens should be provided on either side of fan.
   2) The fans shall be properly grouted on the walls with vibration isolator pads. Vibration isolators shall also be used for suspended fans (from ceiling or primary support).
   3) For ducted application, the fans shall be connected to the duct by means of flexible fire retardant canvas connections.

c) For fans placed in cabinets, the following shall be provided/carried out:
   1) *Door interlock with limit switch* — to switch off the fan and switch on the bulkhead lamp when fan section door is opened.
   2) Safety screens at free fan inlets and outlets.
   3) Adequate lighting in the fan section.
   4) Water drain in fans section.
   5) Transparent inspection windows of minimum 150 mm diameter.
   6) Lockable doors.
   7) Adequate space around fan/motor for ease of service/maintenance.

In case of large size cabinet fans where plug fans (exposed impeller) are provided, double doors at the fan section shall be provided along with limit switch as an added safety precaution.

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12.5 Fire Control

The requirements for smoke control systems are with the objective to accomplish one or more of the following:

a) Inhibit smoke from entering stairwells, means of egress, smoke refuge areas, elevator shafts, or similar areas.

b) Maintain a tenable environment in smoke refuge areas and means of egress during the time required for evacuation.

c) Inhibit the migration of smoke from the smoke zone.

d) Provide conditions outside the smoke zone that enable emergency response personnel to conduct search and rescue operations and to locate and control the fire.

e) Contribute to the protection of life and to the reduction of property loss.

The smoke control system shall meet the requirements of Part 4 'Fire and Life Safety' of the Code.

12.6 Vibration Isolation

The objective of vibration isolation is primarily to minimise the effect, of the dynamic forces generated by moving parts in a machine, being transmitted into the surrounding structure.

This is accomplished by incorporating a resilient material, which when subjected to a static load, deflects and by so doing establishes the natural frequency of the isolation system. The disturbing frequency, f_d, of a machine may be readily determined either by measurement or by the known operating characteristics of the equipment. Generally the lowest revolutions per minute (r.p.m.) in the system is used as the disturbing frequency.

The natural frequency, f_n, of a machine set on resilient material is a function of the static deflection of the resilient material under the imposed load. For practical purposes the natural frequency f_n is described by the formula:

$$f_n = \frac{946.5}{\sqrt{d}}$$

where

d = static deflection, in mm.

The ratio (f_d/f_n) establishes the efficiency of the isolation from the following formula:

$$E = 100.1 - \frac{1}{\left(\frac{f_d}{f_n}\right)^2 - 1}$$

where

E = percentage of vibration isolated;

f_d = disturbing frequency of the isolated machine; and

f_n = natural frequency of the isolated machine.

The percentage of isolation efficiency attained is a measure of the amount of reduction in the amplitude of the transmitted mechanical vibration. Reference may be made to Fig. 4 to readily select the static deflection required to attain desired isolation efficiency.

The percent of isolation efficiency may be determined from Fig. 4, by reading from the graph at the intersection of vibration (disturbing) frequency and static deflection.

12.6.1 *Vibration Transmission and Noise*

Noise and vibration are intrinsic components of several activities in which machinery with moving parts are used. The positioning of anti-vibration devices between the machinery and their support structure acts as isolation, without any intervention on the balancing of the machine itself.

12.6.2 *Vibration Isolation of Mechanical Equipment*

Three principle factors control the selection of an isolator for a particular machine. The first is the weight to be supported, the second is the disturbing frequency of the machine and the third is the rigidity of the structure supporting the machine.

The normal method to isolate the vibration from building services plant is to support the equipment on resilient supports or isolators, for example, helical steel springs; rubber blocks or pads. These resilient supports or isolators, otherwise known in the building services industry as anti-vibration mounts (AVMs), shall be selected and positioned carefully. Incorrect specification and use can equally worsen the vibration problem. Most anti-vibration devices are generally elastomer based, elastomer/metal bonded, springs or fluid based.

12.6.3 *Selection of Suitable Anti-Vibration Mounts*

The following steps may be used for calculation of load and for the selection and positioning of the anti-vibration mount for equipment and for building services pipe work.

a) *Estimating the force or load on each mounting point* — The weight distribution at each mounting point is dependent on the position of that point relative to the centre of gravity of the total mass. The equipment manufacturer shall provide the equipment weight and the centre of gravity. The load on each mounting point may be calculated by taking moments about each mounting point. These calculations may be performed manually, if there are 4 mounting points, each at the corner of a rectangular base. However, if there are more than 4 points, or the base is not rectangular, then the calculations are more complex and computer programs should be used.

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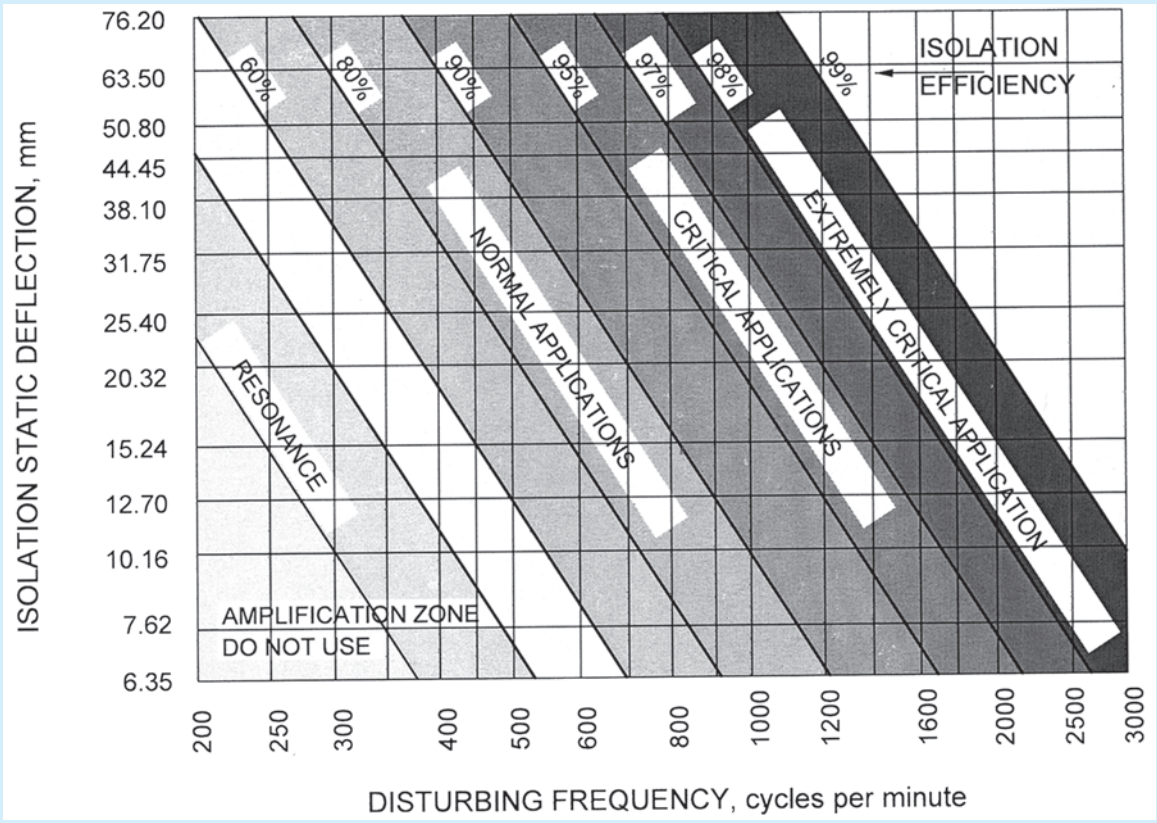


FIG. 4 STATIC DEFLECTION REQUIRED FOR DESIRED ISOLATION EFFICIENCY

b) *Selecting the type of anti-vibration mount* — Once the load on each mounting point has been calculated, or if the information was given directly by the manufacturer, designer shall evaluate to decide which type of mount is best suited for the type of equipment being supported, operating speed (speed of rotation), the supporting building structure, environmental conditions (for example, wind loadings) and space availability, and then select the appropriate mount.

The mathematical model used for the selection of the anti-vibration mounts is a simple spring/ mass arrangement, based on the principle of supporting mass being very large compared with the equipment mass. In practice, if the equipment is placed on suspended supports of increasing span, then these act as further 'springs' in the model, which require a higher performance from the anti-vibration mount. This usually means higher deflection in the case of a spring mount, although the amount of damping offered by the anti-vibration mount may also need to be increased when faced with light weight structures and 'live' steel frameworks.

c) *Selecting the size or load rating of the anti-vibration mount* — Having established the equipment load and type of mount, the next step is to determine the load rating of the mount. The selection will depend upon the load, the speed of rotation (usually the lowest) and the isolation efficiency required. Charts are available for prediction of the isolation efficiency based upon the speed of rotation and the percentage loading of the spring. When selecting rubber mounts, these charts will only give an approximate indication of the isolation efficiency, because rubber has high inherent damping properties that reduce the maximum efficiency attainable.

For each of the load points in turn, one has to look on the selected anti-vibration mount data sheet, and find the next highest load rating. Dividing the actual load by the mount load rating, gives the percentage loading.

12.6.4 *Seismic Isolation of Non-Structural Components*

In addition to the structural framing and the floor and roof systems, buildings include many components and systems which are not structural in nature, but these can be damaged by earthquake effects. These include,

a) mechanical components and systems including air conditioning equipment;

b) electrical components including transformers, switchgear, motor control centres, lighting, and raceways;

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c) fire protection systems including piping and tanks; and

d) plumbing systems and components including piping, fixtures, and equipment.

The design and installation requirements should ensure that,

1) most of these components are adequately attached to the supporting structure so that earthquake shaking does not cause them to topple or fall, injuring building occupants or obstructing exit paths.
2) those pieces of equipment and components which are required to provide for the safety of building occupants (for example, emergency lighting and fire suppression systems), continue to function after an earthquake.
3) non-structural components critical to the operability of essential facilities, such as, hospitals, airports continue to operate following strong earthquake shaking. These facilities (buildings) include,
   i) hospitals,
   ii) airports,
   iii) emergency response centres,
   iv) data centres, and
   v) buildings vital to national defence.

Their design shall conform to the available standards and specialist literature. The performance objecives and compliance method and expectations are given in Table 14 and Table 15.

Table 14 Non-Structural Seismic Performance Objectives
(*Clause* 12.6.4)

Sl No. (1)	Performance Objective (2)	Design Objective Description (3)
i)	Position retention	Maintain positive retention of non-structural position, under design level earthquake demands, without consideration of frictional resistance produced by the effects of gravity. This includes position retention of non-structural anchorage, attachments and the force resisting skeleton.
ii)	Systems interaction avoidance	Account for unwanted interaction, under design-level earthquake demands, between non-structural systems and anything else (building elements or other installed non-structural systems) that might be located in the immediate vicinity of the non-structural installation, so that failure of one system or contact between systems does not cause consequential damage of an essential system.
iii)	Active operation	Maintain active operation functionality of mechanical and electrical equipment and distribution systems following (that is, not during) application of design level earthquake demands.

Table 15 Non-Structural Seismic Compliance Methods and Expectations
(*Clause* 12.6.4)

Sl No. (1)	Performance Objective (2)	Validation Method (3)	Compliance Expectation (4)
i)	Position retention	a) Analysis	Seismic calculation and analysis may be used to validate that non-structural anchorage, force resisting skeleton and attachments have position retention capacity equal to or greater than the project-specific design-level demand for the application installation location. Both strength design and allowable stress design approaches are accepted.
		b) Experience data	The use of earthquake experience data, based upon nationally recognized procedures, may be used to establish non-structural position retention capacity provided that the substantiated seismic capacities equal or exceed the project specific design-level demand for the application installation location.
		c) Testing	The use of seismic simulation testing, based upon an internationally recognized testing standard procedure, may be used to establish non-structural position retention capacity provided that the seismic capacities equal or exceed the project-specific design-level demand for the application installation location.
ii)	Systems interaction avoidance	a) Inspection	Visual inspection of the non-structural installation is performed to validate that no unwanted system interactions may result under the project-specific design-level earthquake demands.
iii)	Active operation	a) Experience data	The use of earthquake experience data, based upon nationally recognized procedures, may be used to establish non-structural active operation capacity provided that the substantiated seismic capacities equal or exceed the project specific design-level demand for the application installation location.
		b) Testing	The use of seismic simulation testing, based upon an internationally recognized testing standard procedure, may be used to establish non-structural active operation capacity provided that the seismic capacities equal or exceed the project-specific design-level demand for the application installation location
		c) Combined testing and analysis	The use of combined seismic calculations and seismic simulation testing may be used to establish non-structural active operation capacity for physically massive systems (that is, large-class) that are impractical to test as complete systems. The testing aspects need to conform to nationally recognized testing standard procedures. The established active operation capacity, using combined testing and analysis, is to equal or exceed the project-specific design-level demand for the application installation location

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13 SYMBOLS, UNITS, COLOUR CODE AND IDENTIFICATION OF SERVICES

13.1 Units and symbols to be used in air conditioning, heating, mechanical ventilation and refrigeration system shall be in accordance with good practice [8-3(16)].

13.2 Colour code is required for easy identification of various items in an air conditioning installation for correct interpretation and identification. This shall promote greater safety and shall lessen chances of error, confusion or inaction in times of emergency. Colour shade shall be generally in accordance with accepted standard [8-3(17)].

13.3 Colour band shall be 150 mm wide, superimposed on ground colour to distinguish type and condition of fluid. The spacing of band shall not exceed 4.0 m.

13.4 Further identification may also be carried out using lettering and marking direction of flow.

13.5 Services Identification

13.5.1 *Pipe Work Services*

13.5.1.1 The scheme of colour code for painting of pipe work services for air conditioning installation shall be as indicated in Table 16.

13.5.1.2 In addition to the colour bands specified above, all pipe work shall be legibly marked with black or white letters to indicate the type of service and the direction of flow, as identified below:

Hot water	:	HW
Chilled water	:	CHW
Condenser water	:	CDW
Steam	:	ST
Condensate drain	:	CN

Table 16 Scheme of Colour Code of Pipe Work Services for Air Conditioning Installation
(*Clause* 13.5.1.1)

Sl No.	Description	Ground Colour	Lettering Colouring	First Colour Band
(1)	(2)	(3)	(4)	(5)
i)	Cooling water	Sea green	Black	French blue
ii)	Chilled water	Sky blue	Black	Black
iii)	Central heating	Dark blue	Black	Canary yellow
iv)	Condensate drain pipe	Black	White	
v)	Vents	White	Black	
vi)	Valves and pipe line fittings	White with black handles	Black	
vii)	Belt guard	Black yellow diagonal strips		
viii)	Machine bases, inertia bases and plinth	Charcoal grey		

13.5.2 *Duct Work Services*

13.5.2.1 For duct work services and its insulation, colour triangle may be provided. The size of the triangle will depend on the size of the duct and viewing distance, but the minimum size should not be less than 150 mm in length.

The colour for various duct work services shall be as given below:

Services	*Colour*
Conditioned air	Blue
Ward air	Yellow
Fresh air	Green
Exhaust/extract/recirculated air	Grey
Foul air	Brown
Dual duct system hot supply air	Red
Cold supply air	Blue

13.5.3 *Valve Labels and Charts*

Each valve shall be provided with a label indicating the service being controlled by it, together with a reference number corresponding with that shown on the valve charts and on the 'as-built' drawings. The labels shall be made from 3-ply (black/white/black) traffolyte material showing white letters and figures on a black background. Labels shall be tied to each valve with chromium plated linked chain.

14 BUILDING AUTOMATION SYSTEM FOR HVAC CONTROL, MONITORING AND VERIFICATION

14.1 General

The energy use of buildings is affected by several factors that change with time. Be it usage patterns, properties of the structure, installed equipment or weather outside — all of them affect the energy consumption of the building significantly. The evaluation of energy savings due to improvements in a building thus becomes a difficult task. Technology is now available that can quantify the factors affecting consumption in more detail than just logging data at the meter.

14.1.1 *Role of Building Automation System (BAS) in HVAC Operation and Maintenance*

The core functionality of BAS is to keep the building indoor environmental conditions, namely, temperature, humidity, lighting and indoor air quality, within the specified range, monitor system performance, and provide device failures and/or malfunction alarms. It typically consists of:

a) *HVAC controls,* consisting of sensors, thermostats, controllers, actuators, communication devices, control panels, and user interface associated with building climate control system;

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b) *Lighting controls,* specifically focused on integrated and networked lighting controls;

c) *Fire and life safety controls,* including sensors, controllers, master panels, actuators, and communication devices for fire detection and control, but excluding actual fire suppression components; and

d) *Security and access controls,* including sensors, access controllers, panels, card-readers, cameras, user interface and IT hardware.

Some of the BAS functions for HVAC include, monitoring status of sensors and controlled devices, scheduling equipment on and off, scheduling set points and setbacks, and trending for equipment operation schedules. BAS is also used to optimize the operation of the various building systems, especially the HVAC system to reduce its energy consumption.

Some of the BAS functions for lighting include scheduling lights to turn on and off, maintain fixed illuminance levels, and integrating daylighting with electrical lighting.

Installing BAS helps in conserving the energy consumed by HVAC system, lighting, etc. However, it is important to note that BAS should be installed only in case of large complex HVAC systems for their optimum usage. It is not required for smaller equipment like split ACs, unitary systems and package units.

14.2 BAS Design Requirements

The BAS design shall take into account the following:

a) *General considerations*:

1) Building construction, for example, metal frame, concrete, size and thermally active building components;

2) Type of building, for example, high rise, single storey, open campus, tunnel;

3) Building usage type and profile, for example, hospital, single/multi-tenant offices, institutional, industrial, and commercial and residential complexes;

4) Space usage profile, for example, occupation schedules, diverse usage of space, continuous operation;

5) System integrity including off-site considerations, for example, communication infrastructure and topology, availability, reliability, response time, safety and security, redundancy;

6) Intended model of building operation and technical services, for example, third party, caretaker, trade segregation, user account levels;

7) Energy supply requirements, for example, alternative energy systems, load shedding, energy monitoring;

8) Safety and security systems integration with BAS and mutual interaction, for example, fire system and access control system with their interoperability area and integration depth;

9) Implementation of the project in phases, for example, timescales for each phase, constraints on plant shutdowns, impact on continuous operation;

10) Budget, for example, charge for O&M, overtime work;

11) Future usage, for example, spare capacity, flexibility, future intended extensions; and

12) Commissioning process.

b) *Integration requirements*:

1) Deployment of special system integration co-ordination group;

2) Allocation of responsibilities, for example, for subsystem functionality and interface, for delivery of integration of subsystems, setting clear battery limits;

3) Vendor and manufacturer independence, for example, standardized protocols, industry standard open back bone like Ethernet/BACnet/Lonworks/Modbus, etc; profiles and interface;

4) Enhanced energy performance, for example, interdisciplinary operation of HVAC, blinds and lighting controls;

5) Compatibility, for example, software/ hardware version of subsystems, protocol version, proprietary protocols;

6) Interoperability, for example, data sharing, event and alarm management, scheduling, trend and event logging, device and network management;

7) Functional interaction, for example, fans disabled by fire conditions;

8) Single seat operation, for example, shared computer, consolidated user information and alarms;

9) Infrastructure sharing, for example, ethernet structured cabling, IT backbone and UPS power systems;

10) Commissioning, for example, availability and interaction of subsystems;

11) Interoperability diagnostics, for example, event recording, device and object binding integrity, protocol analysing; and

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12) Capability to configure a dashboard that will give a summary view of all the different systems integrated and their status to the user.

c) *Physical requirements*:

1) New equipment and its ability to be monitored and controlled, for example, adding monitoring and control;
2) Existing equipment and its ability to be monitored and controlled, for example, reuse, adding functionality;
3) Existing controls or BAS, for example, integrate, migrate, replace;
4) Space, for example, for cabinets, wall mountings, human system interface (HSI);
5) Human system interface, for example, local display, operator workstation;
6) Local conditions, for example, environmental, temperature, humidity, seismic risk, extreme weather;
7) Cabling, for example, topology, media type, size, rating, environment;
8) Power supply, for example, frequency, voltage, emergency power supply, UPS.

d) *Operational requirements*:

1) Priorities for operation of the building, for example, emergency situations, normal conditions, overrides;
2) Occupancy profile, for example, schedules/calendar, set points, operating modes, daylight saving, energy use;
3) Energy performance, for example, energy usage, energy savings;
4) Comfort conditions, for example, thermal, visual, acoustic, air quality;
5) Human system interfaces, for example, local override/indication devices, operator and monitoring units or panels, operator work stations including visual display units, internet browser on different types of platforms.

e) *System requirements*:

1) Priorities for operation, for example, safety of personnel, protection of equipment, occupancy profile, comfort, energy savings, cost savings, reliability, indoor air quality;
2) Control strategies;
3) Management functions;
4) Data storage, data retrieval;
5) Maintenance management requirements, for example, condition-based monitoring, local/remote reporting;
6) Energy management requirements;
7) Alarm strategy, for example, categories, priorities, delivery, routing;
8) Human system interface, for example, localization, multi-language, graphics quality, types, functionality;
9) System support, for example, remote access, technical support;
10) System performance, for example, accuracy, response time, display response;
11) System reliability, for example, availability, redundancy;
12) Documentation, for example, format and media, content, quantity, compliance certificates; and
13) System level diagnostics, to help user diagnose equipment faults, sensor faults, etc. This will help reduce downtime in case of failure.

f) *Site and client-specific requirements*:

1) Installation, for example, electrical, mechanical, controls;
2) Commissioning and handover requirements, for example, witness testing, process for uncompleted actions, summer/winter operation, phased delivery, documentation of the results;
3) Training, for example, instructions for use, operation and maintenance, system/ product training;
4) Documentation, for example, language, content, media, certificates, software licences and backup;
5) Post completion, for example, warranty/ guarantee requirements, spare parts requirement, maintenance;
6) Requirements and software updates;
7) Application of the commissioning process, for example, required qualification and role of commissioning authority; and
8) Ability to upgrade to new feature, new technology that enables vendor or manufacturer independence.

14.3 BAS for Monitoring and Control

BAS is designed to monitor and control the HVAC and lighting, and only monitor the security, fire and flood safety in the building. It also provides the information and tools that building managers need both to

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understand the energy usage of the building and to control and improve the buildings' energy performance.

In order to provide data necessary to improve building systems operation, monitoring and controls should be considered for boilers, chillers, pumps, cooling towers, heat pumps, air handling units, large fan-coil units, major exhaust fans, major water supply pumps, lighting panels, electric heaters, receptacle panels, substation, motor control centre, major feeders, service water heaters, process loads, and computer room. For overall success of the system, it is critical for the BAS to have the capability to allow building staff to measure and record electrical values, such as voltage, current, power, energy, power factor and other power quality parameters for proper performance monitoring. It also calculates, and records system status, water use, energy use at the main meter or of particular end-use systems, demand, and hours of operation, as well as start and stop of building systems, control lighting, and print alarms when systems do not operate within specified limits.

All the measured values are aggregated and trended in both instantaneous and time based numbers for chillers, boilers, air handling units and pumps. The data can be made accessible through a web browser. A graphical user interface must offer trending, scheduling, downloading memory to field devices, real-time graphic programs, parameter changes of properties, set point adjustments, alarm/event information, confirmation of operators, and execution of global commands. This concise representation makes interpretation of collected data robust and more user friendly. A floor manager is able to precisely monitor all aspects using an effective and dynamic system like the BAS.

BAS monitoring can be broadly divided into two aspects, namely, energy monitoring and indoor environment monitoring. Parameters to be measured for energy monitoring have already been listed above. Indoor environmental quality (IEQ) encompasses the conditions inside a building — air quality, lighting, thermal conditions, ergonomics and also their effects on occupants and residents. Strategies for addressing IEQ include those that protect human health, improve quality of life and productivity, and reduce stress and potential injuries. Hence it is necessary to monitor indoor environment quality in both real-time and long-term basis. Since manually managing it is tedious and cumbersome, the use of a BAS is tailor-made to address this specific need. HVAC system provides air to building occupants at a comfortable temperature and humidity, which is also free of harmful concentrations of air pollutants. Also, building ventilation is an important factor affecting the relationship between airborne transmission of respiratory infections and the health and productivity of workers. Improper operation and maintenance of HVAC system is one of the most common problem that impact workplace IEQ. HVAC system includes all of the equipment used to ventilate, heat, and cool the building; to move the air around the building (ductwork); and to filter and clean the air. HVAC system can thus have a significant impact on how pollutants are distributed and removed. Maintaining good IEQ requires constant attention to the building's HVAC system, which includes the design, layout and pollutant source management or air filtration, and the same is facilitated by BAS.

14.4 BAS for Measurement and Verification

Manual analysis of the energy consumption pattern of a building can be a difficult exercise considering that numerous factors such as building envelope design and local climate constantly effect the lighting and HVAC system operation, resulting in a significant impact on building's energy consumption. To simplify this, a process called measurement and verification is used to analyse the energy savings obtained through design and operation of building efficiently. The process of determining the actual savings produced within a facility, upon implementation of an energy efficiency programme, is called measurement and verification (M&V).

In order to measure savings in energy, a comparison is done between the energy usage measured before and after the implementation of the M&V. But this is not enough since energy usage is also dependant on building conditions and hence measurement may require adjustments in the analysis of measured data. Weather and occupancy are examples of factors that regularly change. To assess the effectiveness of the retrofit alone, the influence of these confounding factors must be eliminated through a process of normalization and adjustments. Relationships shall be found between energy use and these factors to remove the influence of the factors from the energy savings measurement. These relationships are usually determined through data analysis. Upon analysing the data, modifications are made to the building to conserve energy or manage demand. These modifications are called energy conservation measures (ECM). ECMs can be of different types, changes to the equipment in the building, operation and maintenance procedures, software, and training to staff and employees.

A typical M&V process may include the following activities:

a) Installation of metering devices,
b) Gathering and screening of data,
c) Development of a computation method with acceptable accuracy,
d) Computation of measured data,

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e) Reporting on analysis and conclusions, and
f) Third party verification.

For efficient measurement and verification, it is important to develop an M&V Plan which is specific to a project or site and is a result of the deliberations and negotiations between the project stakeholders (implementer, owner, investor, regulator, etc) which limits its applicability to the specific project for which it has been developed. It captures the project and individual energy conservation measure boundary, assumptions, engineering calculations/equations, metering infrastructure to be deployed, parameters to be monitored and measured or stipulated, along with their frequency or basis, and agreed upon by all stakeholders.

Most facility managers use building automation system for monitoring and maintenances though it has applications in control of HVAC system as well. The BAS stores and analyses building data to produce reports and dashboards that help facility manager keep track of the energy consumption and other operational data points. The live data stream provided by the BAS is also used to reduce or prevent unwanted events in the future. The real value of data from BAS is in its ability to provide information to anyone, right from an energy auditor or facility manager to the top management, thereby enabling proactive management of building operation.

15 TESTING, COMMISSIONING AND PERFORMANCE VALIDATION

15.1 Inspection of Materials and Equipment

15.1.1 All materials and equipment delivered to site shall be compared with documented and approved specifications and shall be found acceptable to the owner.

15.1.2 Physical properties such as thickness, malleability, test pressure, etc, shall be verified from manufacturer's test certificates. Where test certificates by independent test houses are specified, these shall be produced for acceptance. Agreed lot sizes shall be inspected before use at site.

15.1.3 Testing of equipment shall be done at the (manufacturer's) factory by factory personnel and shall be witnessed by owner's representative, if desired by the owner, and agreed by the contractor/manufacturer.

15.1.4 Equipment test certificates for pressure test, capacity test or any other specified test, shall also be produced and accepted by the owner before the said equipment is taken up for erection/installation.

15.1.5 Agreed method of inspection shall be properly recorded and results of the inspection shall be preserved by the contractor as a record during currency of the contract.

15.1.6 All metering/measuring instruments used for commissioning and testing, shall be calibrated and certificate of calibration shall be on record.

15.2 Cleaning and Stage-Wise Inspection of Work

15.2.1 All equipment, ancillaries, pipes, ducts, insulation material, etc, shall be cleaned prior to use. Cleaning of piping system, duct work, etc, shall be done by an approved and trained agency and the method of cleaning shall be submitted for approval before work is carried out.

15.2.2 Tests on ducts and pipes shall be done in sections, as per approved schematics. Test pressures and applicable standards shall be proposed by the contractor and approved by owner. Once the approval is received, contractor shall prepare and submit testing schedules indicating the sections or circuits where testing is proposed. Contractor shall depute competent staff to supervise testing and arrange for the owner or his representative to witness the testing.

15.2.3 Testing of duct work shall be carried out in manageable sections, and subsequently the entire duct length shall be tested complete with all air outlets in place. For testing, it is recommended to isolate the ductwork at branch damper locations. Contractor shall refer to the commissioning authority and provide adequate number of test points at appropriate locations, as required.

15.2.4 Pipe work shall be tested in parts, floor by floor or zone by zone and by risers which can be isolated by valves.

15.2.5 Cabling and control wiring shall be tested as one complete unit.

15.3 Readiness for Testing

15.3.1 Final pressure testing and leak testing of all piping and ducting systems shall be done and it shall be ensured that any blank offs introduced during testing, have been removed.

15.3.2 All equipment shall be made ready to run. All fan and pump shipping bolts shall be removed and each equipment shall be made ready to start.

15.3.3 For all major equipment such as chiller, VRF unit, cooling tower, air handler, pump ventilation fan, etc, manufacturer or his authorized representative shall certify that the equipment is ready to start.

15.4 Testing

Each components of central air conditioning plant shall be tested for performance as per **15.4.1** to **15.4.4**

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15.4.1 *Testing of Chiller*

Upon completion of installation, the water chilling unit shall be tested for performance. The capacity, in kcal/h (TR), shall be calculated from measurement of temperature difference and flow rate of water in chiller. Power consumption shall be checked from current measurement of the motor which should include the compressor motor as well as fan motor. All calculated and measured values shall match with those provided in technical submittal of chiller.

15.4.2 *Testing of Pump*

Upon completion of installation, capacity of the pump shall be checked by measuring water flow, using the balancing valve in full open position, motor current and pressure differential between the inlet and outlet. The readings shall be compared with actual performance identified in the technical submittal of the pump.

15.4.3 *Testing of Cooling Tower*

Upon completion of installation, the cooling tower shall be tested for performance. The capacity, in kcal/h (TR), shall be calculated from measurement of temperature difference, approach to ambient wet-bulb, and the flow rate of water in condenser. The power consumption shall be checked from current measurement of the motor. All calculated and measured values shall match the data given with the technical submittal of cooling tower.

15.4.4 *Testing of AHU*

Upon completion of installation, the AHU shall be tested for performance. Capacity shall be verified by measurement of air flow (m^3/h) at fan discharge, and power consumption from current drawn for fan motor, measured values shall match with the data given by vendor with the technical submittal of each AHU.

15.5 Pre-Commissioning Inspection

Commissioning and performance validation shall be attempted only after completion of staged tests as well as part pressure tests and results shall be recorded and certified by the contractor.

15.6 Commissioning

Commissioning shall mean putting the equipment or system into active service for the use intended by the owner.

15.6.1 For a window (unitary) air conditioner, or split air conditioner, package unit and VRF unit, this shall involve connecting the unit (after installation) to a suitably sized power socket, switching it on and recording the temperature in various parts of the room. The process will also involve checking whether the unit's promised features such as auto-swing etc, are working properly and also whether the compressor switches off after the desired temperature is achieved. The air flow from the unit shall be measured using an anemometer and compared with the manufacturer's rating listed in their catalogue. The sound level at a distance of 1 m away from the unit shall be measured and recorded.

15.6.2 For a central air conditioning plant or a mechanical ventilation system, the process shall involve a systematic procedure to ensure that the plant performs as per the design parameters and shall include instructing the concerned personnel in proper operation of the plant. Hand over procedure shall include compiling operation manuals for the equipment, service schedule, spare parts list, recommended log recording sheet and regular operation and maintenance procedures; all these shall be made available to the owner.

15.6.2.1 Commissioning engineer should preferably be involved right from the design stage and his/her inputs should be taken while designing and laying out the plant as well as while choosing the control and monitoring system, including the measurement and verification points.

15.7 Scope of Commissioning Activity for Central Air Conditioning System

15.7.1 Commissioning activity shall include the following:

a) Testing, adjusting, and balancing of air side system;
b) Testing, adjusting, and balancing of chilled water and piping system;
c) Measurement of final operating parameters of HVAC system;
d) Sound measurement of equipment where specified;
e) Vibration measurement of equipment where specified; and
f) Testing, adjusting and balancing of smoke control system, exhaust, and fresh air or pressurization system.

15.7.2 The testing, commissioning, and performance validation activities shall be carried out by qualified personnel. The services shall be performed by a third party commissioning agent (independent of the HVAC designer and HVAC works contractor), where so specified.

Necessary documents, drawings and data shall be provided to the commissioning team and manpower for operation of the system shall be provided by the contractor.

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15.7.3 Commissioning shall be a systematic process confirming that building systems have been installed, started, and consistently operated in strict accordance with the contract documents. A documentary proof that all systems are complete and functioning in accordance with the contract documents shall be provided to owner's operating personnel. Commissioning shall include seasonal tests, if specified and approved by the owner.

15.7.4 The commissioning engineer shall prepare a documented plan which shall be approved by the owner. The structure, schedule, and co-ordination plan of the commissioning process from the construction phase through the warranty period, shall satisfy the owner's requirements.

15.7.5 Static inspection of material and component tests that verify proper installation of equipment (for example, belt tension, oil levels, labels affixed, gauges in place, sensors calibrated, etc) shall be approved as complete, and shall be submitted with the request for start-up.

15.7.6 The activities where equipment is initially energized, tested, and operated shall be completed prior to functional performance tests (FPT).

15.7.7 Functional performance test shall mean testing of dynamic functions and operation of equipment and systems. System shall be tested under various modes such as low cooling load, high cooling load, varying ambient condition, power failure, life safety condition, etc, as specified. Functional performance tests shall establish that the system is performing as designed, under these conditions.

15.7.8 Test of dynamic interactive functions and operation of multiple systems under various modes, such as fire alarm and emergency situation, life safety condition, power failure, etc, shall be carried out, as specified. Systems shall be integrally operated through all specified sequences of operation. Components shall be verified to be responding in accordance with contract documents. Integrated system tests shall provide verification that the integrated system will properly function according to the contract documents, under all situations, and shall comply with the relevant fire and safety requirement.

15.7.9 Integrated system test procedure and commissioning protocols and instructions, fully describing system configurations and steps required to determine if the interacting systems are performing and functioning properly, shall be provided by the commissioning engineer. HVAC contractor shall prepare these procedures to document integrated system test.

15.7.10 Functional performance, or integrated system performance tests may be deferred due to partial occupancy, partial equipment load, seasonal requirement, or other site conditions that prohibit the test from being performed, prior to acceptance. Such deferment shall record owner's confirmation and shall also indicate the tentative dates when the tests will be carried out.

15.7.11 Deficiency shall mean a condition of a component, piece of equipment or system that is not in compliance with contract documents.

15.8 Following is an example of the various steps in the commissioning process of a vapour compression type air conditioning system:

a) Check and confirm that working pressures and temperatures are in line with those specified in design.
b) Check compressor oil level, oil should not be foaming.
c) Check compressor body temperature.
d) Check for liquid flood back.
e) Check air and water flow through condenser and evaporator.
f) Check motor current and body temperature.
g) Check refrigerant charge.
h) Clean/Replace liquid and suction strainers till they remain clean after usage.
j) Check superheat at expansion valve.
k) Set the safety controls and confirm their operation.
m) Check the piping for any excessive vibration.
n) Ensure that current drawn by all motors is within motor rating.
p) Check air distribution system, do air balancing and ensure uniform temperature in all air conditioned spaces.
q) Verify and balance chilled water flow through various sections of the system, and then the entire length of the piping.
r) Check the cooling tower operation and make sure wet-bulb approach is with in specified limit.
s) Ensure that guards are provided on all rotating parts.
t) Initiate regular 'log' readings.
u) Operating and maintenance (O&M) manual as per requirements of the technical specifications shall be made available to the owner by the contractor. The contractor shall ensure that the O&M manual content, as built drawings and specifications, component submittal drawings, and other pertinent documents, are available with the owner for review.

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15.9 Performance validation involves verification that the system performs as per design parameters. The design parameters may include,

a) temperature and relative humidity;
b) chilled water or brine temperature and flow rate;
c) maximum ambient dry-bulb and wet-bulb temperature;
d) occupancy in conditioned area;
e) pressure drop across condenser/chiller;
f) water flow rate through condenser/chiller;
g) entering and leaving water temperature for condenser/chiller;
h) chilled water flow rate across cooling coils in AHU;
j) pressure drop across cooling coils;
k) compressor speed;
m) evaporating/condensing temperature/pressure;
n) current drawn by motors;
p) air flow rate across cooling coil of AHU;
q) fresh air quantity;
r) apparatus dew point, if specified;
s) DB/WB temp of air entering/leaving the cooling coil;
t) WB approach of cooling tower; and
u) power consumption, in kWh.

NOTE — The above is not a comprehensive list. Depending on type of plant and application, the parameters may vary. The parameters to be recorded should be as per design data for the particular plant and as agreed to between the owner and the contractor.

15.10 For individual components of an HVAC system following are the critical parameters.

a) *Water cooled condenser*:
   1) Water flow rate as established by pressure drop across the condenser;
   2) Temperature rise; and
   3) Condensing temperature and pressure (leaving temperature difference).
b) *Air cooled condenser*:
   1) Air flow rate across the condenser; and
   2) Condensing temperature and pressure (leaving temperature difference).
c) *Chiller*:
   1) Water or brine flow rate as established by pressured drop across chiller; and
   2) Temperature drop.
d) *Compressor:*
   1) Oil pressure; and
   2) Suction/discharge pressures.
e) *Pumps for condenser/chilled water*:
   1) Water flow rate as established from pump curves based on suction/discharge pressure; and
   2) Pump motor current.
f) *Cooling tower*:
   1) Wet-bulb approach.
g) *Air handling unit*:
   1) Pressure drop through cooling coil;
   2) Water flow through the cooling coil;
   3) DB/WB temperature of entering/leaving air; and
   4) Air flow rate at fan discharge.
h) *Air distribution system*:
   1) Room conditioners at various places in the room. Temperature rise from AHU units to tail end of duct;
   2) Draft in occupied zones (between 15 m/min to 30 m/min); and
   3) Noise level.

15.11 Objectives of performance validation shall be to,

a) verify conformity to design;
b) establish fluid flow rates, operating temperatures and pressures;
c) test all electrical installations for earthing continuity and earth resistance;
d) verify electrical consumption for each motor and for the plant as a whole;
e) establish operating sound levels;
f) check for abnormal vibration;
g) adjust and balance all parameters to design levels; and
h) record and report results in a specified format.

15.12 Controls and Safety Cut-Outs

Operation of all controls and safety cut-outs should be demonstrated during the commissioning process and results should be recorded.

15.13 Calibration of Instruments

All measuring instruments used during the commissioning process should be calibrated, either by an independent calibration agency or in comparison with a calibrated gauge. Calibration certificate of all instruments should be available on record.

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15.14 Handover Procedure

15.14.1 Handover documentation should include all information that the user will need to operate the equipment efficiently and economically. It should include recorded reading of all factory and site testing, including the calibration certificates of measuring instruments, as well as details of all control settings.

15.14.2 Following are the requirements of handover documentation (as applicable from case to case):

a) Description of the installation, schedule of equipment;
b) Heat load calculations and equipment selection details;
c) Schematic drawings for chilled water/ condenser water;
d) Schematic drawings for exhaust and pressurization systems;
e) As-built drawings including air distribution layouts;
f) Operations and maintenance manuals for all equipment/controls/ instrumentation;
g) Manufacturer's spare parts list and ordering instructions;
h) Test certificates/test results, as required;
j) Commissioning readings countersigned by commissioning authority;
k) Guarantee certificate and service escalation matrix; and
m) List of all accessories, tools, spares handed over with system.

15.15 Operation and Maintenance

Operation of the plant shall include a continuous vigilance on the performance of the system and day-to-day routine maintenance.

The operating procedure shall be as given in **15.15.1** to **15.15.5**. The maintenance procedure shall be as laid down in **15.15.6**.

15.15.1 Before starting the plant, the operator shall ensure that,

a) all the valves in the refrigeration system, condenser water lines and chilled water lines are open, except those of the standby items of equipment.
b) there is sufficient water in the cooling tower basin and the make-up water system is working satisfactorily.
c) the make-up water system to the expansion tank of the chilled water circuit is working and there is a regular water supply. Water is lost from the chilled water system through pump gland drips. If the level in the expansion tank is not maintained, air can enter the chilled water system, affecting the system performance substantially. It can even lead to freeze up of the chiller.
d) all the air filters and water strainers are clean. Any dirty filter and/or the blocked strainer shall be cleaned.
e) all doors and windows of the air conditioned/ refrigerated area are closed.
f) the crankcase of the compressor is warm (to the physical touch). If it is not warm, defects in the crankcase heater and/or circuit should be checked for. The compressor shall not be started until the defect is rectified and the crankcase warms up, else it will result to poor lubrication, thereby substantially reducing the life of the bearings of the compressor.
g) the supply voltage is within permissible limits. The windings of the motors can get affected, if run on low voltage conditions.

15.15.2 The starting sequence shall be as follows:

a) Switch 'ON' the mains. Observe the voltage. If it is less than the permissible level, do not start any component of the system.
b) Start air handling unit motors (all dampers have to be checked based on their specific application).
c) Start condenser water pumps. Check that sufficient water pressure is obtained.
d) Start cooling tower fan.
e) Start chilled water pumps and check the pressure.
f) Switch 'ON' the compressor control switch.
g) Start the compressor motor.

15.15.3 Following aspects require special attention:

a) In the compressor with oil pump, the compressor oil pressure should build up as the compressor is started. Check that correct net oil pressure is built up.
b) Check the oil level in the oil sight glass of the compressor. The oil level should be about 40 to 50 percent of the sight glass. In operation, certain amount of oil gets entrained in the refrigerant vapour in the compressor and is carried to the system along with the refrigerant.
c) After the plant operation has stabilized, check all the pressures and temperatures and ensure that the system is working satisfactorily.
d) Record periodically the readings of temperature, pressure, current and other required data in the log sheet.

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e) Check for any unusual noise/vibration in the plant. If something unusual is noticed, trace out the reason for it and rectify the cause.

f) During the operation of the system, if any major component stops suddenly, trace out its reason, before starting the component/system again.

15.15.4 The stopping sequence of the system shall be as follows:

a) Switch off the compressor on the low pressure switch, as the system gets pumped down.

b) Switch off the power supply to compressor.

c) Check that the crankcase electric heater comes on as soon as compressor stops and ensure that the heater is working.

d) Stop chilled water pumps.

e) Stop air handling units.

f) Stop condenser water pumps and cooling tower fans.

15.15.5 Following are standard operating instructions which the operator should follow.

a) In case stand-by chiller, pumps, etc, are provided, systematically change over the stand-by components, periodically. This will ensure uniform wear and tear of the system. Further, this also helps in ensuring that all equipment is in good shape and the stand-by is in working condition.

b) Do not switch off the main switch on the main electrical board or switch off any component of the system, when the plant is in operation.

c) All the water valves in the system shall be kept open and need not be closed, unless specifically instructed by designer. But it is essential to close and open each valve periodically to ensure that the valves work and are not stuck by scale formation or dirt accumulation.

d) Keep the plant room clean. Do not use the plant room, particularly the air handling unit rooms for storage.

15.15.6 Following are the important day-to-day maintenance work which shall be attended to:

a) *Clean the air filters* — A dirty air filter reduces the plant capacity. If not cleaned regularly the filter gets fully loaded with dirt and this dirt can pass on to the cooling coil. In dusty environment, it may be necessary to clean the air filters more often. The filters shall be replaced when cleaning is no longer effective.

b) *Leak testing for refrigerant leak* — Even a minute leak can cause poor oil return, heating of the compressor and ultimately leading to poor refrigeration.

c) *Water pump (packed) glands* — Certain amount of water drip through the gland is necessary to keep the gland cool. But if the drip develops into a regular flow, it is an indication that the gland is not holding. The gland nuts may be tightened to reduce the leak. If this does not improve the situation, the gland packing should be replaced.

d) *Clean the water strainers* — A clogged strainer reduces the water flow rate and thus affect the plant performance.

e) *Belt tension of belt drives* — Check the tension of belts and tighten whenever found loose. A loose belt reduces transmission efficiency.

f) Check the spray of the cooling tower nozzles.

g) *Drain, clean and refill the cooling tower sump* — Cooling tower, being in the open, collect a lot of dust and muck. Hence, the tower shall be cleaned at least once in a week.

h) For adequate heat transfer, it is necessary that tubes of a shell and tube condenser as well as those of a flooded chiller are kept clean. It is recommended that tube cleaning is carried out once in 6 months in case of a condenser and as often as necessary in case of chiller. It is also recommended that automatic in-line chemical dosing systems may be installed which inhibit scale formation in the tubes.

j) It is the pressure gauges and thermometers which give the correct indication of the plant performance and condition. Therefore, it should be ensured that these are in good order and are periodically calibrated.

k) Analyse the pressure and temperature readings of the system from the log book and ensure that these conform to design parameters. Corrective action should be promptly taken when the readings show even a minor discrepancy.

ANNEX A

(*Clause* 6.2)

TEMPERATURE DESIGN CONDITIONS USING ADAPTIVE MODELS[1)]

Sl No.	Mode of Operation →	Naturally Ventilated		Mixed Mode		Air Conditioned			
	Approach →	Operative Temperature °C		Operative Temperature °C		Air Temperature °C		Standard Effective Temperature °C	
	City ↓	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1)	Ahmedabad	32.0-25.5	27.2-20.7	31.1-26.7	24.1-19.7	27.5-26.2	24.5-23.2	26.0-25.8	24.0-23.8
2)	Akola	32.0-26.4	27.2-21.6	31.2-27.2	24.2-20.2	27.5-26.4	24.5-23.4	26.0-25.8	24.0-23.8
3)	Allahabad	32.0-23.6	27.2-18.8	31.3-25.7	24.3-18.7	27.5-26.0	24.5-23.0	26.0-25.7	24.0-23.7
4)	Amritsar	32.0-22.0	27.2-17.2	30.4-25.0	23.4-18.0	27.3-25.9	24.3-22.9	26.0-25.7	24.0-23.7
5)	Aurangabad	32.0-25.7	27.2-20.9	30.5-26.8	23.5-19.8	27.3-26.3	24.3-23.3	26.0-25.8	24.0-23.8
6)	Barmer	32.0-24.6	27.2-19.8	31.2-26.2	24.2-19.2	27.5-26.1	24.5-23.1	26.0-25.8	24.0-23.8
7)	Belgaum	30.7-26.7	25.9-21.9	29.4-27.3	22.4-20.3	27.0-26.4	24.0-23.4	25.9-25.8	23.9-23.8
8)	Bengaluru	30.7-26.5	25.9-21.7	29.4-27.2	22.4-20.2	27.0-26.4	24.0-23.4	25.9-25.8	23.9-23.8
9)	Bhagalpur	32.0-25.2	27.2-20.4	30.2-26.6	23.2-19.6	27.2-26.2	24.2-23.2	26.0-25.8	24.0-23.8
10)	Bhopal	32.0-24.5	27.2-19.7	31.1-26.2	24.1-19.2	27.5-26.1	24.5-23.1	26.0-25.8	24.0-23.8
11)	Bhubaneswar	32.0-26.6	27.2-21.8	30.6-27.3	23.6-20.3	27.3-26.4	24.3-23.4	26.0-25.8	24.0-23.8
12)	Bhuj	32.0-25.4	27.2-20.6	30.5-26.6	23.5-19.6	27.3-26.2	24.3-23.2	26.0-25.8	24.0-23.8
13)	Bikaner	32.0-22.3	27.2-17.5	31.3-25.0	24.3-18.0	27.5-25.9	24.5-22.9	26.0-25.7	24.0-23.7
14)	Chennai	32.0-28.7	27.2-23.9	30.7-28.3	23.7-21.3	27.4-26.7	24.4-23.7	26.0-25.9	24.0-23.9
15)	Chitradurga	31.2-27.2	26.4-22.4	29.6-27.6	22.6-20.6	27.1-26.5	24.1-23.5	25.9-25.8	23.9-23.8
16)	Dehradun	31.0-22.3	26.2-17.5	29.6-25.0	22.6-18.0	27.0-25.9	24.0-22.9	25.9-25.7	23.9-23.7

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ANNEX A — (*Continued*)

Sl No.	Mode of Operation →	Naturally Ventilated		Mixed Mode		Air Conditioned			
	Approach →	Operative Temperature °C		Operative Temperature °C		Air Temperature °C		Standard Effective Temperature °C	
	City ↓	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
17)	Dibrugarh	30.4-23.2	25.6-18.4	29.2-25.5	22.2-18.5	26.9-25.9	23.9-22.9	25.9-25.7	23.9-23.7
18)	Gorakhpur	32.0-22.6	27.2-17.8	30.3-25.2	23.3-18.2	27.2-25.9	24.2-22.9	26.0-25.7	24.0-23.7
19)	Guwahati	30.8-24.2	26.0-19.4	29.4-26.0	22.4-19.0	27.0-26.0	24.0-23.0	25.9-25.8	23.9-23.8
20)	Gwalior	32.0-22.8	27.2-18.0	31.5-25.3	24.5-18.3	27.6-25.9	24.6-22.9	26.0-25.7	24.0-23.7
21)	Hisar	32.0-22.5	27.2-17.7	31.3-25.1	24.3-18.1	27.5-25.9	24.5-22.9	26.0-25.7	24.0-23.7
22)	Hyderabad	32.0-26.8	27.2-22.0	30.3-27.4	23.3-20.4	27.2-26.4	24.2-23.4	26.0-25.8	24.0-23.8
23)	Imphal	29.1-22.1	24.3-17.3	28.6-25.0	21.6-18.0	26.8-25.9	23.8-22.9	25.9-25.7	23.9-23.7
24)	Indore	32.0-24.9	27.2-20.1	30.4-26.4	23.4-19.4	27.3-26.1	24.3-23.1	26.0-25.8	24.0-23.8
25)	Jabalpur	32.0-24.1	27.2-19.3	30.5-26.0	23.5-19.0	27.3-26.0	24.3-23.0	26.0-25.8	24.0-23.8
26)	Jagdalpur	31.4-25.5	26.6-20.7	29.8-26.7	22.8-19.7	27.1-26.2	24.1-23.2	26.0-25.8	24.0-23.8
27)	Jaipur	32.0-23.7	27.2-18.9	31.2-25.8	24.2-18.8	27.5-26.0	24.5-23.0	26.0-25.7	24.0-23.7
28)	Jaisalmer	32.0-24.3	27.2-19.5	31.1-26.1	24.1-19.1	27.5-26.1	24.5-23.1	26.0-25.8	24.0-23.8
29)	Jamnagar	31.8-25.0	27.0-20.2	30.0-26.4	23.0-19.4	27.1-26.2	24.1-23.2	26.0-25.8	24.0-23.8
30)	Jodhpur	32.0-24.9	27.2-20.1	31.2-26.4	24.2-19.4	27.5-26.1	24.5-23.1	26.0-25.8	24.0-23.8
31)	Jorhat	30.9-23.8	26.1-19.0	29.5-25.8	22.5-18.8	27.0-26.0	24.0-23.0	25.9-25.8	23.9-23.8
32)	Kolkata	32.0-25.7	27.2-20.9	30.1-26.8	23.1-19.8	27.2-26.3	24.2-23.3	26.0-25.8	24.0-23.8
33)	Kota	32.0-24.2	27.2-19.4	31.8-26.0	24.8-19.0	27.6-26.0	24.6-23.0	26.1-25.8	24.1-23.8
34)	Kurnool	32.0-27.8	27.2-23.0	31.1-27.9	24.1-20.9	27.5-26.6	24.5-23.6	26.0-25.9	24.0-23.9
35)	Lucknow	32.0-23.3	27.2-18.5	30.7-25.5	23.7-18.5	27.4-25.9	24.4-22.9	26.0-25.7	24.0-23.7
36)	Mangalore	31.2-28.9	26.4-24.1	29.6-28.4	22.6-21.4	27.1-26.7	24.1-23.7	25.9-25.8	23.9-23.8
37)	Mumbai	31.7-28.5	26.9-23.7	29.9-28.3	22.9-21.3	27.1-26.7	24.1-23.7	26.0-25.9	24.0-23.9

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ANNEX A — (*Concluded*)

Sl No.	Mode of Operation →	Naturally Ventilated		Mixed Mode		Air Conditioned			
	Approach →	Operative Temperature °C		Operative Temperature °C		Air Temperature °C		Standard Effective Temperature °C	
	City ↓	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band	90 Percent Upper Band	90 Percent Lower Band
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
38)	Nagpur	32.0-26.1	27.2-21.3	31.5-27.0	24.5-20.0	27.6-26.3	24.6-23.3	26.0-25.8	24.0-23.8
39)	Nellore	32.0-28.5	27.2-23.7	31.0-28.3	24.0-21.3	27.4-26.7	24.4-23.7	26.0-25.9	24.0-23.9
40)	New Delhi	32.0-22.0	27.2-17.2	30.7-25.0	23.7-18.0	27.4-25.9	24.4-22.9	26.0-25.7	24.0-23.7
41)	Panjim	31.5-29.4	26.7-24.6	29.8-28.7	22.8-21.7	27.1-26.8	24.1-23.8	26.0-25.9	24.0-23.9
42)	Patna	32.0-23.8	27.2-19.0	30.3-25.8	23.3-18.8	27.2-26.0	24.2-23.0	26.0-25.8	24.0-23.8
43)	Pune	31.1-25.7	26.3-20.9	29.6-26.8	22.6-19.8	27.0-26.3	24.0-23.3	25.9-25.8	23.9-23.8
44)	Raipur	32.0-25.7	27.2-20.9	31.1-26.8	24.1-19.8	27.5-26.3	24.5-23.3	26.0-25.8	24.0-23.8
45)	Rajkot	32.0-26.3	27.2-21.5	30.8-27.1	23.8-20.1	27.4-26.3	24.4-23.3	26.0-25.8	24.0-23.8
46)	Ramagundam	32.0-27.0	27.2-22.2	31.3-27.4	24.3-20.4	27.5-26.4	24.5-23.4	26.0-25.8	24.0-23.8
47)	Ranchi	31.7-23.7	26.9-18.9	29.9-25.8	22.9-18.8	27.1-26.0	24.1-23.0	26.0-25.7	24.0-23.7
48)	Ratnagiri	31.0-28.6	26.2-23.8	29.5-28.3	22.5-21.3	27.0-26.7	24.0-23.7	25.9-25.8	23.9-23.8
49)	Raxaul	31.3-23.1	26.5-18.3	29.7-25.5	22.7-18.5	27.1-25.9	24.1-22.9	25.9-25.7	23.9-23.7
50)	Saharanpur	31.6-22.0	26.8-17.2	29.8-25.0	22.8-18.0	27.1-25.9	24.1-22.9	26.0-25.7	24.0-23.7
51)	Shillong	25.7-22.0	20.9-17.2	26.8-25.0	19.8-18.0	26.3-25.9	23.3-22.9	25.8-25.7	23.8-23.7
52)	Solapur	32.0-28.1	27.2-23.3	30.6-28.1	23.6-21.1	27.3-26.6	24.3-23.6	26.0-25.9	24.0-23.9
53)	Surat	32.0-27.2	27.2-22.4	30.2-27.6	23.2-20.6	27.2-26.5	24.2-23.5	26.0-25.8	24.0-23.8
54)	Tezpur	30.7-24.4	25.9-19.6	29.4-26.1	22.4-19.1	27.0-26.1	24.0-23.1	25.9-25.8	23.9-23.8
55)	Thiruvananthapuram	31.0-29.6	26.2-24.8	29.5-28.8	22.5-21.8	27.0-26.8	24.0-23.8	25.9-25.8	23.9-23.8
56)	Tiruchchirapalli	32.0-28.9	27.2-24.1	30.5-28.5	23.5-21.5	27.3-26.7	24.3-23.7	26.0-25.9	24.0-23.9
57)	Varanasi	32.0-22.7	27.2-17.9	30.6-25.2	23.6-18.2	27.3-25.9	24.3-22.9	26.0-25.7	24.0-23.7
58)	Veraval	31.6-27.5	26.8-22.7	29.9-27.7	22.9-20.7	27.1-26.5	24.1-23.5	26.0-25.8	24.0-23.8
59)	Vishakhapatnam	31.9-27.6	27.1-22.8	30.0-27.8	23.0-20.8	27.2-26.5	24.2-23.5	26.0-25.9	24.0-23.9

[1] These temperature design conditions are annual values of 99.6 and 0.4 percentile for 90 percent comfort band based on typical weather data

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	3615 : 2007	Glossary of terms used in refrigeration and air conditioning (*first revision*)
(2)	IS/ISO 817	Refrigerants — Designation and safety classification of refrigerants (*second revision*) (*under print*)
(3)	8188 : 1999	Code of practice for treatment of water for cooling towers (*first revision*)
(4)	655 : 2006	Specification for air ducts (*second revision*)
(5)	277 : 2003	Specification for galvanized steel sheets (plain and corrugated) (*sixth revision*)
(6)	737 : 2008	Specification for wrought aluminium and aluminium alloy sheet and strip for general engineering purposes (*fourth revision*)
(7)	1391 (Part 1) : 1992	Specification for room air conditioners: Part 1 Unitary air conditioners (*second revision*)
(8)	1391 (Part 2) : 1992	Specification for room air conditioners: Part 2 Split air conditioners (*second revision*)
(9)	8148 : 2003	Specification for packaged air conditioners (*first revision*)
(10)	3315 : 1994	Specification for evaporative air coolers (desert coolers) (*second revision*)
(11)	661 : 2000	Code of practice for thermal insulation of cold storage (*third revision*)
(12)	12976 : 1990	Code of practice for solar water heating systems
(13)	3103 : 1975	Code of practice for industrial ventilation (*first revision*)
(14)	1239 (Part 1) : 2004	Specification for steel tubes, tubulars and other wrought steel fittings: Part 1 Steel tubes (*sixth revision*)
(15)	3589 : 2001	Specification for steel pipes for water and sewage (168.3 to 2 540 mm outside diameter) (*third revision*)
(16)	4831 : 1968	Recommendation on units and symbols for refrigeration
(17)	5 : 2007	Colours for ready mixed paints and enamels (*sixth revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 4 Acoustics, Sound Insulation and Noise Control

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 8/Section 4) covers the acoustical, sound insulation and noise control requirements in buildings. Emphasis is laid on planning of buildings *vis-a-vis* its surroundings to reduce noise, and in addition, sound insulation aspects of different occupancies are covered for achieving acceptable noise levels.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005. Some of the important changes in the 1983 version included: specifying of approximate measured noise levels due to various types of traffic (air, rail and road) conditions; elaboration of planning and design features of buildings against outdoor noise; modification of impact sound insulation in residential buildings and hearing damage risk criteria in industrial buildings; recommendations regarding planning of open plan schools against noise; planning and design aspects of hotels and hostels, laboratories and test houses, and other miscellaneous buildings, and planning of office buildings with light weight partitions; and elaboration of the public address system to cover public address system at passenger terminals.

Some of the important changes in the 2005 version included: addition of large numbers of important definitions in line with the existing international practice of usage of terms in the field of acoustics, sound insulation and noise control; inclusion of a new clause on highway noise barrier under provisions on planning and design against outdoor noise; deletion of the clause on public address system; addition of a new clause on cinema; and deletion of existing appendices on 'Constructional Measures for Sound Insulation of Buildings' and 'Sound Insulation values for various types of Materials and Construction'; and addition of eight new informative annexes on noise calculations, specification of sound insulation, noise rating, outdoor noise regulations in India, special problems requiring expert advice, airborne and impact sound insulation, basic design techniques for noise control in HVAC and suggested equipment noise data sheet.

This revision has been brought out to incorporate changes based on the experience gained during usage of the last version of this Section. Following are the significant changes made in this revision:

a) Definitions of various existing terms have been reviewed and updated, wherever required, and of new terms have been added, such as noise criteria, sound level difference, ground-borne and structure-borne noise.
b) A new clause on construction noise has been introduced.
c) The provision relating to noise control in open plan schools has been deleted, owing to the changed scenario.
d) In case of auditoria and theatres, provision for effective isolation of mechanical equipment such as lifts from the building structure to help avoid noise transmission, has been included.
e) Also, in case of auditoria and theatres, requirement for adequate damping under light weight metal roofs, with an additional light weight under deck noise sound barrier to reduce rainfall generated noise, has been included.
f) Reverberation time of assembly halls in schools corresponding to 'Maximum for noise control (empty)' has been modified.
g) Reverberation times of classrooms in schools have been modified.
h) Requirement of insulation (R_w) for walls or partitions between rooms in hospitals have been modified.
j) Recommended maximum reverberation time for very large offices and for canteens have been modified.
k) Recommended sound isolation value (D_w) between one room and another room in office has been modified.
m) Recommended sound isolation value (D_w) for clerical offices in which noise does not constitute a major nuisance has been modified.
n) Provision for assembly for partition between guest rooms and between rooms, corridors and floors, in hotels, has been modified.

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p) Examples of common types of wall and floor construction with sound insulation have been reviewed and modified, wherever required.

q) Provisions have been updated to take care of the requirements of persons with disabilities.

There are two types of noises, that is, airborne and structure-borne noise. To reduce the intensity of airborne noise, sound absorbent materials may be used. An absorbent material is one which reduces the intensity of sound reflected from its surface. It may be applied to walls, floors, ceilings or used as furnishings to reduce the sound level by absorption. However, the materials selected for sound absorption shall be consistent with fire safety requirements of the buildings.

To reduce the transmission of airborne noise, sound insulating materials may be used. Sound insulating materials block the passage of noise through them by virtue of their mass and physical properties. The extent of noise reduction provided by a single homogeneous panel is proportional to the logarithm of mass per unit area. For high values of sound insulation, normally heavy panels are required. Thin sheets of materials do not have adequate mass for providing any appreciable sound transmission loss by themselves. However, when thin sheet materials are used in a double panel construction with an intervening air cavity, this special construction can give extremely high sound transmission loss values considering the mass of the partition, if designed properly. Porous materials lack the mass required to provide any appreciable sound transmission loss, and readily allow sound at most frequencies to be transmitted through them.

To reduce the transmission of structure-borne noise (such as noise generated by impacts) special construction methods and elastic discontinuity in the structure may be used. Structure-borne noise reduction is effected by corner joints, changes in cross-section, changes in materials, etc, in construction. The reduction by these construction methods is, however, not appreciable especially when a large amount of noise reduction is required over a short distance. In such cases, introduction of an elastic discontinuity in the structure can result in a very large amount of noise reduction. The noise transmission is affected only above a certain lower frequency which depends on the material thickness and the elastic properties of the material. Bonded fibrous materials, rubber elastomers, cork, etc. are suitable for curtailing structure-borne noise transmission.

This Section is largely based on the following standards:

IS 1950 : 1962	Code of practice for sound insulation of non-industrial buildings
IS 3483 : 1965	Code of practice for noise reduction in industrial buildings
IS 4954 : 1968	Recommendations for noise abatement in town planning
IS 11050 (Part 1) : 1984	Rating of sound insulation in buildings and of building elements: Part 1 Airborne sound insulation in buildings and of interior building elements
IS 11050 (Part 2) : 1984	Rating of sound insulation in buildings and of building elements: Part 2 Impact sound insulation
BS 8233 : 2014	Code of practice for sound insulation and noise reduction for buildings

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 4 Acoustics, Sound Insulation and Noise Control

1 SCOPE

This Code (Part 8/Section 4) covers requirements and guidelines regarding planning against noise, acceptable noise levels and the requirements for sound insulation in buildings with different occupancies.

2 TERMINOLOGY

For the purpose of this Section, the definitions given below shall apply.

2.1 Ambient Noise — The sound pressure levels associated with a given environment. Ambient noise is usually a composite of sounds from near and far sources, none of which are particularly dominant.

2.2 Audible Frequency Range — The range of sound frequencies normally heard by the human ear. The audible range spans from 20 Hz to 20 000 Hz.

2.3 A-Weighted Sound Pressure, p_A — Value of overall sound pressure, measured in pascal (Pa), after the electrical signal derived from a microphone has been passed through an A-weighting network.

NOTE — The A-weighting network modifies the electrical response of a sound level meter with frequency in approximately the same way as the sensitivity of the human hearing system.

2.4 A-Weighted Sound Pressure Level, L_{pA} — The quantity of A-weighted sound pressure, in decibel (dB), as given by the following formula:

$$L_{pA} = 10 \log_{10} (p_A/p_0)^2$$

where

p_A = A-weighted sound pressure, in pascals (Pa); and

p_0 = reference sound pressure (20 μPa).

NOTE — Measurements of A-weighted sound pressure level can be made with a meter and correlate roughly with subjective assessments of loudness, and are usually made to assist in judging the effects of noise on people. The size of A-weighting in 1/3 octave bands, is shown in Annex A (*see* **A-5**). An increase or decrease in level of 10 dBA corresponds roughly to a doubling or halving of loudness.

2.5 Background Noise — The sound pressure levels in a given environment from all sources excluding a specific sound source being investigated or measured.

2.6 Break-In — Unwanted sound transmission into a duct or a quiet environment, from outside.

2.7 Break-Out — Unwanted sound transmission from the inside of a duct or a noisy enclosure, to the outside.

2.8 Broad Band Noise — Spectrum consisting of a large number of frequency components, none of which is individually dominant.

2.9 Cross-Talk — Unwanted sound transmission between one room and another room or space, *via* a duct.

2.10 C_{tr} — Correction term applied against the sound insulation single-number values (R_w, D_w, and $D_{nT,w}$) to provide A-weighting against low frequency performance.

NOTE — The reference values used within the C_{tr} calculation are based on urban traffic noise.

2.11 Decibel — Ten times the logarithm (to the base 10) of the ratio of two mean square values of sound pressure, sound power or sound intensity. The abbreviation for decibel is dB.

2.12 Effective Perceived Noise Level, in Decibel (EPN dB) — The number for rating the noise of an individual aircraft flying overhead is the effective perceived noise level in decibel (EPN dB). The effective perceived noise decibel value takes into account the subjectively annoying effects of the noise including pure tones and duration. In principle, it is a kind of time-integrated loudness level.

2.13 Equivalent Continuous A-Weighted Sound Pressure Level, $L_{Aeq.T}$ — Value of the A-weighted sound pressure level in decibel (dB) of a continuous, steady sound, that within a specified time interval, T, has the same mean squared sound pressure as the sound under consideration that varies with time, and is given by the formula:

$$L_{Aeq.T} = 10 \log_{10} \left(\frac{1}{T} \int_0^T \frac{p_A^2(t)}{p_0^2} \, dt \right)$$

where

$p_A(t)$ = instantaneous A-weighted sound pressure, in pascal (Pa); and

p_0 = reference sound pressure (20 μPa).

NOTE — Equivalent continuous A-weighted sound pressure level is mainly used for the assessment of environmental noise and occupational noise exposure.

2.14 Equivalent Sound Absorption Area of a Room, A — Hypothetical area of a totally absorbing surface without diffraction effects, expressed in square metre (m^2) which, if it were the only absorbing element

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in the room, would give the same reverberation time as the room under consideration.

2.15 Façade Level — Sound pressure level measured 1 m to 2 m in front of the façade.

NOTE — Façade level measurements of L_{pA} are usually 2 dB to 3 dB higher than corresponding free-field measurements.

2.16 Free-Field Level — Sound pressure level measured outside, far away from reflecting surfaces.

NOTE — Measurements made 1.2 m to 1.5 m above the ground and at least 3.5 m away from other reflecting surfaces are usually regarded as being free-field measurements. To minimise the effect of reflections the measuring position should be at least 3.5 m to the side of the reflecting surface (that is, not 3.5 m from the reflecting surface in the direction of the source). Estimates of noise from aircraft overhead usually include a correction of 2 dB to allow for reflections from the ground.

2.17 Frequency — The number of cyclical variations per unit time. Frequency is generally expressed in cycles per second (cps) and is also denoted as Hertz (Hz).

2.18 Impact Sound Pressure Level, L_i — Average sound pressure level in a specific frequency band in a room below a floor, when it is excited by a standard tapping machine.

2.19 Indoor Ambient Noise — Pervasive noise in a given situation at a given time, usually composed of noise from many sources, inside and outside the building, but excluding noise from activities of the occupants.

2.20 Insertion Loss (L_{IL}) — Insertion loss is generally defined as the difference, in decibels, between two sound pressure levels (or power levels or intensity levels) which are measured at the same point in space before and after a muffler or any other noise control device is inserted between the measurement point and the noise source.

2.21 Noise — Unwanted sound which may be hazardous to health, interferes with communications or is disturbing.

2.22 Noise Exposure Forecast (NEF) — The noise exposure forecast at any location is the summation of the noise levels in EPN dB from all aircraft types, on all runways, suitably weighted for the number of operations during day time and night time.

2.23 Noise Criteria — Numerical indices used to define design goals for the maximum allowable noise in a given space.

2.24 Noise Rating (NR) — Graphical method for rating a noise by comparing the noise spectrum with a family of noise rating curves.

NOTE — Noise rating is described in Annex C.

2.25 Noise Reduction Coefficient (NRC) — A single figure descriptor of the sound absorption property of a material. It is the arithmetic mean of the sound absorption coefficients at 250, 500, 1 000 and 2 000 Hz rounded off to the nearest multiple of 0.05.

2.26 Normalized Impact Sound Pressure Level, L_n — Impact sound pressure level normalized for a standard absorption area in the receiving room.

NOTE — Normalized impact sound pressure level is usually used to characterize the insulation of a floor in a laboratory against impact sound in a stated frequency band (*see* Annex B).

2.27 Octave Band — Band of frequencies in which the upper limit of the band is twice the frequency of the lower limit.

2.28 Percentile Level, $L_{AN,T}$ — A-weighted sound pressure level obtained using time-weighting '*F* ', which is exceeded for *N* percent of a specified time interval.

Example:

$L_{A90,1h}$ is the A-weighted level exceeded for 90 percent of 1 h.

NOTE — Percentile levels, determined over a certain time interval cannot accurately be extrapolated to other time intervals. Time-weighting '*F*' or '*S*' can be selected on most modern measuring instruments and used to determine the speed at which the instrument responds to changes in the amplitude of the signal. Time-weighting '*F*' is faster than '*S*' and so its use can lead to higher values when rapidly changing signals are measured.

2.29 Pink Noise — Sound with an uninterrupted frequency spectrum and a power which is steady within frequency band and proportional to centre frequency. An example is constant power level per octave band.

2.30 Pure Tone — A sound emitted at a single frequency.

2.31 Rating Level, L_{Ar}, T_r — Equivalent continuous A-weighted sound pressure level of the noise, plus any adjustment for the characteristic features of the noise.

NOTE — This definition is used for rating industrial noise, where the noise is the specific noise from the source under investigation.

2.32 Reverberation Time, T — Time that would be required for the sound pressure level to decrease by 60 dB after the sound source has stopped.

NOTE — Reverberation time is usually measured in octave or third octave bands. It is not necessary to measure the decay over the full 60 dB range. The decay measured over the range 5 dB to 35 dB below the initial level is denoted by T_{30}, and over the range 5 dB to 25 dB below the initial level by T_{20}.

2.33 Sound — A vibrational disturbance, exciting hearing mechanisms, transmitted in a predictable manner determined by the medium through which it propagates. To be audible the disturbance shall have to

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fall within the frequency range of 20 Hz to 20 000 Hz.

2.34 Sound Exposure Level, L_{AE} — Level of a sound, of 1 s duration, that has the same sound energy as the actual noise event considered.

NOTES

1 The L_{AE} of a discrete noise event is given by the formula:

$$L_{AE} = 10\log_{10}\left(\frac{1}{t_0}\int_{t_1}^{t_2}\frac{p_A^2(t)}{p_0^2}\mathrm{d}t\right)$$

where

$p_A(t)$ = instantaneous A-weighted sound pressure, in pascal (Pa);

$t_2 - t_1$ = stated time interval in seconds (s) long enough to encompass all significant sound energy of the event;

p_0 = reference sound pressure level (20 µPa); and

t_0 = reference time interval (1 s).

2 L_{AE} is also known as L_{AX} (single-event noise exposure level).

2.35 Sound Level Difference, *D* — Difference between the sound pressure level in the source room and the sound pressure level in the receiving room.

NOTE — D is given by the following formula:

$$D = L_1 - L_2$$

where

L_1 = average sound pressure level in the source room; and

L_2 = average sound pressure level in the receiving room.

2.36 Sound Power — The acoustic power of a sound source, expressed in Watt.

2.37 Sound Power Level (L_w) — The acoustic power radiated from a given sound source as related to a reference power level (typically 10-12 watt) and expressed in decibel as :

$$L_p = 10\log_{10}\left\{\frac{W}{10^{-12}}\right\}$$

or

$$L_w = 10 \log W + 120$$

where

W = acoustic power, in watt.

By definition, 1 W therefore corresponds to 120 dB for L_w.

2.38 Sound Pressure, *p* — Root-mean-square value of the variation in air pressure measured in pascal (Pa), above and below atmospheric pressure, caused by the sound.

2.39 Sound Pressure Level, L_p — Quantity of sound pressure, in decibel (dB), given by the formula:

$$L_p = 10 \log_{10} (p/p_0)^2$$

where

p = root mean square sound pressure in pascals (Pa); and

p_0 = reference sound pressure (20 µPa).

NOTE — The range of sound pressures for ordinary sounds is very wide. The use of decibels gives a smaller, more convenient range of numbers. For example, sound pressure levels ranging from 40 dB to 94 dB correspond to sound pressures ranging from 0.002 Pa to 1 Pa. A doubling of sound energy corresponds to an increase in level of 3 dB.

2.40 Sound Receiver — One or more observation points at which sound is evaluated or measured. The effect of sound on an individual receiver is usually evaluated by measurements near the ear or close to the body.

2.41 Sound Reduction Index, *R* — Laboratory measure of the sound insulating properties of a material or building element in a stated frequency band.

NOTE — For further information *see* Annex B.

2.42 Sound Source — Equipment or phenomena which generate sound. Source room is the room containing sound source.

2.43 Spectrum — A quantity expressed as a function of frequency, such as sound pressure versus frequency curve.

2.44 Standardized Impact Sound Pressure Level, L'_{nT} — Impact sound pressure level normalized to that in a receiving room having a reverberation time of 0.5 s.

NOTE — Standardized impact sound pressure level is used to characterize the insulation of floors in buildings against impact sound in a stated frequency band (*see* Annex B).

2.45 Speech Interference Level (SIL) — A descriptor for rating steady noise according to its ability to interfere with conversation between two people. SIL is the arithmetic average of the sound pressure levels in the three octave bands with centre frequencies at 500, 1 000 and 2 000 Hz.

2.46 Standardized Level Difference, D_{nT} — Difference in sound level between a pair of rooms, in a stated frequency band, normalized to a reverberation time of 0.5 s.

NOTE — Standardized level difference takes account of all sound transmission paths between the rooms (*see* Annex B).

2.47 Structure-Borne Noise and Ground-Borne

NOTE — When elements of a structure vibrate they radiate noise and, if the vibration is high enough, this noise can be audible. Ground-borne and structure-borne noises are rarely an issue outside buildings or structures.

2.47.1 *Ground-Borne Noise* — Audible noise caused by the vibration of elements of a structure, for which the vibration propagation path from the source is partially or wholly through the ground.

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NOTE — Common sources of ground-borne noise include railways and heavy construction work on adjacent construction sites.

2.47.2 *Structure-Borne Noise* — Audible noise caused by the vibration of elements of a structure, the source of which is within a building or structure with common elements.

NOTE — Common sources of structure-borne noise include building services plant, manufacturing machinery and construction or demolition of the structure.

2.48 Transient Sound — Sound which is audible for a limited period of time, for example, sound from over flight of an airplane.

2.49 Third Octave Band — Band of frequencies in which the upper limit of the band is $2\frac{1}{3}$ times the frequency of the lower limit.

2.50 Threshold of Hearing — The lowest continuous sound pressure level which will create an auditory sensation for the average human ear. Any sound below these levels will be inaudible and any sound above the threshold will vary in loudness dependent on intensity.

2.51 Vibration Isolation — Reduction of force or displacement transmitted by a vibratory source, often attained by use of a resilient mount.

2.52 Wavelength — The length in space of one complete cycle of a sound wave given by:

$$\lambda = \frac{\text{Speed of sound}}{\text{Frequency}} = \frac{(C)}{(f)}$$

2.53 Weighted Level Difference, D_w — Single-number quantity that characterizes airborne sound insulation between rooms but which is not adjusted to reference conditions.

NOTE — Weighted level difference is used to characterize the insulation between rooms in a building as they are; values cannot normally be compared with measurements made under other conditions {*see* good practice [8-4(1)]}.

2.54 Weighted Sound Reduction Index, R_w — Single number quantity which characterizes the airborne sound insulating properties of a material or building element over a range of frequencies.

NOTE — The weighted sound reduction index is used to characterize the insulation of a material or product that has been measured in a laboratory (*see* Annex B).

2.55 Weighted Standardized Impact Sound Pressure Level, $L'_{nT,w}$ — Single number quantity used to characterize the Impact sound insulation of floors over a range of frequencies.

NOTE — Weighted standardized impact sound pressure level is used to characterize the insulation of floors in buildings (*see* Annex B).

2.56 Weighted Standardized Level Difference, $D_{nT,w}$ — Single-number quantity, which characterizes the airborne sound insulation between rooms

NOTE — Weighted standardized level difference is used to characterize the insulation between rooms in a building (*see* Annex B).

2.57 Weighted Normalized Impact Sound Pressure Level, $L'_{n,w}$ — Single number quantity used to characterize the impact sound insulation of floors over a range of frequencies.

NOTE — Weighted normalized impact sound pressure level is usually used to characterize the insulation of floors tested in a laboratory (*see* Annex B).

2.58 White Noise — A noise whose spectrum (level) density is substantially independent of frequency over a specified range and has equal power for any range of frequencies of constant band width.

3 PLANNING AND DESIGN AGAINST OUTDOOR NOISE

3.1 General

Planning against noise should be an integral part of town and country planning proposals, ranging from regional proposals to detailed zoning, and three-dimensional layouts and road design within built-up areas. Noise nuisance should be fully recognized in zoning regulations.

3.1.1 Noise is either generated by traffic (road, air, and surface and underground railway) or it arises from zones and buildings within built-up areas (industry, commerce, offices and public buildings), and from public gatherings and social activities. For planning, the noise survey should examine all the possible causes of noise and consider the various factors causing actual nuisance.

3.1.2 Noise by night, causing disturbance of sleep, is more of a nuisance than noise by day. For this reason, housing colonies that adjoin areas with heavy traffic movement during the night are liable to cause serious complaints. Also, the factories that work by night are liable to cause serious complaints if housing estates adjoin them. While planning, care should be taken that housing colonies are adequately set back from busy airports, state and national highways, factories, main railway lines and marshalling yards.

3.1.3 There are two aspects of defence by planning. The first is to plan so as to keep the noise at a distance. Under this aspect comes the separation of housing from traffic noise by interposing buffer zones, and the protection of schools and hospitals by green belts, public gardens, etc. The second is the principle of shading or screening. This consists of deliberately

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interposing a less vulnerable building to screen a more vulnerable one or by providing a solid barrier, such as a wall, between the source and the location to be protected.

3.2 Traffic Noise Levels

3.2.1 *For Air Traffic*

For guidance, approximate noise levels due to various types of aircrafts, measured on ground, when the aircrafts fly overhead at a height of 450 m, are given in Table 1.

Table 1 Typical Noise Levels of Some Aircraft Types

(*Clause* 3.2.1)

Sl No.	Type of Aircraft	Flyover Noise Levels at 450 m with Take-off Thrust EPN dB
(1)	(2)	(3)
i)	Boeing 737	107
ii)	Boeing 747-200	103
iii)	Airbus A300	101

3.2.2 *For Rail Traffic*

Noise levels of some typical railway traffic are given in Table 2.

Table 2 Typical Noise Levels of Railway Trains

(*Clause* 3.2.2)

Sl No.	Type of Train	Noise Level at 30 m, Measured on the Side or in the Direction of Train dBA
(1)	(2)	(3)
i)	Steam train, 60 km/h	85
ii)	Diesel train, 60 km/h	83
iii)	Electric train, 60 km/h	77

3.2.3 *For Road Traffic*

The level of noise generated by road traffic depends upon such factors as the number of vehicles passing per hour, the type of traffic, the preponderance of heavy vehicles, average speed, gradient and smoothness of traffic flow. The smoothness of traffic flow also affects variability of the noise and is governed by such features as roundabouts and traffic lights, and the volume of traffic and pedestrian movement with their effects on stopping, starting, overtaking and honking. The level of traffic noise fluctuates continuously and the way it does, has a considerable effect on the nuisance caused. For assessing traffic noise, noise is measured in dBA. Because of the fluctuating nature of traffic, noise levels due to different volumes of traffic flow with a varying mix of vehicles are given in Table 3.

Table 3 Typical Noise Levels Due to Free-Flowing Road Traffic

(*Clause* 3.2.3)

Sl No.	Type of Traffic	L_{10} 30 m from Edge of Road dBA
(1)	(2)	(3)
i)	5 000 vehicles per 18 hour day (10 percent heavy vehicles), 50 km/h	65
ii)	10 000 vehicles per 18 hour day (20 percent heavy vehicles), 60 km/h	70
iii)	10 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 km/h	75
iv)	20 000 vehicles per 18 hour day (40 percent heavy vehicles), 80 km/h	77

NOTE — The values are applicable to free flowing traffic without honking.

3.3 Outdoor Noise Regulations

The outdoor noise regulations in force from time to time shall be complied with (*see also* Annex D).

3.4 Planning and Design

3.4.1 *Air Traffic*

Near airports two sources of aircraft noise should be considered.

a) *Flyover noise* — Flyover noise is that which occurs under flight paths close to airports and is the most serious and common problem. As the aircraft passes overhead the noise level at any particular location rises to a peak and then decreases.

b) *Ground noise* — The noise emitted by an aircraft during ground operations is less variable in direction than flyover noise, but is usually of a longer duration.

3.4.1.1 Aircraft noise may disturb sleep, rest and communication, and as such may be considered potentially harmful to health. It is important that no new development is carried out within areas where the expected noise levels will cause mental and physical fatigue or permanent loss of hearing. In case development in such areas is essential, adequate sound insulation shall be provided for the building.

3.4.1.2 As the problems caused by aircraft noise have become more acute, a number of methods have been devised for evaluating noise exposure in the vicinity of airports. They all combine many factors into a single number evaluation. A commonly used criterion is the noise exposure forecast (NEF). The NEF is used primarily to develop noise contours for areas around airports. It has been accepted generally that noise exposure forecast levels greater than NEF 40 are

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unacceptable to people while levels less than NEF 25 are normally acceptable. Levels between NEF 25 and 40 may lead to subjective complaints.

3.4.1.3 While it is theoretically possible to provide sufficient insulation to achieve an acceptable indoor noise environment in the area of very high outdoor noise, there is a level above which aircraft noise seriously affects living conditions no matter how much sound insulation has been applied to the dwelling unit. For this reason it is recommended that no residential development be allowed beyond the NEF 35 level.

3.4.1.4 During summer months, the windows are normally kept open for adequate ventilation. In view of this, no matter how much sound insulation is provided for the building structure, the noise level inside the room can never be less than 10 dB below the outdoor noise level. For very critical buildings, such as buildings necessary for maintaining and supplementing the airport services, and for commercial development, such as hotels, it is possible to provide sealed windows and to centrally air condition the entire building. However, it is not feasible for most of the residential developments in the country. In such cases proper zoning regulations and siting of vulnerable buildings away from aircraft noise are of vital importance.

3.4.2 *Rail Traffic*

This is a very serious source of noise in built-up areas, both by day and by night. Railway cuttings reduce the spread of noise, whereas embankments extend it. The elevated railway on viaducts or embankment is very common in built-up areas. The elevation increases exposure to noise but in addition the construction of the viaduct may affect the propagation of noise. In this respect solid embankments are preferable to built-up arches, which tend to act as sound boxes. Worst of all are the steel bridges, which greatly magnify the noise due to vibration. Uphill gradients are another feature tending to increase noise, especially of heavy goods trains.

3.4.2.1 Wherever possible, no residential or public building zone should abut onto railway lines, especially on the marshalling yards which is particularly objectionable because of the shrill, clanging and intermittent noise they generate, often at night. The appropriate zones alongside railway lines are industrial and commercial buildings other than office buildings. Where these precautions are not practicable and housing has to abut on to railway lines, every attempt may be made to house as few people as possible in the vicinity of the railway lines.

3.4.2.2 Underground transportation system can be a major cause of disturbance for the neighbouring community. Very high noise levels are propagated to long distances by the underground high speed railway, as a result of wheel-rail interaction. Both airborne noise and ground or structure-borne vibrations are potential sources of complaints. Noise control measures, therefore, need to be considered for the following:

a) In stations, where high noise levels are produced at the arrival and departure of trains;
b) In tunnels, during high speed train movement;
c) Where an underground rail transit system passes close to existing structures or high rise buildings, adequate attention should also be paid to the problem of ground vibration transmitted to the building, and proper isolation should be provided for critical areas;
d) Wherever elevated railway tracks are provided, adequate measures should be taken to avoid the spread of noise in the surrounding built up areas; and
e) In transit cars, where sound insulation is of vital importance to provide comfortable conditions for the commuters.

3.4.3 *Road Traffic*

3.4.3.1 Convoys of long distance heavy trucks at night moving past through built-up areas cause serious noise complaints. On busy roads, the noise of continuous traffic may be a worse nuisance than that of railways. At least the same precautions may, therefore, be taken in the planning of dwellings in relation to arterial and trunk roads as with railways. Care may be taken that local housing roads do not provide short cuts for heavy traffic through residential areas. Hilly roads present the additional noise of gear changing. Trees with heavy foliage planted on both sides of carriageway help slightly to muffle the noise, provided the foliage extends for a considerable distance (30 m or above).

3.4.3.2 Road traffic may give rise to serious nuisance particularly on busy thoroughfares, between continuous high buildings in main streets, at the traffic lights, near bus stops, on steep slopes and in parking spaces and enclosed yards.

3.4.3.3 For zoning and planning of new buildings in urban areas, it is recommended that external L_{A10} be limited to a maximum of 70 dBA when the dwellings are proposed to have sealed windows and 60 dBA when the dwellings are proposed to have open windows. Indeed it is desirable to confine major new residential development to locations subject to L_{A10} levels substantially lower than those given above.

It is recognized, however, that within the large urban areas, the use of sites where the external L_{A10} is greater than 60-70 dBA cannot always be avoided. In that case it is suggested to utilize such design solutions as barrier

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blocks in order to reduce external L_{A10} noise levels to at least 60-70 dBA at any point 1.0 m from any inward looking façade. When the orientation of site and the density of development are such that this cannot be fully achieved some form of dwelling insulation will have to be provided. It should be appreciated that where open windows are necessary, the occupants would have to put up with discomfort if the above conditions are not met.

3.4.3.4 Certain other methods can often be utilized to provide economical and effective protection from noise, as follows:

a) Methods should be adopted to improve the smoothness of flow and reduce number of stopping and starting. This leads to an improvement even, if it leads to increased flows. Flow linking of traffic lights, for example, may reduce noise nuisance.
b) Use of roads passing through residential areas should be prohibited to heavy commercial vehicles. An alternative would be to limit use by commercial vehicles to certain times of the day.
c) Use of honking shall be prohibited near sensitive buildings, such as hospitals and the like.
d) Barriers shall be provided to shield sites from noise.

3.4.4 *Construction Noise*

3.4.4.1 Construction activities relating to building and infrastructure facilities cause noise disturbance to occupants in existing built facilities located around the site.

Construction noise involves both stationary and mobile sources. Common activities and sources of concern in case of construction noise include excavation and site clearing activities, blasting, piling, operation of batching plants, concrete mixers, pumping, running of diesel generators, drilling and chipping, loading/ unloading activities, and truck and other vehicular movement.

The source noise intensity and spectrum is primarily characterized by the type of construction activity, equipment used, ground conditions and associated vehicular movement. Apart from the source characteristics, community noise impact is influenced by the time and sequence of construction related activities.

3.4.4.2 Noise control can be done at the source or in the noise propagation path. While it is preferable to adopt noise control at the source, it may not be practically possible to implement it for some of the construction equipment. Given the diversity of noise sources, mitigation strategies in case of construction noise have to be dealt with appropriately depending on the spectral characteristics of sources.

Source noise control strategies include providing acoustic enclosures for sources like diesel generators, choosing less noisy construction machinery and selecting alternative construction practices which involve lesser noise generation.

Noise control in the propagation paths primarily involves provision of noise barriers around the construction sites.

Positioning of major fixed construction equipment/ installations such as batching plants and diesel generators have a significant impact on the noise spectrum and its impact. Also, time of operation and duration of noisy construction activities have significant impact on the resultant annoyance.

3.4.4.3 Due consideration for environmental noise regulation should be given while scheduling and sequencing noisy construction activities.

3.5 Zoning

The zoning of the different cities shall be done by the town planning authorities, taking into account besides other aspects, the noise levels from different occupancies. Wherever necessary, experts in the field may be consulted. For detailed information on noise reduction for town planning schemes, reference may be made to good practice [8-4(2)].

3.6 Green Belts and Landscaping

Where relief from noise is to be provided by means of green belts these may be of considerable width and be landscaped. (In case of railway tracks, a minimum distance of 50 m to 70 m may be provided between the buildings and the tracks). The extent of relief that may be derived from the above may be estimated only after considering other environmental factors. Only thick belts of planting (greater that 30 m) are of real value. Strong leafy trees may be planted to act as noise baffles. Shrubs or creepers may also be planted for additional protection between tree trunks; artificial mounds and banks should be formed where practicable. As little hard paving and as much grass as possible may be used. The creation of green belt is particularly advisable on the perimeter of aerodromes, along railway lines and arterial roads, through or past built-up areas and adjoining noisy industrial zones.

3.7 Highway Noise Barriers

Barriers are often the most effective means of reducing traffic noise around residential areas. They have the

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great advantage that they generally protect most or all of the site. In nearly all situations, a well-designed barrier of even a modest height (say 3 m) can at least ensure that all areas of open space are free from excessive noise levels.

There are two types of barriers that can be built to protect sites; one which are built solely for the purpose of reducing noise and the other which form part of the building complex (barrier blocks). Free standing walls and artificial mounds are typical examples of the first type while single and multi-storeyed utility buildings and garages are the most common form of the second.

Of the two types, laying out barrier blocks of a complex in an appropriate fashion is a better option because they are cheaper and also tend to form a more effective barrier overall because of their greater height and width. Barrier walls or mounds are more limited in their effect than barrier blocks for they protect little more than the area of the site close to ground level essentially because of the lack of height, as continuous walls much higher than 3 m are often difficult to construct.

3.8 Special Problems Requiring Expert Advice

The purpose of noise control is to ensure that people are neither harmed nor disturbed by noise. In addition to provisions given in this Section, special advice may be required for more complex situations, such as those listed in Annex E.

4 PLANNING AND DESIGN AGAINST INDOOR NOISE

4.1 Acceptable Indoor Noise Levels in Buildings

The generally acceptable noise levels inside buildings are given in Table 4.

Table 4 Acceptable Indoor Noise Levels for Various Buildings

(*Clause* 4.1)

Sl No.	Location	Noise Level dBA
(1)	(2)	(3)
i)	Auditoria and concert halls	20-25
ii)	Radio and TV studios	20-25
iii)	Cinemas	25-30
iv)	Music rooms	25-30
v)	Hospitals	35-40
vi)	Apartments, hotels and homes	35-40
vii)	Conference rooms, small offices and libraries	35-40
viii)	Court rooms and class rooms	40-45
ix)	Large public offices, banks and stores	45-50
x)	Restaurants	50-55

4.2 Vulnerable Buildings

Some buildings or parts of buildings are especially vulnerable to noise, for example, recording and radio studios, hospitals and research laboratories. These should not be sited near loud noise sources. Most vulnerable buildings contain some areas which are themselves noisy and in such buildings the less vulnerable elements should be planned to act as noise buffers. Most noisy buildings also contain quiet accommodation, which equally may be planned to act as a buffer between the noisy part of the building and adjoining vulnerable buildings.

4.3 The details of site and internal planning and insulation requirements are covered under individual occupancies (*see* **5** to **12**) as applicable to the respective character and sources of noise in different buildings.

4.3.1 *Equitable Inclusion of Hearing Impaired Persons in Public Place*s

People with hearing impairments have particular difficulty in making out sounds and words in noisy environments. Therefore, adequate sound insulation would minimise noise from both outside and inside the building. Also, low reverberation times are more suitable for hearing impaired persons and should thus be planned while designing the size and shape of the room.

Persons using hearing aids may require quiet areas with induction loops in very noisy information counters or where announcements are made. Induction loops may also be provided in all areas where there are verbal inputs provided, such as conference halls, auditoria, class rooms and cinema halls.

4.4 Sound Insulation of Non-Industrial Buildings by Constructional Measures

The desired (acceptable) noise levels and the recommended insulation values for the various areas may be achieved by providing sound insulation treatments by constructional measures. The details of the same are given in Annex F. The recommendations given in Annex F are applicable to non-industrial buildings like residences, educational buildings, hospitals and office buildings.

4.5 Special Problems Requiring Expert Advice — *See* **3.8** and Annex E.

5 RESIDENTIAL BUILDINGS

5.1 Sources of Noise Nuisance

5.1.1 *Outdoor Noise*

The main sources of outdoor noise in residential areas are traffic (aeroplane, railways, roadways), children playing, hawkers, services deliveries, road repairs, blaring loud-speakers, various types of moving machinery in the neighbourhood and building operations, and captive power generation machinery.

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5.1.2 *Indoor Noise*

5.1.2.1 As far as indoor noises are concerned, conversation of the occupants, footsteps, banging of doors, shifting of the furniture, operation of the cistern and water closet, playing of radio, television, music system, cooling and ventilation machinery, etc, contribute most of the noise emanating from an adjacent room or an adjacent building. Noise conditions vary from time to time and noise which may not be objectionable during the day may assume annoying proportions in the silence of the night when quiet conditions are essential.

5.1.2.2 In the case of flats the main sources of noise are from other flats and from stairs, lifts and access balconies. Plumbing noise is another cause. In semi-detached buildings, outdoor noises from streets are noticed more than indoor noises from neighbours.

5.2 Recommendations

5.2.1 *Site Planning*

The most desirable method is to locate the residential buildings in a quiet area away from the noisy sources like the industrial areas, rail tracks, aerodromes, roads carrying heavy traffic, etc.

5.2.1.1 To minimise ground reflection, the dwellings should be surrounded by the maximum amount of planting and grassed areas and the minimum amount of hard surfacing. This applies particularly to high density areas. Where for maintenance reasons a large amount of hard paving is necessary, it should be broken up by areas of planting and grassing. Narrow hard paved courts should be avoided between adjacent tall buildings.

5.2.1.2 Roads within a residential area should be kept to a minimum both in width and length, and should be designed to discourage speeding. Area-wise planning, with zones from which vehicular traffic is altogether excluded will greatly help to reduce noise. Roads with through traffic should be excluded from residential areas, but where sites have to be developed adjacent to existing major roads the same principles should be observed in the siting of blocks as with railway lines as covered under **3.4.2.1.**

5.2.1.3 Play areas for older children should be sited as far away from dwellings as possible. Special care should be taken with old peoples' dwellings. They should not be placed immediately adjacent to service entries, play spaces, or to any entrances where children may tend to congregate.

5.2.2 *Internal Planning*

The orientation of buildings in a locality should be planned in such a way as to reduce the noise disturbance from neighbourhood areas. The non-critical areas, such as corridors, kitchens, bathrooms, elevators and service spaces may be located on the noisy side and the critical areas, such as bedrooms and living space, on the quiet side.

5.2.2.1 *Windows and doors*

Windows and doors should be kept away from the noisy side of the building as given below, wherever possible:

a) When windows of a building, particularly those of bedrooms in apartments or flats, face roads carrying heavy traffic or other noises where the external noise is of the order of 80 to 90 dBA, the building should be located at a distance of about 30 m from the road, but a distance of 45 m or more, where possible, should be aimed at for greater relief from noise;

b) When the windows are at right angles to the direction of the above type of noise, the distance from the road should be arranged to be about 15 to 25 m; and

c) In case another building, boundary wall or trees and plantations intervene between the road traffic and the house/flat further noise reduction is achieved and in such cases the above distances may be reduced suitably.

5.2.2.2 *Layout plans*

It is desirable that rooms adjoining party walls and above/below party floors should be of similar use. By this means, bedrooms are not exposed to noise from adjoining living rooms, and there is less risk of disturbance of sleep.

In semi-detached houses, the staircase, hall and kitchen should adjoin each other on each side of the party wall, thus providing a sound baffle between rooms requiring quiet conditions.

Bedrooms should not be planned alongside access balconies, and preferably not underneath them. Where the approach is by an internal corridor, a sound baffle may usefully be provided by arranging internal passages and bathrooms between the corridor and the living room or bedrooms.

Kitchens and water closets should not be planned over living rooms and bedrooms, whether within the same dwelling or over other dwellings. Soil pipes should not be carried in ducts which adjoin living rooms or bedrooms unless the side of the duct next to these rooms is a solid wall containing no inspection openings. Refuse chutes should not be planned next to living rooms or bedrooms.

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5.2.3 *Sound Insulation*

5.2.3.1 *Reduction of airborne noise*

The weighted sound reduction index, R_w, of partitions between individual rooms or apartments of a building unit shall be as given in Table 5. These values may, however, be suitably increased, where required, for critical areas.

Table 5 Sound Insulation Between Individual Rooms (Airborne)

(*Clause* 5.2.3.1)

Sl No.	Situation	R_w dB
(1)	(2)	(3)
i)	Between the living room in one house or flat and the living room and bed-rooms in another	50
ii)	Elsewhere between houses or flats	45
iii)	Between one room and another in the same house or flat	35

NOTES

1 Where communicating doors are provided, all doors should be so designed as to provide recommended insulation between the rooms.

2 There are cases when a set of houses or flats have to be built for the people who work at night and sleep during the day. It is desirable to consider the design of at least one such room in each of the houses or flats which will provide an insulation of about 45 dB in that room.

3 The insulation values referred to are applicable with doors and windows shut.

5.2.3.2 *Suppression of noise at the source itself*

All items of equipment that are potentially noisy should be selected with care. Water closet cisterns should not be fixed on partitions next to bedrooms or living rooms. Plumbing pipes should be isolated from the structures. Lift motors should be mounted on resilient supports. Access doors from machine rooms to internal staircases should be well fitting and of solid construction. Special noise control measures may be required for electrical and mechanical services such as diesel generators, outdoor air conditioning units, cooling towers, etc.

5.2.3.3 *Reduction of airborne noise transmitted through the structure*

Reduction of airborne noise requires the use of rigid and massive walls, or acoustically designed dry walls, without any openings. Openings are the major cause of penetration of noise through a barrier. While designing it should be borne in mind that all components should provide a sound transmission compatible with that of the rest of the barrier so that an equivalent amount of sound energy is transmitted through each portion of the barrier.

Ventilating ducts or air transfer openings where provided should be designed to minimise transmission of noise. For this purpose, sound attenuating devices having necessary insertion loss may be installed in these openings.

All partitions should be sealed effectively where they butt against rest of the structure. All doors and windows should be properly gasketed where a high degree of sound insulation is desired.

5.2.3.4 *Reduction of structure-borne noise*

This requires the use of discontinuous or non-homogeneous materials in the construction of the structure.

5.2.3.5 *Reduction of impact noise*

The floor of a room immediately above the bed room or living room shall result in an impact sound pressure level ($L'_{nT,w}$) not greater than 60 dB. Typically, a 150 mm thick concrete floor with thick carpet (12 mm) covering would satisfy this requirement.

5.2.3.6 Main staircases in blocks of flats are often highly reverberant. Some of the surfaces at least (for example, the soffits of stairs and landings) should be finished with sound absorbent materials, wherever required.

6 EDUCATIONAL BUILDINGS

6.1 Sources of Noise Nuisance

6.1.1 *Outdoor Noise*

The outdoor sources of noise produced on school premises, which cause disturbance within the school, include the noise arising from playgrounds, playing fields and open-air swimming pools. Though playgrounds are used mainly during break periods, they are also used for games and physical education at times when teaching is in progress in the adjoining class rooms.

6.1.2 *Indoor Noise*

Indoor sources of noise are as follows:

a) Singing, instrumental and reproduced music which may take place in class rooms and in dining and assembly halls particularly in primary schools. In secondary schools, specialized music rooms are generally provided;
b) Movement of chairs, desks and tables at the end of one period may disturb a class engaged in a lesson in a room below;
c) Shutting and openings of doors and windows which may occur at any time during teaching periods;
d) Audio-visual presentations in class rooms;
e) Wood and metal workshops, machine shops

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(engineering laboratories), typing rooms, etc, that produce continuous or intermittent sound of considerable loudness;

f) Practical work carried out in general teaching areas;

g) Gymnasia and swimming pools;

h) School kitchens and dining spaces where food preparation and the handling of crockery and utensils persist for the greater part of the school day;

j) Corridors and other circulation spaces; and

k) Plumbing and mechanical services.

6.2 Recommendations

6.2.1 *Site Planning*

Where outdoor noise nuisance exists from local industry, busy roads, railway, airfields, sport grounds or other sources beyond the control of the school authority, school buildings should be sited as far away from the sources of noise, as possible.

6.2.1.1 Rooms should be planned in a manner so that the minimum amount of glazing is placed on the side facing the external noise.

6.2.1.2 Noises arising from the activities of a school and from the use of the buildings after school hours may constitute a nuisance to occupants of surrounding property; therefore, it is desirable to place playgrounds, workshops, swimming pools, music rooms, assembly halls and gymnasia as far away as possible from buildings which require a quiet environment.

6.2.2 *Internal Planning*

The following principles should be observed in the detailed planning of educational buildings:

a) *Grouping* — Noisy rooms should be separated from quiet ones, if possible. In general, it is desirable that rooms should be grouped together in accordance with the classification given in **6.2.4.1**.

b) *Windows and ventilators* — Windows of noisy and quiet rooms should not open on to the same courtyard or be near to one another. Skylights and ventilators over noisy rooms should be avoided, if they are likely to be a source of nuisance to adjacent upper floors.

c) *Doors* — Swing doors into rooms should only be used where no problem of sound transmission exists. Reduction of insulation between rooms and corridors due to doors shall be borne in mind. The type and method of fitting of doors is important and necessary care shall be paid in this respect.

d) Sliding partitions, if used, should be acoustic operable partitions. Pass-through doors, if provided, should be acoustic doors with drop seals.

e) *Open planning and circulation areas* — Where open planning is used to permit spaces, such as assembly halls, dining rooms or entrance halls to be used in association with each other or for circulation, the degree of disturbance caused by interfering noise to teaching areas needs careful consideration; traffic through such areas should be strictly controlled; full use should be made of sound absorbent treatments to reduce the spread of noise from one space to another (*see* **6.2.3**).

   If rooms have large glazed panels or ventilation openings facing directly on the circulation areas, human traffic passing by the rooms should be controlled. Preferably baffled ventilation system or double windows should be used. Fan-lights over doors should be fixed and glazed.

f) *Furniture* — In all educational buildings, regardless of the character of the floor finish, rubber buffers should be fitted to the legs of chairs and tables.

6.2.3 *Noise Reduction within Rooms*

Sound absorbent materials play a useful part in reducing the built-up or airborne noise at source. In rooms, such as classrooms, assembly halls and music rooms, a fairly short reverberation time under occupied conditions is one of the requirements of the acoustic design. The maximum reverberation times permissible for this purpose are usually short enough to give adequate noise control but in addition, the reverberation time should not be excessive under empty conditions, because noise may occur in these rooms with very few occupants. Table 6 gives the reverberation times often arranged in occupied rooms for acoustic reasons and the maximum times recommended in the empty rooms for noise reduction; the times given are for a frequency of 500 Hz, but they should not be greatly exceeded at any frequency. When rooms are used for a variety of purposes, the reverberation period appropriate to the major use should be adopted.

6.2.3.1 Special attention should be given to noise reduction in schools for the hearing impaired and schools for the visually impaired. Hearing impaired children are taught by means of hearing aids which cannot be used satisfactorily in high noise levels or in reverberant conditions. Visually impaired children depend on good hearing for understanding speech and for detecting changes in environment. In both these types of schools, noise levels should be kept low and

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reverberation times short. As an example, the reverberation times in empty classrooms should not exceed 1.0 s in schools for the visually impaired or 0.5 s in schools for the hearing impaired.

Table 6 Reverberation Times in Schools

(*Clause* 6.2.3)

Sl No.	Room	Reverberation Time s	
		Usual for Acoustic Reasons (Full)	Maximum[1)] for Noise Control (Empty)
(1)	(2)	(3)	(4)
i)	Assembly halls	1.0-1.25 according to size	1.5-2.0 according to volume of hall
ii)	Music teaching rooms	0.75-1.25	1.5
iii)	Gymnasia and indoor swimming pools	—	1.5
iv)	Dining rooms	—	1.25
v)	Classrooms	0.6	1.1
vi)	Headmasters room and staff rooms	0.5-1.00	1.0

[1)] Shorter reverberation times are desirable for noise control, whenever possible.

6.2.4 *Sound Insulation*

6.2.4.1 *Airborne noise*

For purposes of sound insulation, rooms in educational buildings may be classified as follows:

Class A	Noise producing	a) Workshops b) Kitchens c) Dining rooms d) Gymnasiums e) Indoor swimming pools
Class B	Noise producing but needing quiet at times	a) Assembly halls b) Lecture halls c) Music rooms d) Typing rooms
Class C	Average	a) General class-rooms b) Practical rooms c) Laboratories d) Offices
Class D	Rooms needing quiet	a) Libraries b) Studies
Class E	Rooms needing privacy	a) Medical rooms b) Staff rooms

6.2.4.2 The recommended minimum sound reduction (D_w) between rooms of the same class is as follows:

a) Class A : 25 dB
b) Class C or D : 35 dB
c) Class B or E : 45 dB

6.2.4.3 Where a room is likely to have a dual use, for example, a dining room to be used as a classroom, the higher sound insulation value should be used.

6.2.4.4 The recommended minimum sound reduction (D_w) between rooms in different classes is 45 dB subject to the following:

a) In schools or institutes with a technical bias where noisy activities, such as sheet metal work, plumbing and woodwork, are likely to be practised extensively in normal hours, workshops should be regarded as a special category requiring more than 45 dB isolation (D_w) from rooms of any other class.
b) Assembly halls and music rooms are special cases in that, as well as producing noise, they also require protection from it and may need more than 45 dB isolation (D_w) from rooms in Class A, if the latter are very noisy.
c) Circulation spaces may vary from a long and frequented corridor to a small private lobby and it is therefore difficult to give precise recommendations to cover them. For partitions between rooms in Class C and most corridors, an R_w of 35 dB for the partition itself is adequate. For partitions between rooms in other classes and corridors, more or less insulation may be necessary, depending upon the specific usage.
d) The problem of noise in circulation areas is as a rule greatly mitigated in schools by the fact that classes usually change rooms together at regular times. In colleges and evening institutes, however, this is much less true and in such buildings particular attention should be paid to insulation between rooms and corridors.

6.2.4.5 *Impact noise*

In the case of schools, the concrete floor of the room immediately above the teaching rooms shall provide an impact sound pressure level, $L'_{nT,w}$ not greater than 70 dB. For example, a covering of 6 mm linoleum or cork tiles on concrete floor (hollow or solid) weighing not less than 220 kg/m^2 will usually meet the above requirement.

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7 HOSPITAL BUILDINGS

7.1 General

Problems of noise control vary from hospital to hospital but the principles outlined below apply to all types. A quiet environment in hospitals is desirable for patients who are acutely ill. Staffs require quiet conditions for consultations and examinations and also in their living and sleeping quarters. There have been rapid rises in noise levels in hospitals due to the higher levels of outdoor noise, increasing use of mechanical and mobile equipment (some of which is now brought much nearer to the patient in order to facilitate nursing procedure) and the introduction of loudspeaker, radio, television and call systems. Noise control in the hospital is made much more difficult by the extensive use of hard washable surfaces which reflect and intensify the noise. In most hospitals, windows to the open air and fanlights to corridors are usually open for the purpose of ventilation, admitting noise from outside and allowing it to spread through the building.

7.2 Sources of Noise Nuisance

7.2.1 *Outdoor Noise*

This may be classified into two main categories:

a) Noise from sources outside the hospital premises, for example, traffic and industrial noises; and

b) Noise from sources outside the building but usually within the control of the hospital authority, for example, ambulances, motor-cars and service vehicles, fuel and stores deliveries, laundries, refuse collection, trucks and trolleys.

7.2.2 *Indoor Noise*

A hospital is a complex building with many services and the numerous internal sources of structure-borne and airborne noises are grouped into three main categories:

a) Noise consequent upon hospital routines. This category includes sources which transmit noise through both structure-borne and airborne paths, many of which may be quite near to patients particularly those in wards, such as the following:

   1) Wheeled trolleys of various kinds, for food and medical supplies;
   2) Sterilizing equipment;
   3) Sluice room equipment including bedpan washers;
   4) Ward kitchen equipment;
   5) Footsteps;
   6) Doors banging;
   7) Handling of metal or glass equipment;
   8) Noises caused during maintenance and overhaul of engineering services; and
   9) Vacuum cleaners, mechanical polishers, etc.

b) Loudspeaker, radio or television, audible call system, telephone bells and buzzers, and other airborne noises, such as loud conversation; and

c) Noises from fixed or mobile equipment and services not directly concerned with hospital routines. These include all the fixed services as given below:

   1) Plumbing and sanitary fittings;
   2) Steam hot and cold water and central heating pipes;
   3) Ventilation shafts and ducts;
   4) Fans
   5) Boilers;
   6) Pumps;
   7) Air compressors;
   8) Pneumatic tubes;
   9) Electrical and mechanical motors and equipment;
   10) Lifts;
   11) Laundry equipment; and
   12) Main kitchen equipment (refrigerators, mixers, steam boilers, etc).

7.3 Recommendations

7.3.1 *Site Planning*

Hospital sites with their high degree of sensitivity to outside noise should be as far away from outside sources as may be compatible with other considerations, such as accessibility and availability of services. The building should be so arranged on the site that sensitive areas like wards, consulting and treatment rooms, operating theatres and staff bedrooms are placed away from outdoor sources of noise, if possible, with their windows overlooking areas of acoustic shadow.

7.3.2 *Detailed Planning*

There is a very large number of unit and room classification in hospital design and in planning the units in relation to each other and to the common services, (such as X-ray departments, operating theatre suits and main kitchens), noise reduction in the sensitive areas should be weighed carefully against other design factors. Special care in overall planning and internal planning against noise is required in the planning within the building of units which are themselves potential noise sources, for example, children's wards and

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outpatients' departments, parts of which require protection against noise.

7.3.2.1 Unloading bays, refuse disposal areas, boiler houses, workshops and laundries are examples of service units which should be as far from sensitive areas as possible.

7.3.2.2 The kitchen is a constant source of both airborne and structure-borne noise and should preferably be in a separate building away from or screened from the sensitive areas. If this is not possible and the main kitchens shall form part of a multi-storeyed building, noise control is easier if they are placed below and not above the wards and other sensitive rooms so as to facilitate the insulation of the equipment and machinery in order to reduce the transmission of structure-borne noise to a minimum.

7.3.2.3 In ward units, the kitchens, sluice rooms, utility rooms, sterilizing rooms and other ancillary rooms, need to be placed quite near to the beds if they are to fulfil their purposes, which are all sources of noise. Some form of noise baffling between open wards and rooms of this kind will be needed.

7.3.3 *Reduction of Noise at Source*

In view of the difficulty of suppressing noise in hospital buildings, it is important to eliminate noise at its source, wherever possible.

7.3.3.1 *Use of resilient material*

Mats of rubber or other resilient material on draining boards and rubber-shod equipment will greatly reduce noise from utility rooms, sluice rooms and ward kitchens. The use of plastics or other resilient materials for sinks, draining boards, utensils and bowls would also reduce the noise. Many items of equipment especially mobile equipment, such as trolleys, beds and movable furniture, may be silenced by means of rubber-tyred wheels and rubber bumper and the provision of resilient floor finishes (*see* **7.3.4.1**). The latter also reduces footstep noise. Silent type curtain rails, rings and runners should be used. Lift gates and doors should be fitted with buffers and silent closing gear. Fans and other machinery should be mounted on suitable resilient mountings to prevent the spread of noise through the structure.

7.3.3.2 *Other measures*

Noise from water or heating pipes may be reduced by installing systems which operate at comparatively low pressure and velocities. Silencing pipes and specially designed flushing action reduce water closet noise at source and make structural measures easier to apply. The ventilation system should be designed so as not to create a noise problem. Silent closers should be fitted to doors.

7.3.4 *Reduction of Noise by Structural Means*

7.3.4.1 *Insulation*

Since the various departments or units may be planned in many ways, only general guidance on the insulation values for walls and partitions is as given below:

a) It is recommended that walls or partitions between rooms should normally have an R_w of at least 45 dB. Higher values of R_w of at least 50 dB are necessary where a noisy room is adjacent to one requiring quiet conditions. Doors should be solid with close fitting in the frames.

b) There is little insulation value in double swing doors and where these are fitted to a noisy room the opening should be planned so that it is screened from areas requiring quiet by a baffle lobby lined with absorbent material. Very high insulation values may be necessary in special cases and exceptional measures may be required.

c) Solid floors with floating finishes and resilient surfaces are necessary particularly between wards and other parts of the building. Ordinary timber board on joist floors should never be used.

d) Conduits, ventilation ducts, chases, etc, should be constructed so as not to form easy by-pass for disseminating noise about the building, and should be provided with sufficient sound insulation. Pipe ducts should be completely sealed around the pipes where they pass through walls or floors. Ducts carrying waste or water pipes should be lined with sound insulating material to prevent noise from the pipes passing through duct walls into the rooms through which they pass.

7.3.4.2 *Absorption*

Most surfaces in hospitals should be easily cleanable, so as to prevent the build-up of bacteria which may cause cross-infection. Many sound absorbent materials of a soft nature and difficult to clean are unsuitable for use in some hospital areas and lose much of their effectiveness, if painted for hygienic reasons.

Some porous materials with very thin non-porous coverings (like mineral wool covered with thin plastic sheets) have good sound absorption and when covered with a perforated sheet metal facing can be used in most areas requiring a washable acoustical treatment. In noisy areas, such as corridors and waiting rooms, however, a wider choice of absorbents is available.

In the ward, bed curtains, window curtain, etc, add to the absorbent properties of the room and help reduce

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reverberation in otherwise hard surfaced surroundings.

7.3.5 Sensitive areas such as operation theatres, doctors' consultation rooms, intensive care units (ICU) require special consideration against noise control. Apart from outdoor noise, a common problem is the transmission of sound between the consulting room and the waiting room. To ensure silence, a sound isolation D_w of 45 dBA, between the rooms shall be provided. If the doors are directly connected by a single communicating door it will not be possible to achieve these values of isolation D_w. To obtain 40-45 dBA insulation between communicating rooms, it is necessary to provide two doors separated by an air gap, such as a lobby or corridor.

8 OFFICE BUILDINGS

8.1 General

Modern office buildings are often noisier than older buildings due to the use of thinner and more rigid forms of construction, harder finishes, more austere furnishings and use of business machines.

8.2 Sources of Noise Nuisance

8.2.1 *Indoor Noise*

Main sources of indoor noise include the following:

a) Office machines, such as keyboards, typewriters, and printers;
b) Telephonic conversation;
c) Noise from the public admitted to the building;
d) Footsteps, voices and slamming of doors in circulation spaces, lift doors and gates;
e) Sound reproduction in staff training rooms, conference rooms and recreation rooms, etc;
f) Handling of crockery and utensils in canteens and kitchens; and
g) HVAC and lift machinery.

8.3 Recommendations

8.3.1 *Site Planning*

Rooms demanding quiet conditions should be placed on the quiet side of the site. Even on quiet thoroughfares, these rooms should also not be planned at street level. They should also not be planned on enclosed yards used for parking of cars, scooters, etc. Where, however, the problems cannot be resolved by planning, the provision of double windows may be necessary.

8.3.2 *Detailed Planning*

8.3.2.1 *Noise reduction within rooms*

The reverberation time should not exceed 1.0 s in all general offices of the types listed in **8.3.2.2** to **8.3.2.6**. In small private offices, the reverberation time should not exceed 0.75 s, in very large offices the reverberation time may be increased to 1.0 s. For canteens, the recommended maximum reverberation time is 1.0 s.

NOTE — All reverberation times are specified for a frequency of 500 Hz.

8.3.2.2 *Large general offices*

The grouping of departments and machines together in one room should be avoided, wherever possible. Where supervision is necessary the provision of glazed screens carried up to the ceiling should be considered. If it is essential to the work of an office for machine operators and clerks to work side by side in the same room, the machines should be enclosed by panels or low screens lined with absorbent material and the ceiling should be sound absorbent. In addition, the machines should be as quiet as possible in operation and mounted on suitable resilient mountings.

NOTE — A quiet area should be planned for prolonged telephonic conversation.

8.3.2.3 *Light weight construction*

Modern construction methods and economy dictate the use of light weight construction for many office buildings. While the lightweight materials lead to fast fabrication and erection and also effect considerable economy in the building structure, they may lead to tremendous sound insulation problems between adjacent offices and areas. Light weight construction is also frequently employed for the subdivision of large space into executive cabins and secretarial areas. Where such construction is considered desirable, efforts should be made to provide a double-skin panel. The panels should be isolated from each other as far as possible either by the use of separate framing or by the use of elastic discontinuities in the construction, and a sound absorbing material may be introduced in the air cavity between the panel. The partitions should be of full height up to the bottom of the roof above and any openings required for air movement should be provided with sound attenuators compatible with the rest of the partition.

When light weight floors are provided in multi-use buildings, adequate attention shall be paid to the question of airborne and structure-borne noise transmission from the upper floors to the floors below. For effective reduction of airborne noise, a double panel hollow floor construction may be employed with some heavy sound damping material introduced between the panels and the panel isolated from each other. The sound damping material could be sand, mineral wool, etc. In case impact noise isolation is also required, the upper panel should be effectively isolated from the rest

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of the floors and building structure. The choice of the isolation layer would of course depend upon the lowest frequency of interest.

Another point to be kept in mind when going in for light weight construction is to ensure that the light weight panels are not in resonance with the natural frequencies of any mechanical equipment installed inside the building. Light weight materials have high natural frequencies well within the audio range and may resonate or vibrate due to an applied vibratory force. This vibratory force is caused by mechanical equipment, road traffic, rail traffic, etc. Special measures also need to be taken to isolate either the source or the building so as to reduce the amount of vibration transmitted to the building structure.

8.3.2.4 *Open plan offices*

A new concept in office planning is the use of open plan offices. Large open floor spaces are converted into an office area with senior executives, junior executives and secretarial staff all seated within the same area without the use of any partitions or walls. While this method of planning is appreciated, it leads to a problem of inadequate acoustical privacy between adjacent work spaces. Speech privacy in open plan offices is defined by the speech interference level of intruding noise. Speech privacy between two adjacent rooms or spaces is, therefore, a function of two key parameters; noise reduction of the intervening partition and background noise levels.

Special design measures are, therefore, required to reduce the level of intruding sounds at work places to acceptable low value so that people are not disturbed and adequate privacy is maintained. Some special measures which might be considered for such open plan offices are the use of an acoustical ceiling together with partial height barriers between work spaces, all designed to provide adequate privacy between adjacent work spaces. In addition use may have to be made of an electronic background masking noise system which provides a constant level of a generally acceptable background noise in the entire office area. The masking noise system is a very useful concept in open plan office design because by raising the background level at every workplace, intruding noises are made less disturbing. A background music system cannot serve as a noise masking system because the music does not have a constant spectrum or sound level. In fact the background noise masking system shall be introduced gradually without the knowledge of employees. The air-conditioning system can also be used to generate background masking noise, if the noise level from the fans, ducts and grills is suitably tailored to generate the desired frequency spectrum. However, it is not simple to predict the noise level of air conditioning components accurately. On the other hand, the electronic system enables both the level and the spectrum of the background noise to be accurately adjusted to suit individual job requirements.

8.3.2.5 *Office equipment rooms*

It is important that machines like keyboards, typewriters, printer, etc, should be quiet in themselves and also be fitted with resilient pads, to prevent the floors or tables on which they stand from acting as large radiating panels. It is desirable to locate machines further apart and to apply sound absorbent treatment to the ceiling.

8.3.2.6 *Banking halls*

If banking halls are large and lofty, noise nuisance tends to be aggravated. It is advisable to avoid high reflective ceilings. The worst effects may be reduced by segregating the noise from the quiet operations and screening one from the other and by applying sound absorbent materials to the surfaces of the ceilings, screens and nearby walls. Resilient flooring is also recommended.

8.3.2.7 *Public offices and waiting spaces*

Noise nuisance may be minimised by the provision of resilient flooring, sound absorbent ceilings and heavy full height screens between the public space and the clerical office.

8.3.2.8 *Canteens*

The provision of a sound absorbent ceiling, resilient flooring and the use of plastics trays and tables with quiet tops are recommended.

8.3.2.9 *Circulation spaces*

The effective length of long corridors should be limited by providing swing doors at intervals. Hard floor finishes and board and batten floors in corridors should be avoided. The provision of a sound absorbent ceiling in corridors is recommended. Floor ducts should be planned on one side of corridors.

The noise from slamming of doors may be reduced by fitting automatic quiet action type door closers. Door buffers are useful but may reduce insulation of airborne sound due to the inevitable gaps between buffers. Continuous soft, resilient strip let into the door frames is preferable. The use of quiet action door latches is recommended.

Staircases and lifts should be isolated from quiet rooms and should have silent type doors.

8.3.3 *Requirement of Sound Insulation*

With open window (single or double) the sound reduction (D_w) will be 5-10dB, and with sealed double

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windows it will be 40-45 dB. Intermediate values are obtainable with closed openable windows (single or double) but only, of course, at such times as ventilation may be dispensed with. Having to choose between ventilation and noise exclusion is a serious handicap to efficient working in offices. In large office blocks on noisy sites, consideration should be given to the provision of sealed double windows and mechanical ventilation at least in the offices on the sides of the building exposed to noise.

8.3.3.1 The insulation necessary between adjoining rooms, both horizontally and vertically, depends upon the amount of noise created within the rooms, the amount of intruding noise and whether it is important that conversation should not be overheard between rooms. Generally a sound isolation value (D_w) of 40 dB between one room and another room in office is recommended.

8.3.3.2 The following list may be considered as broad classification of noise producing rooms and rooms requiring quiet though many offices fall into both categories. Where rooms in opposing categories are planned adjacent to each other, a sound reduction (D_w) of at least 45 dB should be provided between them.

Sl No.	*Noise Producing Rooms*	
i)	Entrance and reception halls, staircases and corridors used by the public	
ii)	Lifts and lift halls	
iii)	Motor and plant rooms	
iv)	Lavatories	
v)	Public offices	
vi)	Canteen and kitchens	
vii)	Office machine rooms and typing pools	
viii)	Recreation rooms	
ix)	Large general offices	
x)	Cinemas and projection rooms:	
Sl No.	*Rooms Requiring Quiet Conditions*	
i)	Executive's rooms, Conference rooms and board rooms	
ii)	Interview rooms	
iii)	Offices for one or two persons	
iv)	Medical officer's rooms	
v)	Sick rooms	
vi)	Rest rooms	
vii)	Libraries	
viii)	Telephoning rooms	
		D_w
a)	Rooms requiring quiet (as listed above) on a quiet site where privacy is required	45 dB
b)	Rooms requiring quiet (as listed above) but on a noisy site or where a lower degree of privacy is tolerable	40 dB
c)	Clerical offices in which noise does not constitute a major nuisance	30 dB

8.3.3.3 It is recommended that the minimum sound reduction index, R_w for floors should be 45 dB, and the floors should have a resilient finish.

9 HOTELS AND HOSTELS

9.1 General

Hotels and hostels are primarily used as dwelling units, and hotels also provide for public entertainment. The most serious risk, of course, is disturbance to sleep, and adequate care therefore needs to be taken to protect the occupants from being disturbed by outdoor and indoor noise.

9.1.1 *Outdoor Noise*

Hotels near railway stations, airports, highways and those situated in highly urbanized areas are especially vulnerable to outdoor noise. The outdoor noise in many of the areas is of a high level even late at night and early in the morning. The noise could also be due to other types of activities such as building construction (pile driving, concrete mixing, etc) and due to various types of portable utility equipment, such as compressors or generators.

9.1.2 *Indoor Noise*

Insofar as indoor noise is concerned, the noise could be due to the occupants themselves, which is transmitted from one room to the other. It could also be due to public functions and late night use of restaurants located in the hotel, as also due to miscellaneous utility equipment installed for providing and maintaining the services in the hotel, such as air conditioning equipment, pumping equipment, power laundry and kitchen. Sometimes hotels equipped with standby generators are a potential source of noise. Another source which could lead to disturbance to the occupants is the plumbing system.

9.2 Recommendations

9.2.1 *Site Planning*

While it is desirable to locate the hotel, or hostel away from an area where there is a high ambient noise level, many a time these have to be located in noisy areas for public convenience. Hotels near airports and railway stations are becoming popular because they are convenient for passengers in transit. Hotels located in the commercial areas of a city are also a commercially

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viable proposition and many a time this factor outweighs the other problems associated with such a location. When a reasonably quiet location is not possible, it is desirable that adequate measures be considered to provide a comfortable acoustical environment for the occupants.

9.2.2 *Internal Planning*

Where a hotel is located in a noisy environment, the provision of sealed windows (single or double) and provision of an air conditioning system is desirable for rooms exposed to noise. The requirements for the windows would of course depend upon the level and character of noise in the area.

The general recommendations for satisfactory acoustical design of hotels and hostels are given in **9.2.2.1** to **9.2.2.7**.

9.2.2.1 Hotels of all classes shall by necessity provide good protection against indoor noise. Since hotels can be considered as flats, the standards of protection recommended for flats are also applicable to hotels. Partition between guest rooms and between rooms, corridors and floors shall not be less than 230 mm brick wall plastered or equivalent (R_w = 50 dB). The floors shall have proper impact insulation. Special attention should be paid to built-in wall cupboards as these are potential areas of sound leakage. These will not serve as sound insulating partitions and may not be relied upon to increase the insulation value of partitions against which they may be built. In fact, partitions between adjoining rooms should be continuous behind the cupboards. Use of silent type door gear and cupboard catches is also highly desirable.

9.2.2.2 Door openings on opposite sides of corridors shall be staggered and doors shall be provided with gaskets on head, sides and threshold. Inter-communicating doors should be double doors, fully gasketed. Doors should also have quiet action latches. Whenever possible, rooms should be entered through a baffle lobby. Wherever possible, corridor walls should not have ventilators unless they are double glazed and non-openable.

9.2.2.3 Corridors and staircases may have resilient floor coverings and sound absorbent ceilings are desirable unless the corridor is fully carpeted. Staircases and lift wells may be cut off from corridors by means of swing doors and, if possible, isolated from guest rooms by linen stores or similar rooms. Room service pantries on floors can also be a source of noise and may be separated from corridors by baffle lobbies, unless the rooms themselves have baffle lobbies.

9.2.2.4 Except within the same suite, bathrooms should not be planned next to bedrooms. Where this is unavoidable, internal pipe shafts with heavy walls, unpierced on bedrooms side may be used as means of separation. It is important to choose quiet type of sanitary fittings and to design the plumbing system so as not to create noise by avoiding sharp bends, restrictions of flow, quick-action valves that might cause water hammer, etc.

9.2.2.5 Air conditioning system should be quiet in operation. Care should also be taken that the air-conditioning ducts do not lead to a cross-talk problem between rooms. Suitable acoustical lining should be provided in the ducts consistent with the fire safety requirements of the buildings.

9.2.2.6 Large hotels often have banquet halls and conference halls which are separately hired out for public and private functions. Late night restaurants and night clubs are also popular and functions in all these areas may go on well into the night. It is therefore essential that these rooms be effectively isolated from bedrooms and effective insulation from all possible noise sources is considered. Here it is not only necessary to consider the airborne sound insulation but it is also necessary to consider the question of structure-borne and impact noise transmitted from areas where there might be dancing late into the night. Floating floors may be considered for structure-borne sound isolation for dance floors and loudspeakers.

9.2.2.7 While most of the noise problems encountered in hotels are applicable to hostels, the latter are normally of more economical construction and, therefore, do not cater for special sound insulation provisions. However, as far as possible, precautions should be taken to provide comfortable conditions in hostel rooms. This is especially true for student hostels where each room is also a living room. Students might play music or have loud discussions late into the night.

This may disturb sleep or study of other students. Proper precautions should, therefore, be taken to provide satisfactory conditions.

10 INDUSTRIAL BUILDINGS

10.1 General

Industrial buildings are primarily producers rather than receivers of noise. The level of industrial noise commonly exceeds that from any other source with the exception of aircraft. As compared with traffic noise, its effects are less widespread but it is often more annoying in character.

10.1.1 Many industrial noises contain very strong high frequency whines, screeches and clatter-these components are relatively more attenuated by passage through the air and by the insulation of light structure than are noises of lower frequencies.

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10.1.2 Intermittent noises are either isolated explosions or reports, or noises of a periodic nature, such as those of pressure relief valves of blow off, or the noises of work occurring at random intervals, for example, hammering, grinding and sawing operations; the latter class may be especially irritating because of high frequency components.

10.2 Sources of Industrial Noise

10.2.1 Noises in industrial buildings are mainly of indoor origin. Noise in factories and workshops is generally caused by machine tools and by operations involved in making and handling the product and they are classified into the following groups, depending on how the noise energy is generated.

10.2.1.1 *Impact*

Noise caused by impact is the most intense and widespread of all industrial noises. It is normally coupled with resonant response of the structural members connected to the impacting surface. Common sources of this type of noise are forging, riveting, chipping, pressing, tumbling, cutting, weaving, etc. Intense impact noise may also be produced during handling of materials as in the case of sheared steel plates falling one over another in collecting trays in a steel factory. Impact noise is usually intermittent and impulsive in character, but it may also be continuous as in the case of tumbling.

10.2.1.2 *Friction*

Most of the noise due to friction is produced in such processes as sawing, grinding and sanding. Friction also occurs at the cutting edge on lathes and other machine tools and in brakes and from bearings. The spectrum of frictional noise often predominates in high frequency and is very unpleasant in character.

10.2.1.3 *Rotation and reciprocation*

A rotating or reciprocating machine generates noise due to unbalanced forces and/or pressure fluctuations in the fluids inside the machines. In many cases, the moving surfaces radiate noise directly and in other cases, the pressure fluctuations are transmitted to the outer casings of the machine from where they are radiated as noise. Interaction of rotating component with the fluid stream can also give rise to pure tone components, such as the whine in a turbine. Since most machine casings have radiation efficiencies of unity in the higher frequency range, the amount of sound radiated is often substantial.

10.2.1.4 *Air turbulence*

Noise may be generated by rapid variation in air pressure caused by turbulence from high velocity air, steam or gases. Common examples are the exhaust noise from pneumatic tools and air jets. The noise is intense, and broad based in character and the frequency criteria depends on the size of the jet. The intensity increases rapidly with the velocity of the air stream.

10.2.1.5 *Noises with pure tone components*

Whining noise from turbines and humming noise from transformers come under this group.

10.3 Noise Criteria

10.3.1 *Hearing Damage — Risk Criteria*

Continuous exposure to high noise levels may result in permanent noise induced hearing loss in the course of time. Damage-risk criteria specify the maximum levels and duration of noise exposure that may be considered safe. Generally accepted damage-risk criteria for exposure to continuous, steady broad band noise are shown in Table 7. Whenever the sound levels at the workers position in a factory exceed the levels and the duration suggested, feasible engineering controls shall be utilized to reduce the sound to the limits shown. If such controls fail to reduce sound levels within the levels of Table 7, personal hearing protection equipment shall be provided and used to reduce sound levels within the level shown.

10.3.2 *Interference with Communication*

In factories where audible warning signals are used, or where an operator follows the operation of his machine by ear, the background noise should not be so loud as to mask the signal or desired sound (the information sound) to be heard. Noise may be the cause of accidents by hindering communication or by masking warning signals.

10.4 Methods of Reducing Noise

10.4.1 *Noise Control by Location*

Machines, processes and work areas which are approximately equally noisy should be located together as far as possible. Areas that are particularly noisy should be segregated from quiet areas by buffer zones that produce and may tolerate intermediate noise levels.

10.4.2 *Noise Reduction by Layout*

The office space in a factory should as far as possible be located preferably in a separate building. This building should not have a wall common with the production area. Where a common wall is unavoidable, it should be heavy with few connecting doors and no permanent openings.

10.4.3 *Noise Reduction at Source*

10.4.3.1 *Selection of machinery*

Noise should be reduced as near the source as possible. While the operational processes in a factory may be

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Table 7 Permissible Exposure Limits for Steady-State Noise

(*Clause* 10.3.1)

Sl No.	Sound Level (Slow Response) dBA	Time Permitted, *T* h : min
(1)	(2)	(3)
i)	85	16:00
ii)	86	13:56
iii)	87	12:08
iv)	88	10:34
v)	89	9:11
vi)	90	8:00
vii)	91	6:58
viii)	92	6:04
ix)	93	5:17
x)	94	4:36
xi)	95	4:00
xii)	96	3:29
xiii)	97	3:02
xiv)	98	2:50
xv)	99	2:15
xvi)	100	2:00
xvii)	101	1:44
xviii)	102	1:31
xix)	103	1:19
xx)	104	1:09
xxi)	105	1:00
xxii)	106	0:52
xxiii)	107	0:46
xxiv)	108	0:40
xxv)	109	0:34
xxvi)	110	0:30
xxvii)	111	0:26
xxviii)	112	0:23
xxix)	113	0:20
xxx)	114	0:17
xxxi)	115	0:15

NOTES

1 Where the table does not reflect the actual exposure times and levels, the permissible exposure to continuous noise at a single level shall not exceed the time *T* (in h) computed from the formula:

$$T = \frac{16}{2^{[0.2(L-85)]}}$$

where

L = work place sound level measured in dBA.

2 When the daily noise exposure is composed of two or more periods of different levels, their combined effect should be considered rather than the individual effect of each. The combined levels may not exceed a daily noise dose, *D* of unity where *D* is computed from the formula:

$$D = \frac{C_1}{T_1} + \frac{C_2}{T_2} + ... + \frac{C_n}{T_n}$$

where, C_1, C_2 ……. C_n indicate the total duration of exposure (in hour) at a given steady-state noise level; and T_1, T_2,…,T_n are the noise exposure limits (in hour for the respective levels given in the table or computed by the equation in Note 1. Exposure to continuous noise shall not exceed 115 dBA regardless of any value computed by the formula for the daily noise dose, *D* or by the equation in Note 2.

fixed and may have no quieter alternative, careful selection of the machine tools and equipment to be used may considerably help attaining lower noise levels in the machine shop.

10.4.3.2 *Reducing noise from potential sources*

Impact that is not essential to a process should be quietened. Noise from handling and dropping of materials on hard surface may be reduced by using soft resilient materials on containers, fixing rubber tyres on trucks, trolleys, etc. Machine noise may be kept to a minimum by proper maintenance. Proper lubrication reduces noise by friction conveyors, rollers, etc.

10.4.3.3 The noise from the radiating surfaces may be reduced by reducing the radiating area. For example, if the area is halved, the noise intensity will be reduced by 3 dB and at low frequencies the reduction will be much greater.

10.4.3.4 Supporting structures for vibrating machines and other equipment should be frames rather than cabinets or sheeted enclosures. If an enclosure is used, precaution should be taken to isolate it and line it on the inside with sound-absorbent material. Penetration through the enclosure should be adequately sealed. The noise radiated by machinery guards can be minimised by making them of perforated sheet or of wire mesh.

10.4.3.5 *Reducing transmission of mechanical vibration*

A vibrating source does not usually contain a large radiating surface but the vibration is conducted along mechanically rigid paths to surfaces that can act as effective radiator. If the rigid connecting paths are interrupted by resilient materials, the transmission of vibration and consequently the noise radiated may be greatly reduced. The reduction depends on the ratio of the driving (forcing) frequency of the source to the natural frequency of the resilient system. The natural frequency may be determined from static deflection under actual load as given in Fig. 1. The higher the ratio between the two frequencies, the lesser is the transmissibility, which is defined as the ratio of the force transmitted through the resilient isolator to the exciting force applied to it. Transmissibility and the equivalent noise reduction for various frequency ratios are given in Fig. 2. For satisfactory operation, a ratio of 3 : 1 or more between the driving and natural frequencies is recommended.

Materials for isolators and their position are given below:

a) *Material for isolators* — Vibration isolators are usually made of resilient materials like steel in the form of springs and rubber.

   1) Because of the large range of deflections

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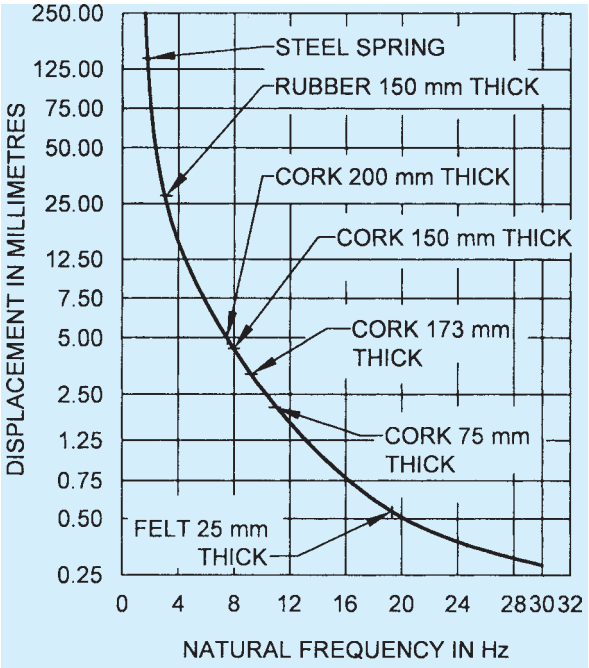


FIG.1 RELATION BETWEEN STATIC DEFLECTION AND NATURAL FREQUENCY

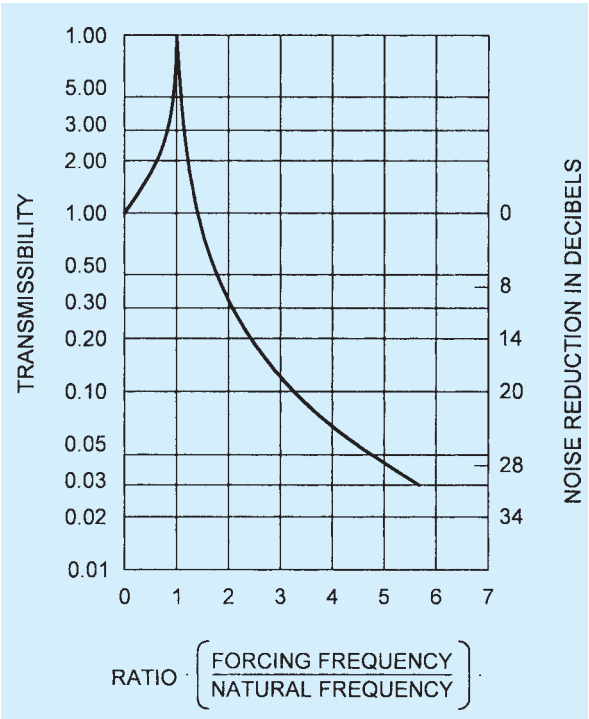


FIG. 2 TRANSMISSIBILITY AND EQUIVALENT NOISE REDUCTION FOR DIFFERENT RATIOS OF FORCING AND NATURAL FREQUENCIES

obtainable in coil springs, they may isolate vibrations over a large spectrum of low frequencies. Metal springs transmit high frequency (from about two hundred to several thousand c/s) very readily. Transmission of these frequencies can be reduced by eliminating direct contact between the spring and the supporting structure. Rubber or felt pads may be inserted between the ends of the spring and the surfaces to which it is fastened.

2) Rubber in the form of pads may be used to very effectively isolate engines, motors, etc. It may be used in compression or in shear. Some rubber mountings use rubber-in-shear as the primary elastic elements and rubber-in-compression as a secondary element which furnishes snubbing action if the mounting is subjected to an overload.

3) Felt or cork or both may be used as resilient mats or pads under machine bases. The load per unit area shall be chosen to produce enough deflection for the isolation required; and shall be such that at this deflection, it is not loaded beyond its elastic limit.

b) *Position of isolators* — The normal position of the isolators is between the machine and its foundation. However, if the forcing frequency of the machine is low (less than 10 Hz) and vibration isolators with the requisite deflection for this location are not available, the machine may be bolted directly to an independent heavy inertia concrete base and the available vibration isolators used below the concrete base.

1) Large press and drop hammers which create serious impact vibration in heavy machine shops may be mounted rigidly on very massive blocks of concrete having weights several times greater than the weights of the supported machines. The inertia blocks may, in turn, be isolated from the building structure by large wooden blocks and with thick pads of cork.

2) In critical installations (*see* Note), attempt should be made to locate the resilient mounts in a plane which contains the centre of gravity of the mounted assembly. It is also preferable to locate the mounts laterally as far away as possible from the centre of the machine.

NOTE — Critical installations are those installations where transmission of vibration from these installations seriously hamper the normal working.

3) Rigid mechanical ties between vibrating machine and building structure, short-

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circuit or reduce the effectiveness of isolators. Loose and flexible connections should be inserted in all pipes and conduits leading from the vibrating machine. Where flexible connections are impracticable, bends should be inserted into the pipes or the pipes themselves should be supported on vibration mounts for a considerable distance from the source.

4) *Flexibility of foundation* — The effect of flexibility of the foundation on the isolator transmissibility shall be considered in the selection of practical vibration isolating mountings. The simplified vibration isolation theory assumes a completely rigid foundation. However, in practice, this can never be achieved. The foundation is never actually completely rigid. Generally, the relatively low stiffness of the isolation system permits the assumption of the foundation to be rigid. However, if the stiffness of the isolator is allowed to become comparable to the foundation stiffness (or greater), the deflection of the isolator will become smaller and the foundation will also deflect with increased transmissibility and decreased isolator efficiency. In a dynamic sense, supporting foundation or floors should have natural frequency as high and be as stiff as possible compared to the system being isolated. Good design practice requires that the isolators should be designed assuming a rigid foundation with the stipulation that the selected machine isolation system frequency should be well below the foundation frequency. This point should especially be kept in mind when installing machines at upper levels in buildings because supported slabs generally have lower natural frequencies (low stiffness) than slabs on grade in basement or ground floor locations.

10.4.4 *Noise Reduction by Enclosures and Barriers*

10.4.4.1 *Enclosures*

Airborne noise generated by a machine may be reduced by placing the machine in an enclosure or behind a barrier. The enclosure may be in the form of close-fitting acoustic box around the machine such that the operator performs his normal work outside the box and thus is not subjected to the high noise levels of the machine. The enclosure may be made of sheet metal lined inside with an acoustical material.

Where size of the machine, working area and the operation do not permit close-fitting enclosures, the machine may be housed in a room of its own. The inside of the enclosure should be lined with sound-absorbing materials to reduce the noise level of the contained sound. The bounding walls of the enclosures shall also have adequate transmission loss to provide desired noise reduction.

10.4.4.2 *Barriers*

A partial reduction of noise in certain directions may be obtained by barriers or partial enclosures or partial height walls. Two-sided or three-sided barrier, with or without a top and invariably covered on the machine side with acoustic absorption material should face a wall covered with sound-absorbing material. If the top of the enclosure is open, the reduction may be increased by placing sound-absorbing material on the ceiling overhead.

10.4.5 *Acoustical Absorption Devices*

10.4.5.1 *Acoustical treatment of ceilings and side walls*

In order to reduce the general reverberant noise level in machine shops, acoustical material may be provided on as much of the available area on the ceiling and side walls. With this treatment 3 to 6 dB reduction of middle and high frequency noise may be achieved. While the noise level at the source, affecting the operator, may not be reduced materially, the treatment would bring down the built-up noise level away from the source in reverberant field.

10.4.5.2 *Functional sound absorbers*

For efficient noise reduction functional sound absorbers may be clustered as near the machines as possible. These units may be suspended and distributed in any pattern to obtain lower noise levels within the machine shop. Compared on the basis of equal total exposed surface areas, functional sound absorbers have higher noise reduction coefficients (NRC) than conventional acoustical materials placed directly on ceilings and walls.

11 LABORATORIES AND TEST HOUSES

11.1 Sources of Noise

11.1.1 *Outdoor Noise*

In a test house or laboratory, where research workers and scientists are engaged in performing sophisticated experiments, the external noise is mostly contributed by noise emitting buildings (workshops, machine rooms), airports, railway stations and general traffic noises. The outdoor sources of noise in a college

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laboratory include noises produced in a playground as well.

11.1.2 *Indoor Noise*

The following sources mainly contribute to indoor noises in research institutions/college laboratories:

a) Workshops, machine rooms, cafeteria, etc;
b) Air conditioning and exhaust fans;
c) Noise produced within the test house or laboratory while performing experiments; and
d) Typing or other machine noises, telephone service, lift, sanitary services, etc.

11.2 Recommendations

11.2.1 *Site Planning*

While planning for a laboratory or test house, care should be taken in the design that no noise emitting installations should exist in its neighbourhood. However, where outdoor noises exist, such as from local factory, heavy traffic airports, railway lines, sport grounds or busy markets, buildings should be kept as far away as possible from the source of noise.

11.2.1.1 The window and door openings towards the noise sources should be minimum. Minimum amount of glazing should be placed on walls directly facing the noise sources.

11.2.2 *Internal Planning*

11.2.2.1 Noisy places should be kept separate from the quiet ones. The location of laboratories or test houses should be so chosen that it is cut off from the noisy zones. Where there are offices attached to a laboratory, provision should be made to treat the offices and to use acoustical partitions, to achieve a sound isolation D_w of at least 35 dB.

11.2.2.2 In a laboratory, mostly hard reflecting surfaces and bare furnishings are found, which produce very reverberant conditions. The noise condition still deteriorates when noise producing instruments are switched on or a heavy object is dropped on the floor. Under these conditions, sound absorbing treatment of the space is very essential. Sound absorbing ceilings are recommended to deaden such noises. Rubber buffers may also be fitted to the legs of furniture.

11.2.2.3 In large span laboratories or test houses where scientists and researchers are engaged in work and/or simultaneously busy in calculations or desk work requiring high degree of mental concentration, use of sound absorbing screens is recommended.

11.2.2.4 Noise reduction between the test house or laboratory and corridors or general circulation space should be well kept in mind and due care should be taken of the type of doors and the manner of their fittings, etc. Transmission of noise through service ducts, pipes, lifts and staircases should also be guarded.

Telephones should preferably be placed in a separate small enclosure or acoustically efficient telephone booth.

11.2.2.5 To isolate a laboratory or a test house from structure-borne noises originating from upper floor, sandwich type floor construction is recommended.

11.2.2.6 Wherever the provision of double glazed windows is necessary to reduce the heat losses, care should be taken to provide sealed double windows rather than double glazing in a single window.

NOTE — Double glazed windows for sound insulation should have a minimum gap of 100 mm between the two glasses.

12 MISCELLANEOUS BUILDINGS

12.1 Law Courts and Council Chambers

It is important that law courts and council chambers be protected from the intrusion of outdoor noise and from indoor noise arising both from ancillary offices and circulation spaces. The general recommendations on site planning given in **3** apply to law courts and municipal buildings, but in the larger buildings at least, further protection against outdoor noise can be obtained by planning offices and other rooms around the court rooms or chambers, and separating the offices from the central rooms by means of corridors. This arrangement is usually convenient to the function of the buildings.

12.1.1 The wall between the corridors and the central rooms should have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) to insulate against airborne noise in the corridors. Entrances from halls or corridors into court rooms or council chambers should be through baffle lobbies with two sets of quiet action doors. Sound absorbing treatment on ceilings and upper parts or walls or entrance lobbies is recommended.

12.1.2 The whole of the floor of the court room or chamber including steps and seating areas set aside for the public should have a resilient floor finish to reduce the noise of footsteps and shuffling of feet. Any tip-up seats should be quiet in action.

12.1.3 Sound absorbing treatment applied for acoustic purposes serves also to reduce the build-up of noise within the room. It is desirable to provide sound absorbing ceiling in the court room.

12.2 Libraries, Museums and Art Galleries

Quiet conditions for reading and study are essential in

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these types of buildings and, since their occupancy is not noise producing, intruding noise is more noticeable and distracting. Every opportunity therefore should be taken to plan for noise defence, both in respect of siting of the building and internal planning. When possible, stack rooms, store rooms and administrative offices should be planned to screen reading rooms, print rooms and lecture rooms from noise sources. In public libraries, the reference library and lecture rooms should receive first consideration; the lending library, newspaper and periodical rooms have a higher background noise and are secondary in importance.

12.2.1 In large libraries, museums and art galleries echoes from lofty, large domed or concave ceilings are often a nuisance. Small noises such as footsteps, coughs, chair scraping and closing of books are reinforced by reverberation, and concave surfaces even when treated with a sound absorbent may focus these noises. Treated flat ceilings, if not too high, obviate these troubles. Books on shelves in libraries constitute a valuable wall absorbent.

12.2.2 Floor finishes are important. The impact noise of footsteps on marble, terrazzo or wood block flooring, and especially on hardwood strip and batten flooring, can be disturbing both within the room in which the noise is generated and the rooms below. On solid floors, resilient floor finishes, such as rubber, cork and linoleum on an underlay, are highly desirable. In the children's sections of libraries and museums they are essential. In existing buildings, rubber linoleum or vinyl asbestos tiles laid over the floor in the traffic areas are often a solution to the problem.

12.2.3 Reference libraries in universities, research establishments, office buildings and science buildings having machines and testing benches, should be planned in a quiet part of the building. Walls enclosing the library should normally have a sound reduction index, R_w of not less than 50 dB (for example 230 mm brick) and baffle lobbies should be planned between the library and halls and corridors. Walls facing on to corridors or other noisy areas should not have fanlights unless they are double glazed and non-operable.

12.3 Auditoria and Theatres

The sources of noise that have to be considered in concert halls, opera house, theatres and similar auditorium buildings are as follows:

a) Outdoor noise entering through walls, roofs, doors, windows or ventilation openings;
b) Noise from any other hall in the same building, especially if let out separately for revenue;
c) Noise from foyers, service rooms and other ancillary rooms, particularly rehearsal rooms;
d) Noise from air conditioning plant, etc, and the cross-transmission of other internal noises *via* ventilating duct system; and
e) Impact generated noise due to rainfall on light weight metal roofs.

12.3.1 Because of greatly increased outdoor noise, all auditorium buildings now need more care in siting than formerly. For listening to speech or music, a very low background noise level is desirable; in concert halls especially the quietest possible conditions should be provided because the pauses and moments of silence which are essential elements of music cannot otherwise be given full value. Therefore, sites at crossroads or close to steel railway bridges, religious places or near churches where bell ringing is practiced, should be avoided unless very high standards of structural sound insulation are contemplated. Sites adjoining underground railways may also prove unsatisfactory at basement levels owing to low-pitched noise or rumble transmitted through the ground; special isolation measure need to be adopted for isolating large buildings from ground vibration of this sort.

12.3.2 Whenever possible, for concert halls and theatres on city sites a noise survey of the site should be made; a suitable sound reduction value for the structure of the building can then be chosen so as to keep down to certain maximum noise levels within the auditorium. The maximum octave-band sound pressure levels (SPL) recommended are given in Table 8.

Table 8 Maximum Sound Pressure Levels Due to External and Mechanical Equipment Noise in Auditoria (dB)

(*Clause* 12.3.2)

Sl No.	Type of Auditorium	Centre Frequency, Hz							
		63	125	250	500	1 000	2 000	4 000	8 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
i)	Concert halls [dBA-25]	51	39	31	24	20	17	14	13
ii)	Drama theatres and cinemas [dBA-30]	55	44	35	29	25	22	20	18

12.3.3 The minimum standard of sound reduction index, R_w likely to be required for the envelope of an auditorium in a city to protect it against external noise is of the order of 65 dB for a concert hall or 55-60 dB for a theatre. This reduction should be provided on all sides, but it would be reasonable to make the R_w for the roof 5 to 10 dB less provided the building is not unduly exposed to noise from aircraft in flight. Surrounding the auditorium with ancillary rooms and foyers is an obvious and invaluable planning method

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of obtaining the required insulation against outdoor noise.

12.3.4 Ventilation intakes and returns are vulnerable features in the defence against external noise. They should be positioned so as to avoid exposure to noise, and in addition sufficient length of both inlet and outlet ducts should be provided with carefully designed silencers. The ventilation system should also be designed to avoid transmitting or adding to internal noise.

12.3.5 The most serious internal noise problem arises when there are two halls meant for separate use in the same building, especially if one of them is a concert hall. The latter is a very loud potential source of noise and requires a high standard of protection against extraneous noise. In these circumstances it is doubtful whether a 'single' wall can be adequate for insulating the two halls unless it is designed with a wide unbridged cavity. Separation by planning is preferable.

12.3.6 Other sources of internal noise are rehearsal rooms, scenery bays and workshops, stages of other halls where rehearsals or erection of stage sets might be in progress and foyers and bars where loud conversation might occur. The insulation of the internal walls should be adequate to protect the auditorium from these noise sources and the insulation should not be by-passed by openings, doorways, etc. The general noise due to banging of doors also needs to be taken care of; soft sealing materials should be provided for all doors to ensure quiet closing.

12.3.7 Mechanical equipment such as lifts shall be effectively isolated from the building structure to help avoid noise transmission.

12.3.8 Adequate damping shall be provided under light weight metal roofs with an additional light weight under deck noise sound barrier to reduce rainfall generated noise.

12.3.9 For detailed acoustical design of auditoria and conference halls reference may be made to good practice [8-4(3)].

12.4 Cinemas

The main objective of the design should be to control noise from adjacent screens, the projection area, the foyer, and outside the cinema. The first of these, controlling noise from adjacent screens, is likely to be the most difficult with modern digital sound systems. As most cinemas are air conditioned, there will be some noise from services. To ensure reasonable listening conditions, this should be limited to 30 dBA. This will provide some masking of the noise from adjacent screens, but a high performance partition will still be essential. Masonry or lightweight construction may be used, and a typical performance specification for a lightweight wall separating two screens is given in Table 9. Cinema design, however, normally requires specialist acoustic advice.

Table 9 Typical Sound Insulation Specification for Wall Separating Two Cinema Screens

(*Clause* 12.4)

Sl No.	Octave band Hz	Sound Reduction Index, R dB
i)	63	38
ii)	125	44
iii)	250	50
iv)	500	61
v)	1 000	57
vi)	2 000	58
vii)	4 000	57
viii)	8 000	55

13 NOISE FROM BUILDING SERVICES

13.1 Mechanical, electrical, air conditioning, heating and mechanical ventilation, and other services are provided in almost all large buildings including residential, commercial and industrial buildings. Noise control measures should be incorporated during the design and installation of such services to adhere to the recommended outdoor and indoor noise criteria for the kind of occupancy. For detailed design of noise control for services, specialist advice should be sought.

Some basic design techniques for noise control in air conditioning, heating and mechanical ventilation system are given in Annex G.

13.2 Control of noise from mechanical equipment can also be done by specifying noise control requirements while purchasing the equipment (*see* Annex H).

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ANNEX A

(*Clause* 2.4)

NOISE CALCULATIONS

A-1 GENERAL

Some of the simpler types of noise calculation are described in this annex.

A-2 ADDITION OF TWO NOISE LEVELS

To determine the combined sound pressure level (L_c) resulting from the sound pressure levels of two or more noise sources (L_1, L_2, etc), it is necessary to calculate and add the mean square values of their individual sound pressures and then convert this back to a sound pressure level. This can be done using the following formula:

$$L_c = 10\log_{10}\left(10^{L_1/10} + 10^{L_2/10}\right)$$

As the individual sound pressure levels are logarithms of the mean square sound pressures, they cannot simply be added arithmetically. Figure 3 shows a graphical method for adding the sound pressure levels from two independent sources to obtain the combined sound pressure level at a particular place. This graph may also be used for multiple sources by combining sources two at a time to produce virtual sources that can then be combined. The most accurate approach is to start with the lowest levels and work towards the highest.

The graph should be used with caution where the noise sources are not independent. For example, the sound pressure level from two large transformers fed with currents in phase will be very sensitive to the receiving position. This is because the effect of the constructive and destructive interference of the sounds from the two sources is very dependent on position.

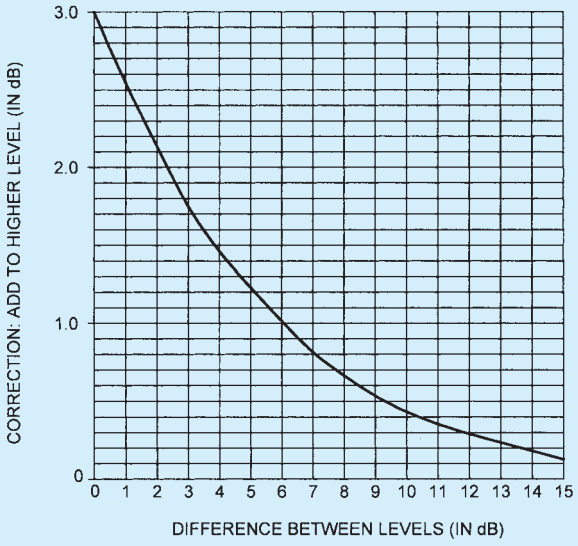


FIG. 3 ADDITION OF TWO NOISE LEVELS

A-3 SUBTRACTION OF TWO NOISE LEVELS

When measuring noise from a source, the true noise level of the source alone will be less than that shown by the meter, if the level of extraneous noise is less than about 10 dB below the total noise level. An estimate of the true source level can be obtained from Fig. 4.

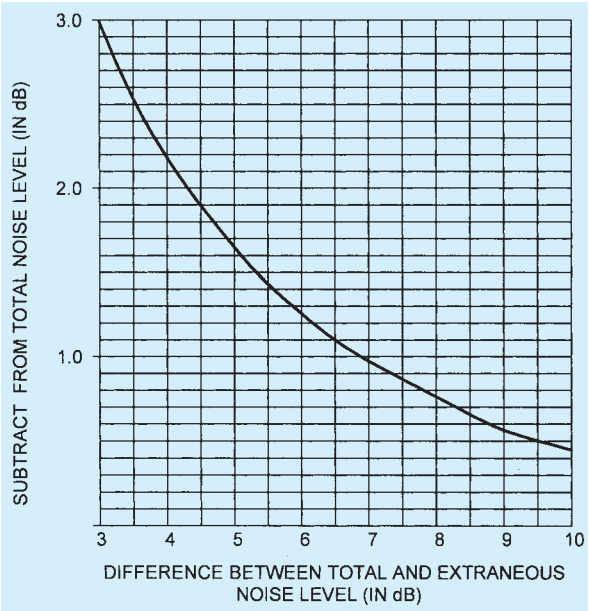


FIG. 4 SUBTRACTION OF NOISE LEVELS

A-4 NON-UNIFORM COMPOSITE PARTITIONS

Figure 5 provides for calculating the overall sound insulation of a composite partition consisting of two parts having different sound-insulating properties, for example, a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

A-5 A-WEIGHTING CALCULATIONS

The equivalent A-weighted level is often required when data on a noise source is available as a set of octave band or one-third octave band levels. The conversion can be done manually, using the standard A-weighting values (*see* Table 10) and the graph for combining levels (*see* Fig. 3). For all but the simplest situations it is more convenient to use a computer spreadsheet to do the conversion.

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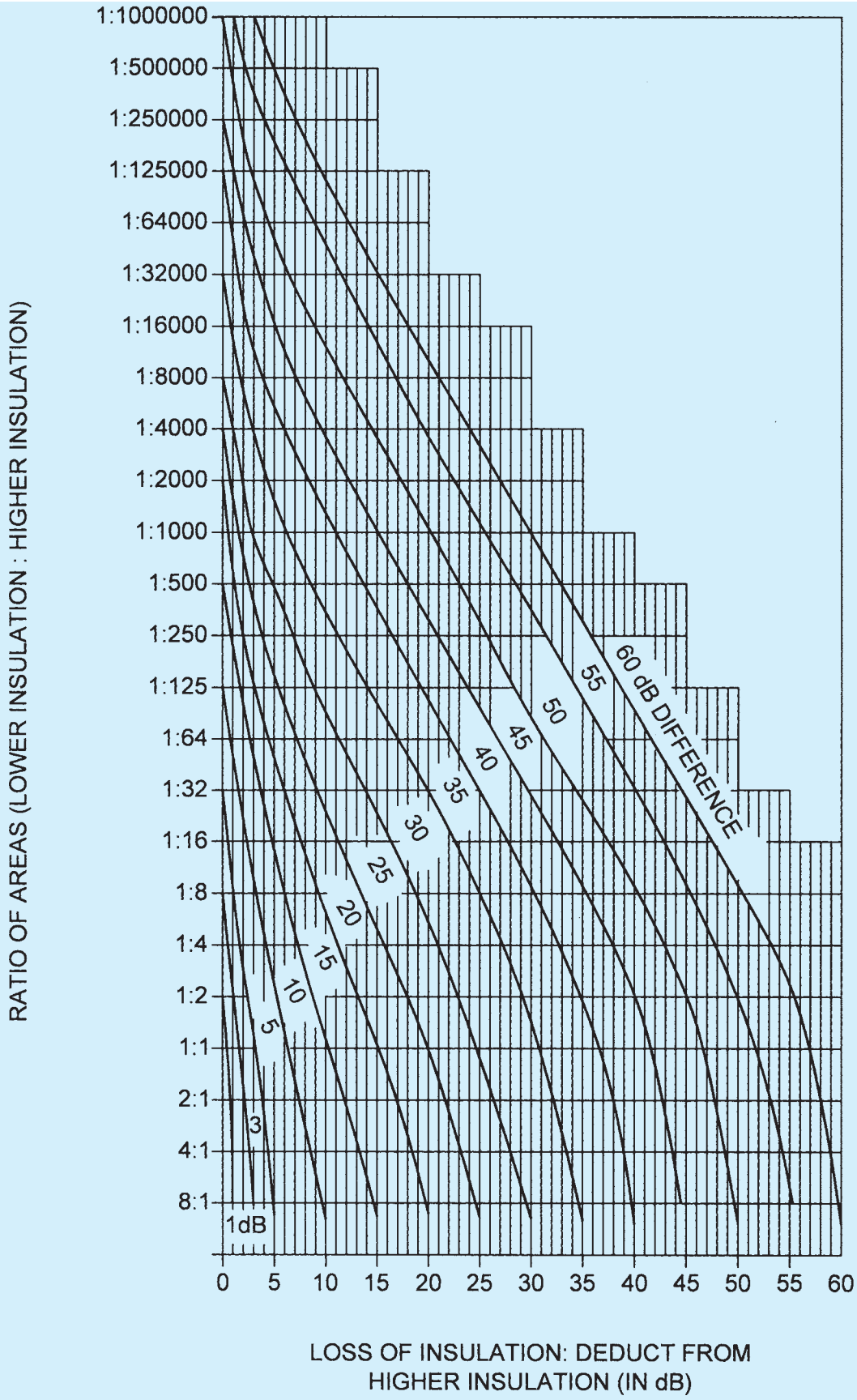


FIG. 5 SOUND INSULATION OF NON-UNIFORM PARTITIONS

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Table 10 Standard A-Weighting Values (dB)
(*Clause* A-5)

Sl No.	Third Octave Band Centre Frequency	A-Weighting	Third Octave Band Centre Frequency	A-Weighting
	Hz	dB	Hz	dB
(1)	(2)	(3)	(4)	(5)
i)	10	–70.4	500	–3.2
ii)	12.5	–63.4	630	–1.9
iii)	16	–56.7	800	–0.8
iv)	20	–50.5	1 000	0
v)	25	–44.7	1 250	0.6
vi)	31.5	–39.4	1 600	1.0
vii)	40	–34.6	2 000	1.2
viii)	50	–30.2	2 500	1.3
ix)	63	–26.2	3 150	1.2
x)	80	–22.5	4 000	1.0
xi)	100	–19.1	5 000	0.6
xii)	125	–16.1	6 300	–0.1
xiii)	160	–13.4	8 000	–1.1
xiv)	200	–10.9	10 000	–2.5
xv)	250	–8.6	12 500	–4.3
xvi)	315	–6.6	16 000	–6.6
xvii)	400	–4.8	20 000	–9.3

A-6 REVERBERATION TIME CALCULATION

An estimate of the reverberation time (T) of a room can be obtained from the Sabine formula:

$$T = \frac{(0.16V)}{\sum A_i}$$

where

V = volume of the room, in cubic metre (m^3); and

A_i = equivalent sound absorbing area in the room, in square metre (m^2).

The A_i are the absorbing areas of each surface, or other permanent fixture in the room. Each A_i is determined by multiplying the area of that surface in square metre (m^2) by its absorption coefficient α_{si}. The surface of each significant fixture or feature of the room should be considered as well as the walls, ceiling and floor.

The total absorption is obtained by summing the individual A_i values. As the values of α_{si} are frequency dependent, this calculation should be repeated for each octave band of interest.

An allowance should also be made for people and furnishings in the room.

ANNEX B

(*Clauses* 2.26, 2.41, 2.44, 2.46, 2.54, 2.55, 2.56 *and* 2.57)

SPECIFICATION OF SOUND INSULATION

B-1 GENERAL

Sound insulating elements work mainly by reflecting sound energy back into the source room, not by absorbing it. The methods of measurement and the terms used are described in **B-2** to **B-4**.

B-2 INSULATION AGAINST AIRBORNE SOUND

As per the standard tests, the insulation between a pair of rooms is measured either in third octave bands having centre frequencies which cover at least the range 100 Hz to 3 150 Hz, or in octave bands which cover at least the range 125 to 2 000 Hz. The noise is produced by a loudspeaker in one of the rooms (called the source room) and at each frequency the average noise levels are measured in the source room (L_S) and in the adjacent receiving room (L_R). The difference between these two levels (D) is a measure of the sound insulation between the rooms regardless of the transmission path(s) the sound energy followed to travel between the rooms. The equation is as follows:

$$D = L_S - L_R$$

The actual level in the receiving room depends on the following:

a) Sound insulation of the separating wall or floor;
b) Area of the separating wall or floor;
c) Volume of the receiving room;
d) Amount of flanking transmission (that is the importance of transmission paths other than the separating wall or floor); and
e) Amount of absorbing material (for example furniture) in the receiving room.

For field measurements, apart from the amount of absorption, these factors are a property of the building and should be taken into account by the measurement procedure. As the amount of absorbing material (for example soft furniture) in the room at the time of measurement is arbitrary, it should be allowed for separately. This is achieved by measuring the reverberation time (T) of the room in second (in s), which is a measure of how long it takes a sound to die away after the source has been switched off. As the sound energy is dissipated as heat in the absorbing

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material (T), it is related to the total amount of absorption in the room. The receiving room level may then be corrected to the level it would be if the room had a standard reverberation time (T_0) which is typical of furnished rooms, and is taken to be 0.5 s. The corrected level difference is known as the standardized level difference, which has the symbol D_{nT} and is calculated using the following equation:

$$D_{nT} = L_S - L_R + 10\log_{10}(T/T_0)$$

For laboratory measurements, the insulation of the separating wall or floor being tested is required in a way which is independent of the actual measuring laboratory. For this reason, laboratories are designed to have minimal flanking transmission and a different correction is applied to account for the other factors. This correction is $10\log_{10}(S/A)$.

where

S = common area of the separating wall or floor, in square metre (m^2); and

A = equivalent absorption area in the receiving room, in square metre (m^2).

The laboratory corrected level difference at each frequency is known as the sound reduction index, which has the symbol R and is calculated using the following equation:

$$R = L_S - L_R + 10\log_{10}(S/A)$$

If the test wall or floor is mounted in a realistic way in the laboratory and flanking transmission will be low in the field, the sound reduction index may be used to predict its performance in the field. The relation between D_{nT} and R is given by the following equation:

$$D_{nT} = R - 10\log_{10}(3S/V)$$

where

S = area of the separating wall or floor in the field, in square metre (m^2); and

V = volume of the receiving room in the field, in cubic metre (m^3).

This equation shows that if the source and receiving rooms have different volumes, D_{nT} will depend on which is used as the source room; using the larger room as the source room will give lower value.

B-3 INSULATION AGAINST IMPACT SOUND

The procedure to measure the impact insulation of floors is rather different. Instead of a loudspeaker, a machine containing five small hammers is placed on the floor. While the hammers strike the floor at a rate of 10 blows a second, the resulting noise level (L_i) is measured in the receiving room below at each of the same frequency bands used for airborne insulation. In the field, the receiving room levels are again 'corrected' to a standard reverberation time (T_0) of 0.5 s to give the standardized impact sound pressure level, L_{nT}, which is calculated as follows:

$$L_{nT} = L_i - 10\log_{10}(T/T_0)$$

In the laboratory, the noise level depends mainly on the characteristics of the floor being tested and the amount of absorption (A m^2) in the laboratory. It is therefore appropriate to correct the noise level to a standard area of absorption. The area used is 10 m^2. The resulting normalized impact sound pressure level is given the symbol L_n and calculated as follows:

$$L_n = L_i + 10\log_{10}(A/10)$$

B-4 RATING SOUND INSULATION

Measurements of insulation against both airborne and impact sounds yield values in a number of frequency bands. To make this information more manageable, rating methods such as those in accordance with good practice [8-4(1)] are used to reduce the frequency band values to single figure ratings. These single figure ratings should be good predictors of subjective assessments of insulation. However, this is not always the case and it is prudent to examine the full measurement data in critical situations. The impact insulation measured on a floor with a carpet is likely to be overestimated by this method.

The more common indices used to describe sound insulation are summarized in Table 11.

Table 11 Common Indices Used to Describe Airborne and Impact Sound Insulation

(*Clause* B-4)

Sl No.	Air-borne (*A*) Impact (*I*)	Lab (*L*) Field (*F*)	Measured Values		Single Number Quantity	
			Name	Symbol	Name	Symbol
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	*A*	*F*	Standardized level difference	D_{nT}	Weighted standardized level difference	$D_{nT,w}$
ii)	*A*	*L*	Sound reduction index	R	Weighted sound reduction index	R_w
iii)	*I*	*F*	Standardized impact sound pressure level	L'_{nT}	Weighted standardized impact sound pressure level	$L'_{nT,w}$
iv)	*I*	*L*	Normalized impact sound pressure level	L'_n	Weighted normalized impact sound pressure level	$L'_{n,w}$

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ANNEX C

(*Clause* 2.24)

NOISE RATING

C-1 Noise rating (NR) is a graphical method for assigning a single number rating to a noise spectrum. It can be used to specify the maximum acceptable level in each octave band of a frequency spectrum, or to assess the acceptability of a noise spectrum for a particular application. The method was originally proposed for use in assessing environmental noise, but was later also found suitable for describing noise from mechanical ventilation systems in buildings. To make a rating, the noise spectrum is superposed on a family of NR contours; the NR of the spectrum corresponds to the value of the first NR contour that is entirely above the spectrum. The data for drawing NR contours (from NR 0 to NR 75) is given in Table 12 for the frequency range 31.5 Hz to 8 kHz.

Table 12 Noise Rating Values

(*Clause* C-1)

Sl No.	Noise Rating	Octave Band Centre Frequency, Hz Sound Pressure Levels dB_{re} 20 µPa								
		31.5	63	125	250	500	1 000	2 000	4 000	8 000
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	NR75	106	95	87	82	78	75	73	71	69
ii)	NR70	103	91	83	77	73	70	68	66	64
iii)	NR65	100	87	79	72	68	65	62	61	59
iv)	NR60	96	83	74	68	63	60	57	55	54
v)	NR55	93	79	70	63	58	55	52	50	49
vi)	NR50	89	75	66	59	53	50	47	45	43
vii)	NR45	86	71	61	54	48	45	42	40	38
viii)	NR40	83	67	57	49	44	40	37	35	33
ix)	NR35	79	63	52	45	39	35	32	30	28
x)	NR30	76	59	48	40	34	30	27	25	23
xi)	NR25	72	55	44	35	29	25	22	20	18
xii)	NR20	69	51	39	31	24	20	17	14	13
xiii)	NR15	66	47	35	26	19	15	12	9	7
xiv)	NR10	62	43	31	21	15	10	7	4	2
xv)	NR5	59	39	26	17	10	5	2	–1	–3
xvi)	NR0	55	35	22	12	5	0	–4	–6	–8

C-2 For computational methods the curves are defined by the equation:

$$L = a + bN$$

where

L = octave band sound pressure level corresponding to NR level N; and

a and b = constants for each frequency band, as given in Table 13.

NOTE — NR values cannot be converted directly to dBA values but the following approximate relationship applies:

$$NR = dBA - 6$$

C-3 Although the NR system is currently the preferred method for rating noise from mechanical ventilation system, other methods which are more sensitive to noise at low frequencies are available, but they are not yet widely accepted. Low frequency noise may be disturbing or fatiguing to occupants, but may not have much effect on the dBA or NR value.

Table 13 Values of *a* and *b*

(*Clause* C-2)

Sl No.	Octave Band Centre Frequency Hz	*a*	*b*
(1)	(2)	(3)	(4)
i)	31.5	55.4	0.681
ii)	63	35.4	0.790
iii)	125	22.0	0.870
iv)	250	12.0	0.930
v)	500	4.2	0.980
vi)	1 000	0.0	1.000
vii)	2 000	–3.5	1.015
viii)	4 000	–6.1	1.025
ix)	8 000	–8.0	1.030

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ANNEX D

(*Clause* 3.3)

OUTDOOR NOISE REGULATIONS IN INDIA

D-1 Government notifications are issued from time to time on the allowable ambient noise levels in general and specifically in different zones of various metropolitan cities of India.

D-2 Noise regulations and notifications are also issued from time to time specifying the maximum permissible sound levels from equipment commonly used in and around the residential areas and around sensitive buildings, specifically with regard to noise levels from electricity generating sets, construction equipment and HVAC utility equipment installed outdoors.

D-3 These regulations should be referred to by the designer for the design of measures for control of external noise.

ANNEX E

(*Clauses* 3.8 *and* 4.5)

SPECIAL PROBLEMS REQUIRING EXPERT ADVICE

E-1 GENERAL

Certain design problems require reliable advice of a kind which is not easy to find in published material. The advice of an expert should be sought for these kinds of problems, some examples of which are given in **E-2** to **E-9.**

E-2 ACOUSTIC TEST ROOMS

The design of rooms in which acoustic measurements are carried out, such as reverberation chambers, free-field anechoic rooms and audiometric test rooms, usually requires the advice of an expert.

E-3 PERFORMING SPACES

The design of theatres, opera houses, concert halls and similar performing spaces usually requires expertise in room acoustics and noise control. The intrusion of quite low levels of noise may seriously interfere with the enjoyment of the performance and distract the performers. The requirements for low noise levels often mean that more room has to be allocated for low velocity ventilation ductwork and the impact on the design of the ventilation system is often substantial.

E-4 BROADCASTING AND RECORDING STUDIOS

Broadcasting and recording studios have requirements similar to those of performing spaces. For some infrequent intrusive noises, the requirements are sometimes relaxed on the grounds that a retake of a recording can be done, but this can result in higher operating costs.

E-5 AIRCRAFT NOISE

As there are many variables affecting the level of aircraft noise heard on the ground, expert advice is almost always required. Contours of daytime $L_{Aeq,T}$ levels are available from most major airports. Where measurements of façade insulation are necessary a standard test method may be referred.

E-6 GROUND-BORNE NOISE

Projects involving ground-borne noise from underground trains usually require expert advice.

E-7 LOW FREQUENCY NOISE

Projects involving low-frequency noise usually require expert advice as accurate measurement is difficult and there is a shortage of reliable data below 100 Hz.

E-8 ACTIVE NOISE CONTROL

Active noise control is the reduction of noise by cancellation with a similar noise (anti-noise) generated by electro-acoustic means. The technique is still under development, but commercial systems are available which successfully reduce low frequency noise from mechanical ventilation systems.

E-9 NOISE SURVEYS

Noise surveys are carried out for a variety of reasons, for example,

a) Before construction, to establish the existing noise climate at the site of a proposed development where reliable prediction is

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impracticable, as an aid to the design of the building envelope, either to protect against external noise or contain internally produced noise;

b) During construction, to monitor noise from building activity, either to assess the likely nuisance to the local community or the risk of hearing damage to the work force;

c) At the end of a building contract to check the insulation of the building envelope, or the noise levels produced by the services;

d) As part of a planning requirement;

e) To provide objective evidence to support or defend a legal action.

The expense of carrying out a comprehensive noise survey of any kind is likely to be high, so the cost-effectiveness of a full or partial survey should be weighed against alternatives such as prediction. A survey will generally be more accurate and can take account of factors such as prevailing wind conditions.

ANNEX F

(*Clause* 4.4)

AIRBORNE AND IMPACT SOUND INSULATION

F-1 GENERAL

Airborne sound refers to sources which produce sound by directly setting the air around them into vibration. Impact sound refers to sources which produce sound by impulsive mechanical excitation of part of a building (for example by footsteps, electric light switches, slamming doors). Many sources of impact sound also produce significant levels of airborne sound. The term structure-borne sound has no very precise meaning as the structure can be excited by both airborne and impact sources; it is often used to refer to sound that travels for long distances *via* the structure, especially in connection with vibrating machinery linked directly to the structure.

F-2 DIRECT AND INDIRECT TRANSMISSION

Figure 6 shows diagrammatically a pair of rooms in a house where the construction consists of solid walls, etc, bonded together. Sound travelling from room 1 to room 2 may travel *via* the direct path a-a and by the many indirect, or flanking, paths shown. The term flanking transmission is usually used to mean transmission paths involving the structure, while the term indirect transmission includes flanking paths and airborne paths through gaps and ducts, etc. The indirect paths may limit the sound insulation attainable no matter how much the direct sound is reduced by the separating wall or floor. The indirect transmission can be reduced by measures such as the following:

a) Increasing the mass of the flanking walls;

b) Increasing the mass of the partition and bonding it to the flanking walls;

c) Introducing discontinuities in the indirect paths;

d) Erecting independent wall linings adjacent to the flanking walls to prevent energy entering the flanking construction; and

e) Sealing any air gaps and paths through ducts.

Figure 7 shows a number of indirect paths that have been found in offices.

It is important to remember that standard test laboratories are designed to minimise transmission by all paths other than the direct path. This makes it difficult to relate the results of laboratory measurements to those likely to be obtained in the field.

F-3 AIRBORNE SOUND INSULATION

F-3.1 General

The sound insulation of structural elements such as walls and floors always varies with frequency, the insulation rising in general as the frequency rises.

F-3.2 Terminology

Results from field measurements are usually expressed in terms of the weighted standardized level difference, while laboratory measurements are usually expressed in terms of the sound reduction index. In the absence of significant flanking transmission, the numerical difference between the weighted standardized level difference and the sound reduction index of a wall or floor is usually small for furnished rooms in dwellings, and so either quantity may be used in considering principles; for this purpose it is, therefore, convenient

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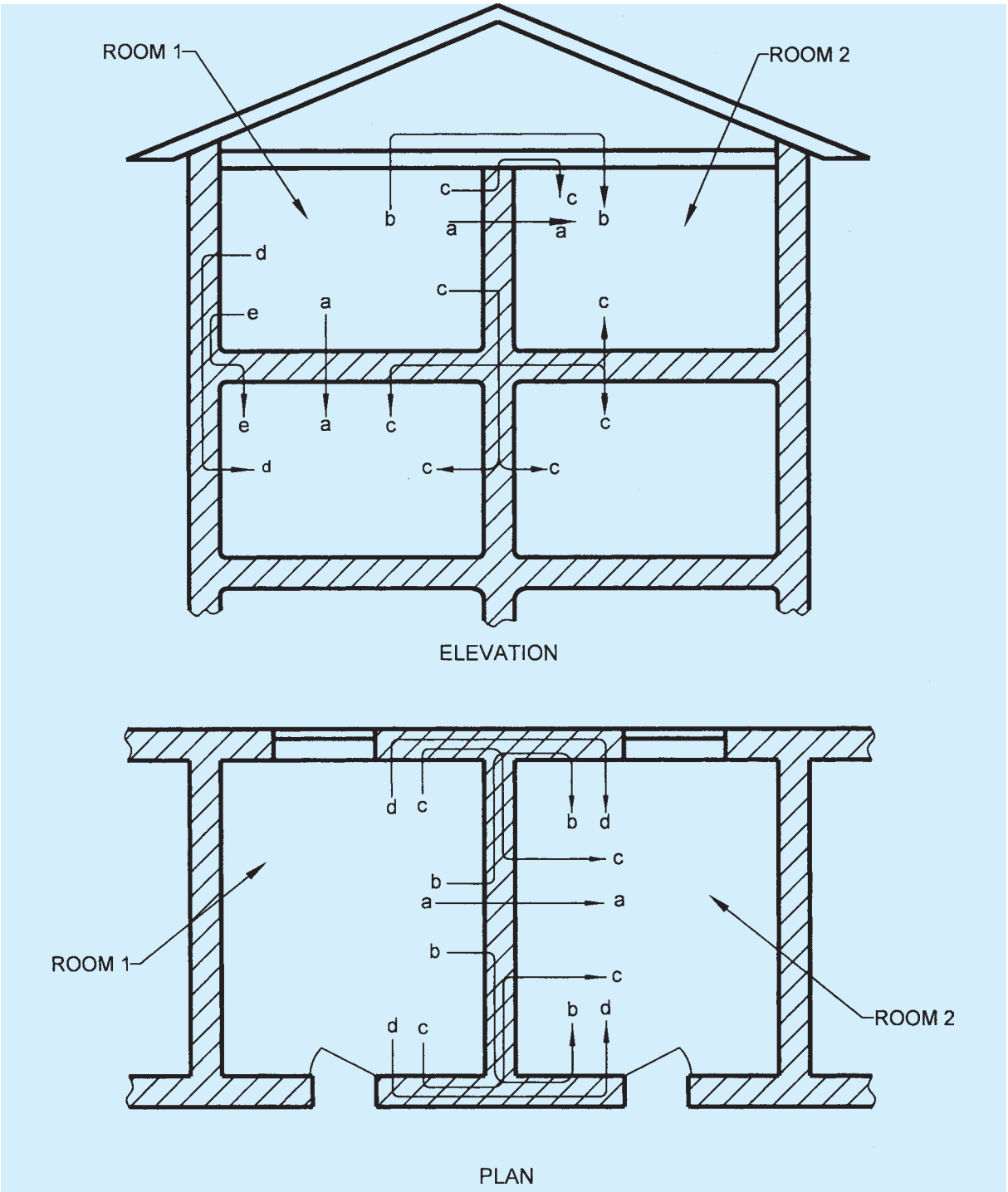


FIG. 6 TRANSMISSION PATHS (*VIA* THE STRUCTURE) OF NOISE ORIGINATING IN ROOM 1 (DIAGRAMMATIC)

to use the general term insulation.

F-3.3 Mass Law

An approximate empirical relationship has been established between sound insulation and mass for single leaf constructions as shown in Fig. 8. This so called 'Mass Law' gives a useful first approximation to the behaviour of a single sheet or plate. In practice, the sound insulation predicted by the mass law may not be attained because of factors such as the coincidence effect, which is outlined in **F-3.4**. Results for specific materials vary around the value given by the Mass Law relationship, and so measured data should be used when available. Table 14 gives a lists of materials and indicates the sound insulation of a single,

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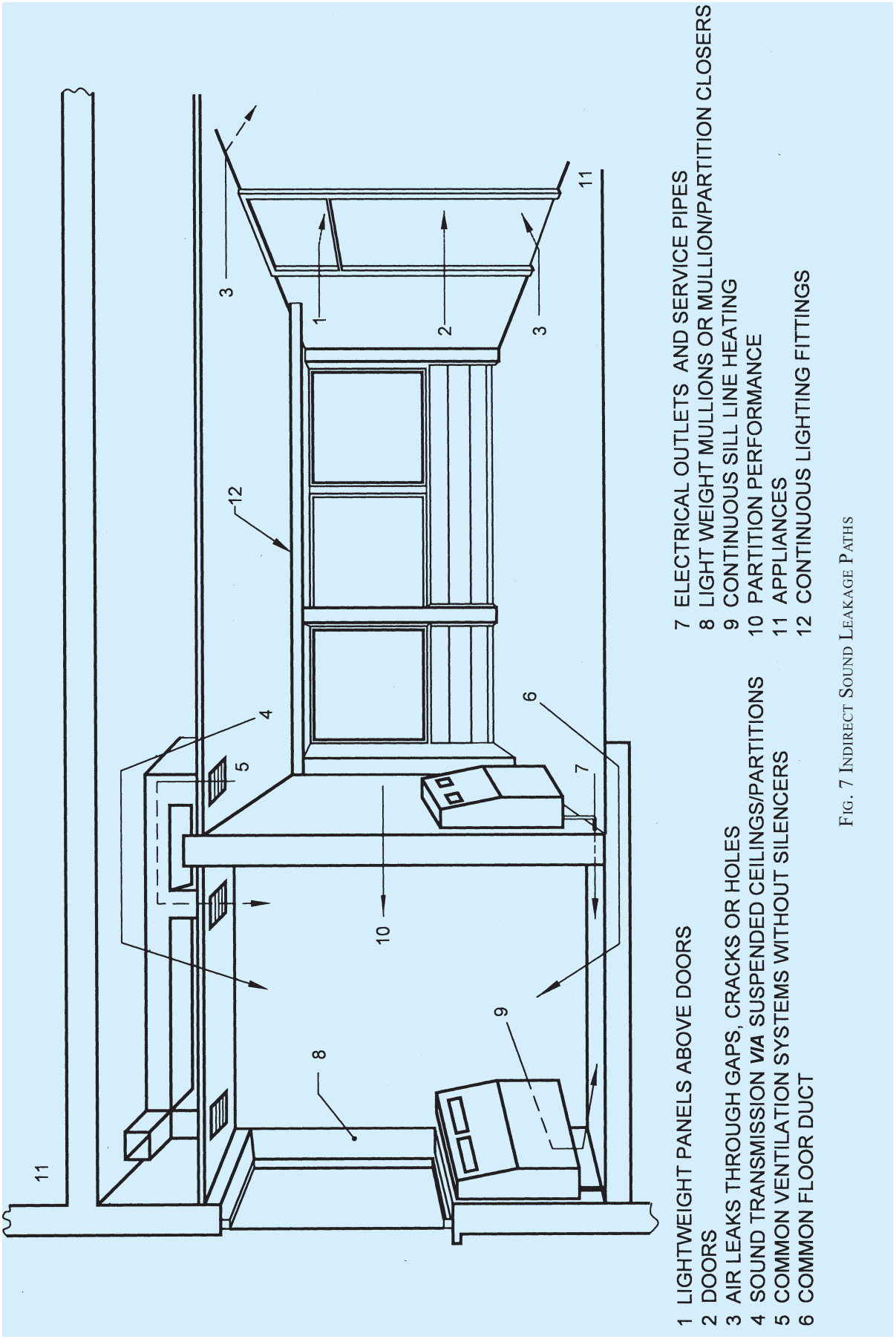


FIG. 7 INDIRECT SOUND LEAKAGE PATHS

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imperforate sheet when fixed to a suitable wood or metal framework. These values are useful, for example when assessing existing structures.

Table 14 Sound Insulation of Imperforate Sheet Materials

(*Clause* F-3.3)

Sl No.	Material	Surface Mass	Typical Weighted Sound Reduction Index R_w
		kg/m^2	dB
(1)	(2)	(3)	(4)
i)	3 mm glass sheet	7.0	26
ii)	12.5 mm plasterboard	10.5	31
iii)	18 mm wood particle board	8.0	27
iv)	19 mm plywood	3.0	24
v)	16 mm plywood	4.5	24
vi)	1 mm steel sheet	11.0	29
vii)	6 mm hardboard	5.0	25
viii)	12 mm wood fibre insulation board	4.0	24
ix)	13 mm mineral fibre board	4.0	24
x)	50 mm wood-wool screeded one side	35.0	33

F-3.4 Coincidence Effect

The coincidence effect occurs when the wavelength of the wave impressed on the panel by the incident sound wave is close to the wavelength of free bending waves in the panel. The effect of coincidence is to lower the sound insulation of a construction by as much as 10 dB below the level expected from its mass per unit area over a limited frequency range. The coincidence effect can be pronounced with thin light weight partitions, resulting in loss of insulation at middle and high frequencies. Reducing the stiffness without a corresponding reduction of mass can raise the critical frequency above 3 150 Hz, and so improve the insulation over the important 100 Hz to 3 150 Hz range. An increase of stiffness will have the reverse effect.

It is possible to design lightweight stud partitions so that they perform to their maximum effect in the speech frequency region between 250 Hz and 2 000 Hz, that is between the mass-spring-mass and coincidence regions respectively.

The worst coincidence dips occur in materials such as plate glass and rigid metal sheets. Heavily damped materials such as lead sheets are least affected.

F-3.5 Mass-Spring-Mass Frequency

A double leaf wall can perform better than a single leaf wall of similar mass because the sound has to pass through two barriers. If the two leaves are not connected to each other, the insulation values of the two leaves may be added together. However, in practice the leaves are often connected by ties or studs, and the full insulation cannot be achieved. Even where the two leaves are isolated from each other, the full benefit can only be obtained above a certain frequency that depends on the cavity width. This is because the air in the cavity behaves like a spring connecting the leaves together, and causes a resonance at the mass-spring-mass frequency. Below this frequency, the two leaves behave more like an equivalent single leaf.

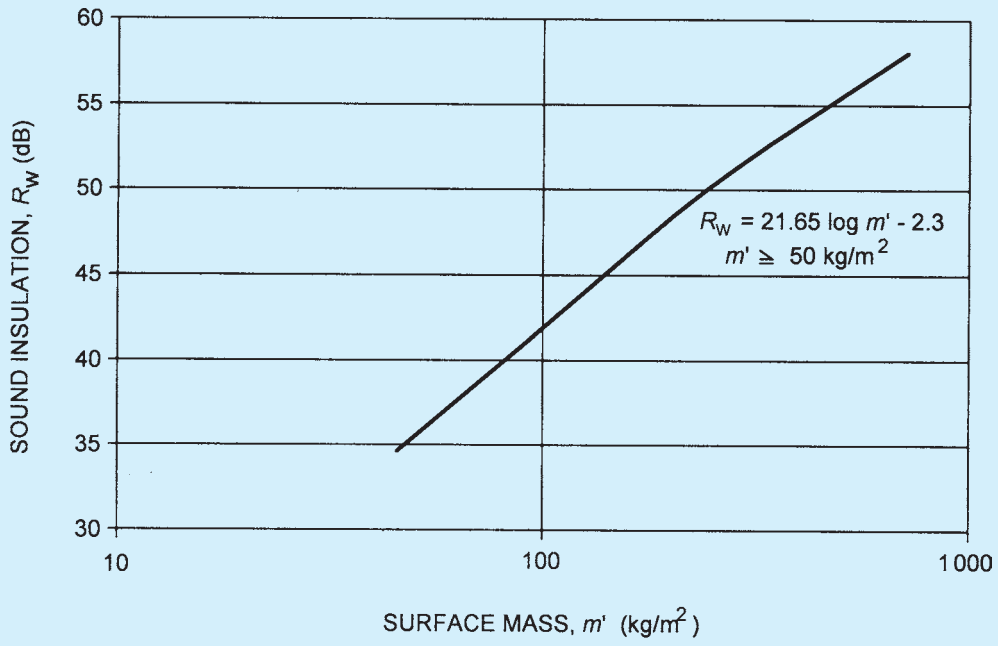


FIG. 8 MASS LAW CURVE

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Making the cavity width wide can reduce the mass-spring-mass frequency, as in the case of sound insulating secondary glazing. The mass-spring-mass frequency (F_0) may be estimated from the following equation:

$$F_0 = 59.6\sqrt{\frac{1}{d}\left(\frac{1}{m_1}+\frac{1}{m_2}\right)}$$

where

m_1 and m_2 = surface masses of the two leaves, in kilogram per square metre (kg/m^2); and

d = cavity width, in metre (m).

F-3.6 Impact Sound Control

A structure that receives an impact or has a vibrating source in contact with it behaves more like an extension of the source rather than an intervening element between source and listener. For this reason, a relatively small amount of impact energy may produce a loud sound and, if the structure is continuous, the sound may travel a long distance. Control is usually obtained by inserting a resilient surface at the point of contact with the source (for example laying a carpet on a floor) or by introducing a structural discontinuity.

Floating floors, which are an example of the latter approach, are a common method of controlling impact sound from footsteps. However, it should be noted that an effective floating floor may result in increased sound from impacts on the source side of the floor.

F-4 AIRBORNE INSULATION VALUES OF WALLS AND AIRBORNE AND IMPACT INSULATION VALUES OF FLOORS

Table 15 and Table 16 give examples of common types of wall and floor construction with sound insulation in the ranges shown. The insulation indices are for field measurements accessed in accordance with good practice [8-4(4)]. The insulation values given are necessarily approximate since examples of nominally identical constructions may show variations of several decibels. All the figures represent values expected in the field, that is, in actual buildings. Many are based directly on field measurements, though other (in the absence of representative field measurements) have been assessed from laboratory data, with an allowance for typical flanking conditions in normal buildings. Variation in the amount of indirect transmission may affect significantly the insulation between two rooms separated by a given barrier. For example, the sound insulation of some types of floor may be reduced by indirect transmission along the walls supporting them, particularly if these walls are of lightweight masonry and carried past the floor.

In many cases, simple solid partitions give insulation values according to their mass (*see* **F-3.3**). Moreover, with partitions of this type there is usually little variation between field and laboratory test results unless the laboratory insulation exceeds 45 dB. Exceptions may occur in buildings that have not been specially designed to minimise common cavities and strongly coupled elements in lightweight panelling. The examples given are not exhaustive. Flanking structures are not listed since these can vary widely and are often dependent upon other factors such as thermal insulation, which are outside the scope of this Code.

Table 15 Airborne Sound Insulation of Walls and Partitions

(*Clause* F-4)

Sl No.	Sound Insulation $D_{nT,w}$ dB	Type of Wall or Partition
(1)	(2)	(3)
i)	26 to 33	a) 1 mm steel sheet panels fixed to steel frame members to form demountable partition units 50 mm overall thickness. Mineral wool cavity insulation b) Plywood or wood fibre board 12 mm thick nailed both sides of 50 mm × 50 mm timber framing members spaced at 400 mm centres c) Paper faced strawboard or wood wool 50 mm thick panels plastered both sides d) Chipboard hollow panels 50 mm thick tongued and grooved edges, hardboard faced. Joints covered with wood trim
ii)	33 to 37	a) Lightweight masonry blockwork. Plaster or drylining on at least one side. Overall mass per unit area not less than 50 kg/m^2 b) Laminated plasterboard at least 50 mm thick fixed to timber perimeter framing, any suitable finish. Approximate mass per unit area 35 kg/m^2 c) Timber stud partitions any size timbers greater than 50 mm × 50 mm, 400 mm centres, cross noggins, 9.5 mm plasterboard lining on both sides, any suitable finish d) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. Approximate mass per unit area 18 kg/m^2 e) 50 mm lightweight masonry blockwork, plastered both sides to 12 mm thickness or drylined with 9.5 mm plasterboard
iii)	37 to 43	a) Lightweight masonry blockwork, plaster or dry lining on at least one side. Overall mass per unit area not less than 75 kg/m^2 b) Metal stud partition, 50 mm studs 600 mm centres, clad both sides with 12.5 mm plasterboard, joints filled and perimeters sealed. 25 mm mineral fibre quilt hung between studs. Approximate mass per unit area 18 kg/m^2

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Table 15 — (*Continued*)

(1)	(2)	(3)
iv)	43 to 50	a) Masonry wall, joints well filled. Either plaster or dry lining on both sides. Overall mass per unit area not less than 150 kg/m^2 b) 100 mm metal stud partition, 'C' section studs not greater than 600 mm spacing, not less than nominal 50 mm web depth. Clad on both sides with two layers of plasterboard of not less than 25 mm combined thickness. Mineral fibre quilt hung between studs. Approximate mass per unit area 35 kg/m^2 c) 75 mm × 50 mm timbers framing using staged studs at 300 mm spacing with 25 mm stagger forward and back. Frame clad with two layers of 12.5 mm of plasterboard on both sides. Mineral fibre quilt hung between studs. Approximate mass per unit area 36 kg/m^2 d) 50 mm × 25 mm timber stud partition to form a 25 mm cavity, clad on both sides with minimum 38 mm wood wool slabs having their outer faces screeded or plastered e) Solid autoclaved aerated concrete block 215 mm thick plaster or dry lined finish on both sides, blockwork joints well filled. Overall mass per unit area not less than 160 kg/m^2
v)	50 to 54	a) Two separate frames of timber studs not less than 89 mm × 38 mm, or boxed metal studwork with 50 mm minimum web depth Studs at 600 mm maximum centres. A 25 mm mineral wool quilt suspended between frames. Frames spaced to give a minimum 200 mm overall cavity. Clad on outside of each frame with a minimum of 30 mm plasterboard layers (for example 19 mm plus 12.5 thickness). Approximate mass per unit area 54 kg/m^2 [1)] b) Either *in-situ* or pre-cast concrete wall panel not less than 175 mm thick and not less than 415 kg/m^2. All joints well filled[1)] c) Brick wall nominal 230 mm thickness, weight (including plaster) not less than 380 kg/m^2. Plaster or dry-lined finish both sides. Brick work joints well filled[1)] d) 'No fines' concrete 225 mm thickness, weight (including plaster) not less than 415 kg/m^2. Plaster or dry-lined finish both sides[1)] e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2 [1)] f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Dry lined finish on both sides. Joints in block work well filled. Overall mass per unit area not less than 415 kg/m^2 [1)] g) Autoclaved aerated concrete block cavity wall consisting of two leaves, 100 mm blocks not less than 75 mm apart, with wall ties of the butterfly type. Plaster or dry line finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 150 kg/m^2 [1)]
vi)	54 to 60	a) Two separate frames of timber studs not less than 100 mm × 50 mm spaced at 600 mm maximum centres. A 50 mm mineral wool quilt in each frame between studs. Frames spaced to give a minimum 300 mm overall cavity. Each frame clad on outside with three layers of 12.5 mm plasterboard nailed to framing. Approximate mass per unit area 51 kg/m^2 [1)] b) Two separate frames of boxed 'C' section galvanized nominal 150 mm steel studs 100 mm apart with a 400 mm overall cavity. 50 mm mineral wool quilt fixed to the back of one frame each frame clad on outside with three layers of 12.5 mm plasterboard by self drilling or tapping screws. Approximate mass per unit area 47 kg/m^2 [1)] c) Solid masonry with an overall mass per unit area of not less than 700 kg/m^2 fully sealed both sides [1)] d) Dense aggregate concrete block solid wall 215 mm thick plaster finish to both surfaces. Overall mass per unit area not less than 415 kg/m^2 [1)] e) Cavity lightweight aggregate block (maximum density of block 1 600 kg/m^3) with 75 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 300 kg/m^2 [1)] f) Dense aggregate concrete block cavity wall with 50 mm cavity and wall ties of the butterfly wire type. Plaster finish on both sides. Joints in blockwork well filled. Overall mass per unit area not less than 415 kg/m^2 [1)]

Table 15 — (*Concluded*)

NOTES

1 Construction details and workmanship are important, if the levels of sound insulation indicated are to be achieved.

2 Where plasterboard is specified it is assumed that the surface mass will be at least 6.5 kg/m^2 for 9.5 mm thick board, at least 8.5 kg/m^2 for 12.5 mm thick board, and at least 14.5 kg/m^2 for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] When considering these constructions for separating walls, expert advice should be sought.

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Table 16 Airborne and Impact Sound Insulation of Floor Constructions

(*Clause* F-4)

Sl No.	Sound Insulation dB	Type of Floor Construction
(1)	(2)	(3)
i)	$D_{nT,w}$ = 49 to 54 $L_{'nT,w}$ = 56 to 65	a) A concrete floor having mass per unit area not less than 365 kg/m^2, including any screed or ceiling finish directly bonded to the floor slab; together with a floating floor or resilient floor covering equivalent to rubber or sponge rubber underlay or thick cork tile (for example carpet and underlay or sponge rubber backed vinyl flooring) b) A solid floor consisting of, 1) a solid slab; or 2) concrete beams and infilling blocks; or 3) hollow concrete planks; together with a floating floor. A ceiling finish is required for a beam and block floor. In each case the slab should have a mass per unit area of at least 300 kg/m^2, including any screed or ceiling finish directly bonded to it. Where a floating floor is laid over a floor of beams and hollow infill blocks or hollow beams along the top of the structural floor, it should be sealed and levelled before the resilient layer is put down. It is also essential to have due regard for conduits and pipework which should be laid and covered so as to prevent any short circuit of the floor's isolating properties. If precast units are used as a structural floor, it is essential that the joints are filled to ensure that the sound insulation performance is maintained. The resilient material is laid to cover completely the structural floor and turned up against the surrounding wall along all edges. The resilient layer is usually of mineral fibre, or a special grade of expanded polystyrene. When the screed is laid, it is important that none of the mix finds its way through the resilient layer to the structural floor, as this will short circuit the isolation between the two decks and significantly reduce the sound insulation c) A floor consisting of boarding nailed to battens laid to float upon an isolating layer of mineral fibre capable of retaining its resilience under imposed loading. With battens running along the joists, a dense fibre layer can be used in strips. The ceiling below to be of metal lath and plaster not less than 29 mm thick, with pugging on the ceiling such that the combined mass per unit area of the floor, ceiling and pugging is not less than 120 kg/m^2. This construction will only give values for $D_{nT,w}$ of 50 to 53 dB, and a value for $L'_{nT,w}$ of 75 dB d) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard laid on battens running parallel to the joists and supported on 25 mm thick mineral wool of about 90 kg/m^3 to 140 kg/m^3 density; 100 mm of fibre absorbent (as used for insulation in roof spaces) laid between the joists on top of the plasterboard ceiling[1)] e) A floor consisting of 18 mm tongued and grooved chipboard on 19 mm plasterboard floating on a 25 mm thick mineral wool layer of about 60 kg/m^3 to 80 kg/m^3 density; this on a 12.5 mm plywood platform; 100 mm of fibre absorbent laid between the joists on top of the plasterboard ceiling[1)]
ii)	$D_{nT,w}$ = 32 to 36 $L'_{nT,w}$ = 80 to 85	Timber joist floor consisting of 22 mm tongued and grooved floor boarding or equivalent fixed directly to floor joists. Ceiling of 12.5 mm plasterboard and skim with no floor covering

NOTES

1 Construction details and workmanship are important if the levels of sound insulation indicated are to be achieved.

2 Where plasterboard is specified it is assumed that the surface mass will be at least 8.5 kg/m^3 for 12.5 mm thick board, and at least 14.5 kg/m^2 for 19 mm thick board. If less dense plasterboard is used, the thickness should be increased.

[1)] In these types of floor construction, the ceiling may be 19 mm plus 12.5 mm plasterboard. It is imperative that the resilient layer is not punctured by nails.

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ANNEX G

(*Clause* 13.1)

BASIC DESIGN TECHNIQUES FOR NOISE CONTROL IN AIR CONDITIONING, HEATING AND MECHANICAL VENTILATION SYSTEM

G-1 When selecting fans and other related mechanical equipment and when designing air distribution systems to minimise the sound transmitted from different components to the occupied spaces that they serve, the following recommendations should be considered:

a) Design the air distribution system to minimise flow resistance and turbulence. High flow resistance increases the required fan pressure, which results in higher noise being generated by the fan. Turbulence increases the flow noise generated by duct fittings and dampers in the air distribution system, especially at low frequencies.

b) Select a fan to operate as near as possible to its rated peak efficiency when handling the required quantity of air and static pressure. Also, select a fan that generates the lowest possible noise but still meets the required design conditions for which it is selected. Using an oversized or undersized fan that does not operate at or near rated peak efficiency may result in substantially higher noise levels.

c) Design duct connections at both the fan inlet and outlet for uniform and straight air flow. Failure to do this may result in severe turbulence at the fan inlet and outlet and in flow separation at the fan blades. Both of these may significantly increase the noise generated by the fan.

d) Select duct silencers that do not significantly increase the required fan total static pressure.

e) Place fan-powered mixing boxes associated with variable volume air distribution systems away from noise-sensitive areas.

f) Minimise flow-generated noise by elbows or duct branch take-offs, whenever possible, by locating them at least four to five duct diameters from each other. For high velocity systems, it may be necessary to increase this distance to up to ten duct diameters in critical noise areas.

g) Keep airflow velocity in the duct as low as possible (7.5 m/s or less) near critical noise areas by expanding the duct cross-section area. However, do not exceed an included expansion angle of greater than 15°. Flow separation, resulting from expansion angles greater than 15°, may produce rumble noise. Expanding the duct cross-section area will reduce potential flow noise associated with turbulence in these areas.

h) Use turning vanes in large 90° rectangular elbows and branch takeoffs. This provides a smoother transmission in which the air can change flow direction, thus reducing turbulence.

j) Place grilles, diffusers and registers into occupied spaces as far as possible from elbows and branch takeoffs.

k) Minimise the use of volume dampers near grills, diffusers and registers in acoustically critical situations.

m) Vibration isolates all vibrating reciprocating and rotating equipment if mechanical equipment is located on upper floors or is roof-mounted. Also, it is usually necessary to vibration isolate the mechanical equipment that is located in the basement of a building as well as piping supported from the ceiling slab of a basement, directly below tenant space. It may be necessary to use flexible piping connectors and flexible electrical conduit between rotating or reciprocating equipment and pipes and ducts that are connected to the equipment.

n) Vibration isolates ducts and pipes, using spring and/or neoprene hangers for at least the first 15m from the vibration-isolated equipment.

p) Use barriers near outdoor equipment when noise associated with the equipment will disturb adjacent properties if barriers are not used. In normal practice, barriers typically produce no more than 15 dB of sound attenuation in the mid-frequency range.

q) Table 17 lists several common sound sources associated with mechanical equipment noise. Anticipated sound transmission paths and recommended noise reduction methods are also listed in the Table 18. Airborne and/or structure-borne sound can follow any or all of the transmission paths associated with a specified sound source.

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Table 17 Sound Sources, Transmission Paths and Recommended Noise Reduction Methods

[*Clause* G-1(q)]

Sl No.	Sound Source	Path No. (*see* Table 18)
(1)	(2)	(3)
i)	Circulating fans, grilles, registers, diffusers, unitary equipment in room	1
ii)	Induction coil and fan-powered VAV mixing units	1, 2
iii)	Unitary equipment located outside of room served; remotely located air handling equipment, such as fans, blowers, dampers, duct fitting, and air washers	2, 3
iv)	Compressors, pumps, and other reciprocating and rotating equipment (excluding air handling equipment)	4, 5, 6
v)	Cooling towers; air-cooled condensers	4, 5, 6, 7
vi)	Exhaust fans; window air conditioners	7, 8
vii)	Sound transmission between rooms	9, 10

Table 18 Sound Transmission Paths and Recommended Noise Reduction Methods

[*Clause* G-1(q) *and Table* 17]

Sl No.	Path No.	Transmission Paths	Noise Reduction Methods
(1)	(2)	(3)	(4)
i)	1	Direct sound radiated from sound sources to ear Reflected sound from walls, ceiling and floor	Direct sound can be controlled only by selecting quiet equipment Reflected sound is controlled by adding sound absorption to the room and to equipment location
ii)	2	Air and structure-borne sound radiated from casings and through walls of ducts and plenums is transmitted through walls and ceiling into rooms	Design duct and fittings for low turbulence; locate high velocity ducts in noncritical areas; isolate ducts and sound plenums from structure with neoprene or spring hangers
iii)	3	Airborne sound radiated through supply and return air ducts to diffusers in room and then to listener by Path 1	Select fans for minimum sound power; use ducts lined with sound-absorbing material; use duct silencers or sound plenums in supply and return air ducts
iv)	4	Noise transmitted through equipment room walls and floors to adjacent rooms	Locate equipment rooms away from critical areas; use masonry blocks or concrete for equipment room walls and floor
v)	5	Vibration transmitted *via* building structure to adjacent walls and ceilings, from which it radiates as noise into room by Path 1	Mount all machines on properly designed vibration isolators; design mechanical equipment room for dynamic loads; balance rotating and reciprocating equipment
vi)	6	Vibration transmission along pipes and duct walls	Isolate pipe and ducts from structure with neoprene or spring hangers; install flexible connectors between pipes, ducts, and vibrating machines
vii)	7	Noise radiated to outside enters room windows	Locate equipment away from critical areas; use barriers and covers to interrupt noise paths; select quiet equipment
vii)	8	Inside noise follows Path 1	Select quiet equipment
ix)	9	Noise transmitted to an air diffusers in a room, into a duct, and out through an air diffuser in another room	Design and install duct attenuation to match transmission loss of wall between rooms
x)	10	Sound transmission through, over, and around room partition	Extend partition to ceiling slab and tightly seal all around; seal all pipe, conduit, duct and other partition penetrations

ANNEX H

(*Clause* 13.2)

SUGGESTED EQUIPMENT NOISE DATA SHEET

H-1 It is recommended that an equipment noise data sheet be furnished to intending bidders of mechanical equipment such as air conditioning, heating and mechanical ventilation machinery or diesel generating units specifying noise requirements at the time of request for quotation. Following is a sample noise data sheet suggested for the purpose:

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SAMPLE OF EQUIPMENT NOISE DATA SHEET FOR NOISE SPECIFICATION TO BE SENT TO SUPPLIERS

Equipment Description_____ Type_____ Item No. _____

Octave-Band Centre Frequency Hz	Desired Sound Pressure Level L_p	Supplier to Complete		
		Actual	Special Design	Special Noise Control Measures Recommended
(1)	(2)	(3)	(4)	(5)
63				
125				
250				
500				
1 000				
2 000				
4 000				
8 000				

NOTES

1 The measurements of SPL shall be at a distance of 1.0 m from the equipment and 1.5 m above grade or floor. The measurement method shall be described and the point of maximum levels furnished.

2 Complete column 3 for actual levels of standard equipment.

3 Complete column 4 for special design for low noise (if such alternative is available).

4 Complete column 5 for noise control measures such as enclosure.

5 Indicate if the equipment meets the specified noise levels without modification (Yes/No).

6 If no, additional costs required :

For Column 4 _____

For Column 5 _____

It will be observed from the cols 3, 4 and 5 that the buyer would get quotation for supply of standard equipment at a price P-1, whose noise characteristics would be as per col 3. Column 4 would indicate acoustical performance for a special design at a price P-2. Column 5 would indicate the acoustical performance if the owners were to provide special noise control measures for the installation (whose broad details and approximate estimated cost is also furnished by the vendor).

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in this Code. In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	11050 (Part 1) : 1984	Rating of sound insulation in buildings and of building elements : Part 1 Airborne sound insulation in buildings and of interior building elements
(2)	4954 : 1968	Recommendations for noise abatement in town planning
(3)	2526 : 1963	Code of practice for acoustical design of auditoriums and conference halls
(4)	11050 (Part 1) : 1984	Rating of sound insulation in buildings and of building elements : Part 1 Airborne sound insulation in buildings and of interior building elements
	11050 (Part 2) : 1984	Rating of sound insulation in buildings and of building elements : Part 2 Impact sound insulation

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts, Escalators and Moving Walks:

5A Lifts

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 8/Subsection 5A) deals with the installation requirements for planning, design, installation, operation, maintenance and inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) so as to ensure safe movement of people with satisfactory performance.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005. This Section covers the requirements for installation and maintenance of lifts and escalators in buildings. This Section shall be read with Part 4 'Fire and Life Safety' of the Code from fire safety requirements point of view. The major changes in the first revision of 1983 were addition of outline dimensions of different types of lifts and requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

The significant changes incorporated in the last revision in 2005 included addition of new clauses/recommendations on Building Management System; addition of new clauses on fireman's lift, infrared light curtain safety and Braille button for blind people and updation of provisions as per the revised standards on lifts on which this section was based.

As a result of experience gained since implementation of 2005 version of the Code and feedback received as well as revisions of Indian Standards on which this Section was based, a need was felt to revise this Section. In this revision, the erstwhile Section 5 on Lifts and Escalators has been divided into two subsections namely:

5A Installation of Lifts

5B Installation of Escalators and Moving Walks

This revision has, therefore, been formulated to take care of these. The significant changes incorporated in this revision (Subsection 5A) include the following:

a) Definitions of a number of terms relating to performance measurement of lifts, and seismic and maintenance aspects of lifts have been included, apart from other modifications in the terminology clause.
b) Requirements for high speed lifts and lifts for tall buildings including elaboration of lifts for fire-fighting and emergency evacuation have been included.
c) Considerations for machine room less (MRL) lifts have been covered.
d) The clause on preliminary design has been expanded to cover the requirements for various building functions.
e) Provisions related to destination control system have been included.
f) Various special requirements have been detailed in a separate clause.
g) Provisions for seismic resistance aspects in lifts have been included.
h) Performance measurements for lifts have been included.
j) A new clause on operation and maintenance of lifts has been included.
k) The provisions have been updated as per the revised Indian Standards on lifts on which this Subsection is based.
m) The list of Indian Standards as good practices/accepted standards has been updated.

The information contained in this Section is largely based on the following Indian Standards:

IS No.	*Title*
14665 (Part 1) : 2000	Electric Traction Lifts Guidelines for outline dimensions of passenger, goods, service and hospital lifts
(Part 2/Sections 1 and 2 : 2000	Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts

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IS No.	*Title*
(Part 3/Sections 1 and 2) : 2000	Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
(Part 4/ Sections 1 to 9) : 2001	Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(Part 5 : 1999)	Inspection manual
IS 14671 : 1999	Code of Practice for installation and maintenance of hydraulic lifts
IS 15330 : 2003	Code of Practice for installation and maintenance of lifts for handicapped persons
IS 15785 : 2007	Code of Practice for installation and maintenance of lift without conventional machine rooms

Assistance has also been derived from the following publications for the formulation of this Subsection:

EN 81-20 : 2014	Safety rules for the construction and installation of lifts — Lifts for the transport of persons and goods — Part 20: Passenger and goods passenger lifts
EN 81-77 : 2013	Safety rules for the construction and installations of lifts. Particular applications for passenger and goods passenger lifts. Lifts subject to seismic conditions
EN 81-50 : 2014	Safety rules for the construction and installation of lifts — Examinations and tests — Part 50: Design rules, calculations, examinations and tests of lift components
ISO 18738-1 : 2012	Measurement of ride quality — Part 1: Lifts (elevators)
ISO 7465 : 2007	Passenger lifts and service lifts — Guide rails for lift cars and counterweights — T-type
ISO/TS 18870 : 2014	Lifts (elevators) — Requirements for lifts used to assist in building evacuation
ISO 3008-2 : 2014	Fire-resistance tests — Part 2: Lift landing door assemblies
ISO 3864-1 : 2011	Graphical symbols — Safety colours and safety signs — Part 1: Design principles for safety signs and safety markings
ISO 4190-1 : 2010	Lift (Elevator) installation — Part 1: Class I, II, III and VI lifts
ISO 4190-5 : 2006	Lift (Elevator) installation — Part 5: Control devices, signals and additional fittings
CIBSE Guide D: 2015	Transportation Systems in Buildings 2015, The Chartered Institution of Building Services Engineers, London, U.K.
CTBUH 2004	Emergency Evacuation: Elevator Systems Guidelines, Council on Tall Buildings and Urban Habitat, Illinois, USA

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts, Escalators and Moving Walks: 5A Lifts

1 SCOPE

1.1 This Code (Part 8/Subsection 5A) covers the requirements for planning, design, installation, operation, maintenance and inspection of lifts (passenger lifts, goods lifts, hospital lifts, service lifts and dumb waiter) so as to ensure safe movement of people with satisfactory performance.

1.2 This Subsection gives information that should be exchanged among the architect/engineer, the consulting engineer and the lift manufacturer from the stage of planning to installation including maintenance.

NOTE — The provisions given in this Subsection are primarily for electric traction lifts; however, most of these provisions are also applicable to hydraulic lifts {*see* good practice [8-5A(1)]}.

2 TERMINOLOGY

For the purpose of this subsection, the following definitions shall apply.

2.1 General Terms Relating to Lifts

2.1.1 *Automatic Rescue Device (ARD)* — A device meant to bring a lift stuck between floors due to loss of power, to the nearest landing level in either direction and open the doors in order to allow trapped passengers to be evacuated. Such a device may use some form of internal auxiliary power source for such purpose, complying with all the safety requirements of the lift during normal run. The speed of travel is usually lower than the normal speed. On reaching the level, in case of manual door lifts, the device shall allow the door to be opened and in case of power operated door lifts the device shall automatically open the door.

2.1.2 *Bottom Car Run-by* — The distance between the car buffer striker plate and the striking surface of the car buffer when the car is in level with the bottom terminal landing.

2.1.3 *Bottom Counterweight Run-by* — The distance between the counter weight buffer striker plate and the striking surface of the counterweight buffer when the car is in level with the top terminal landing.

2.1.4 *Buffer* — A device designed to stop a descending car or counter weight beyond its normal limit of travel by storing or by absorbing and dissipating the kinetic energy of the car or counterweight.

2.1.4.1 *Oil buffer* — A buffer using oil as a medium which absorbs and dissipates the kinetic energy of the descending car or counterweight.

2.1.4.1.1 *Oil buffer stroke* — The oil displacing movement of the buffer plunger or piston, excluding the travel of the buffer plunger accelerating device.

2.1.4.2 *Spring buffer* — A buffer which stores in a spring the kinetic energy of the descending car or counterweight.

2.1.4.2.1 *Spring buffer load rating* — The load required to compress the spring by an amount equal to its stroke.

2.1.4.2.2 *Spring buffer stroke* — The distance, the contact end of the spring can move under a compressive load until the spring is compressed solid.

2.1.5 *Call Indicator* — A visual and audible device in the car to indicate to the attendant the lift landings from which calls have been made.

2.1.6 *Car Bodywork* — The enclosing bodywork of the lift car which comprises the sides and roof and is built upon the car platform.

2.1.7 *Car Door Electric Contact* — An electric device, the function of which is to prevent operation of the driving machine by the normal operating device of the lift unless the car door is in the closed position.

2.1.8 *Car Frame* — The supporting frame or sling to which the platform of the lift car, its safety gear, guide shoes and suspension ropes are attached.

2.1.9 *Car Platform* — The part of the lift car which forms the floor and directly supports the load.

2.1.10 *Clearance*

2.1.10.1 *Bottom car clearance* — The clear vertical distance from the pit floor to the lowest structural or mechanical part, equipment or device installed beneath the car platform, except the guide shoes, rollers, safety jaw blocks and platform apron or guard located within 300 mm, measured horizontally from the sides of the car platform when the car rests on its fully compressed buffers.

2.1.10.2 *Top car clearance* — The shortest vertical distance between the top of the car crosshead, or between the top of the car where no crosshead is

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provided, and the nearest part of the overhead structure or any other obstruction when the car floor is level with the top terminal landing.

2.1.10.3 *Top counterweight clearance* — The shortest vertical distance between any part of the counterweight structure and the nearest part of the overhead structure or any other obstruction when the car floor is level with the bottom terminal landing.

2.1.11 *Control* — The system governing starting, stopping, direction of motion, acceleration, speed and retardation of moving member.

2.1.11.1 *Single-speed alternating current control* — A control for a driving machine induction motor which is arranged to run at a single-speed.

2.1.11.2 *Two-speed alternating current control* — A control for a two-speed driving machine induction motor which is arranged to run at two different synchronous speeds either by pole changing of a single motor or by two different armatures.

2.1.11.3 *Rheostatic control* — A system of control which is accomplished by varying resistance or reactance or both in the armature or field circuit or both of the driving machine motor.

2.1.11.4 *Variable voltage motor control (generator field control)* — A system of control which is accomplished by the use of an individual generator for each lift wherein the voltage applied to the driving machine motor is adjusted by varying the strength and direction of the generator field.

2.1.11.5 *Electronic devices* — A system of control which is accomplished by the use of electronic devices for driving the lift motor at variable speed.

2.1.11.6 *Alternating current variable voltage (ACVV) control* — A system of speed control which is accomplished by varying the driving and braking torque by way of voltage variation of the power supply to the driving machine induction motor.

2.1.11.7 *Alternating current variable voltage variable frequency (ACVVVF) control* — A system of speed control which is accomplished by varying the voltage and frequency of the power supply to the driving machine induction motor.

2.1.11.8 *Solid-state d.c. variable voltage control* — A solid-state system of speed control which is accomplished by varying the voltage and direction of the power supply to the armature of driving machine d.c. motor.

2.1.12 *Counterweight* — A weight or series of weights to counterbalance the weight of the lift car and part of the rated load.

2.1.13 *Deflector Sheave* — An idler pulley used to change the direction of a rope lead.

2.1.14 *Door (Lift Landing Door and Lift Car Door)*

2.1.14.1 *Door, centre opening sliding* — A door which slides horizontally and consists of two or more panels which open from the centre and are usually so interconnected that they move simultaneously.

2.1.14.2 *Door, mid-bar collapsible* — A collapsible door with vertical bars mounted between the normal vertical members.

2.1.14.3 *Door, multi-panel* — A door arrangement whereby more than one panel is used such that the panels are connected together and can slide over one another by which means the clear opening can be maximized for a given shaft width. Multipanels are used in centre opening and two speed sliding doors.

2.1.14.4 *Door, single slide* — A single panel door which slides horizontally.

2.1.14.5 *Door, two speed sliding* — A door which slides horizontally and consists of two or more panels, one of which moves at twice the speed of the other.

2.1.14.6 *Door, vertical bi-parting* — A door which slides vertically and consists of two panels or sets of panels that move away from each other to open and are so interconnected that they move simultaneously.

2.1.14.7 *Door, vertical lifting* — A single panel door, which slides in the same plane vertically up to open.

2.1.14.8 *Door, swing* — A swinging type single panel door which is opened manually and closed by means of a door closer when released.

2.1.15 *Door Closer* — A device which automatically closes a manually opened door.

2.1.16 *Door Operator* — A power-operated device for opening and closing doors.

2.1.17 *Dumb Waiter* — A lift with a car which moves in guides in a vertical direction; has a net floor area not exceeding 1 m^2 , total inside height of 1.2 m, whether or not provided with fixed or removable shelves; has a capacity not exceeding 250 kg and is exclusively used for carrying materials and shall not carry any person.

2.1.18 *Electrical and Mechanical Interlock* — A device provided to prevent simultaneous operation of both up and down relays or power contactors.

2.1.19 *Electro-Mechanical Lock* — A device which combines in one unit, electrical contact and a mechanical lock jointly used for the landing and/or car doors.

2.1.20 *Floor Levelling Switch* — A switch for bringing

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the car to level at slow speed in case of double speed or variable speed machines.

2.1.21 *Floor Selector* — A mechanism forming a part of the control equipment, in certain automatic lifts, designed to operate controls which cause the lift car to stop at the required landings.

2.1.22 *Floor Stopping Switch* — A switch or combination of switches arranged to bring the car to rest automatically at or near any pre-selected landing.

2.1.23 *Geared Machine* — A machine in which the power is transmitted to the sheave through worm and worm wheel or spur reduction gearing.

2.1.24 *Gearless Machine* — A lift machine in which the motive power is transmitted to the driving sheave from the motor without intermediate reduction gearing and has the brake drum mounted directly on the motor shaft.

2.1.25 *Goods Lift* — A lift designed primarily for the transport of goods, but which may carry a lift attendant or other personnel necessary for the loading or unloading of goods.

2.1.26 *Guide Rails* — The members used to guide the movement of a lift car or counterweight in a vertical direction.

2.1.27 *Guide Rails Fixing* — The complete assembly comprising the guide rails bracket and its fastenings.

2.1.28 *Guide Shoe* — An attachment to the car frame or counterweight for the purpose of guiding the lift car or counter weight frame.

2.1.29 *Hoisting Beam* — A beam, mounted immediately below the machine room ceiling/machinery space ceiling, to which lifting tackle can be fixed for raising or lowering parts of the lift machine.

2.1.30 *Hospital Lift* — A lift normally installed in a hospital, dispensary or clinic and designed to accommodate one bed or stretcher along its depth, with sufficient space around to carry a minimum of three attendants in addition to the lift operator.

2.1.31 *Landing Call Push* — A push button fitted at a lift landing, either for calling the lift car, or for actuating the call indicator.

2.1.32 *Landing Door* — The hinged or sliding portion of a lift well enclosure, controlling access to a lift car at a lift landing.

2.1.33 *Landing Zone* — A space extending from a horizontal plane 400 mm below a landing level to a plane 400 mm above the landing level.

2.1.34 *Levelling Devices*

2.1.34.1 *Levelling device, lift car* — Any mechanism which either automatically or under the control of the operator, moves the car within the levelling zone towards the landing only, and automatically stops it at the landing.

2.1.34.2 *Levelling device, one way automatic* — A device which corrects the car level only in case of under run of the car but will not maintain the level during loading and unloading.

2.1.34.3 *Levelling device, two-way automatic maintaining* — A device which corrects the car level on both under run and over-run and maintains the level during loading and unloading.

2.1.34.4 *Levelling device, two way automatic non-maintaining* — A device which corrects the car level on both under run and over run but will not maintain the level during loading and unloading.

2.1.35 *Levelling Zone* — The limited distance above or below a lift landing within which the levelling device may cause movement of the car towards the landing.

2.1.36 *Lift* — An appliance designed to transport persons or materials between two or more levels in a vertical or substantially vertical direction by means of a guided car. The word ‘elevator’ is also synonymously used for ‘lift’.

2.1.37 *Lift Car* — The load carrying unit with its floor or platform, enclosing bodywork, and car door.

2.1.38 *Lift Landing* — That portion of a building or structure used for discharge of passengers or goods or both into or from a lift car.

2.1.39 *Lift Machine* — The part of the lift equipment comprising the motor and the control gear therewith, reduction gear (if any), brake(s) and winding drum or sheave, by which the lift car is raised or lowered.

2.1.40 *Lift Pit* — The space in the lift well below the level of the lowest lift landing served.

2.1.41 *Lift Well* — The unobstructed space within an enclosure provided for the vertical movement of the lift car(s) and any counterweight(s), including the lift pit and the space for top clearance.

2.1.42 *Lift Well Enclosure* — Any structure which separates the lift well from its surroundings.

2.1.43 *Operation* — The method of actuating the control of lift machine.

2.1.43.1 *Automatic operation* — A method of operation in which by a momentary activation of a call button the lift car is set in motion and caused to stop automatically at any required lift landing.

2.1.43.2 *Non-selective collective automatic operation* — Automatic operation by means of one

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button in the car for each landing level served and one button at each landing, wherein all stops registered by the momentary actuation of landing or car buttons are made irrespective of the number of buttons actuated or of the sequence in which the buttons are actuated. With this type of operation, the car stops at all landings for which buttons have been actuated making the stops in the order in which the landings are reached after the buttons have been actuated but irrespective of its direction of travel.

2.1.43.3 *Selective collective automatic operation* — Automatic operation by means of one button in the car for each landing level served and by up and down buttons at the landings, wherein all stops registered by the momentary actuation of the car made as defined under non-selective collective automatic operation, but wherein the stops registered by the momentary actuation of the landing buttons are made in the order in which the landings are reached in each direction of travel after the buttons have been actuated. With this type of operation, all 'up' landing calls are answered when the car is travelling in the up direction and all 'down' landing calls are answered when the car is travelling in the down direction, except in the case of the uppermost or lowermost calls which are answered as soon as they are reached irrespective of the direction of travel of the car.

2.1.43.4 *Single automatic operation* — Automatic operation by means of one button in the car for each landing level served and one button at each landing so arranged that if any car or landing button has been actuated, the actuation of any other car or landing operation button will have no effect on the movement of the car until the response to the first button has been completed.

2.1.43.5 *Group automatic operation* — Automatic operation of two or more non-attendant lifts equipped with power-operated car and landing doors. The operation of the cars is coordinated by a supervisory operation system including automatic dispatching means whereby selected cars at designated dispatching points automatically close their doors and proceed on their trips in a regulated manner.

Typically, it includes one button in each car for each floor served and up and down buttons at each landing (single buttons at terminal landings). The stops set up by the momentary actuation of the car buttons are made automatically in succession as a car reaches the corresponding landings irrespective of its direction of travel or the sequence in which the buttons are actuated. The stops set up by the momentary actuation of the landing buttons may be accomplished by any lift in the group, and are made automatically by the first available car that approaches the landing in the corresponding direction.

2.1.43.6 *Car switch operation* — Method of operation by which the movement of lift car is directly under the operation of the attendant by means of a handle.

2.1.43.7 *Signal operation* — Same as collective operation, except that the closing of the door is initiated by the attendant.

2.1.43.8 *Double button (continuous pressure) operation* — Operation by means of buttons or switches in the car and at the landings any of which may be used to control the movement of the car as long as the button or switch is manually pressed in the actuating position.

2.1.44 *Operating Device* — A car switch, push button or other device employed to actuate the control.

2.1.45 *Overhead Beams* — The members, usually of steel, which immediately support the lift equipment at the top of the lift well.

2.1.46 *Over Speed Governor* — An automatic device which brings the lift car and/or counter weight to rest by operating the safety gear in the event of the speed in a descending direction exceeding a predetermined limit.

2.1.47 *Passenger Lift* — A lift designed for the transport of passengers.

2.1.48 *Position and/or Direction Indicator* — A device which indicates on the lift landing or in the lift car or both, the position of the car in the lift well or the direction in which the lift car is travelling or both.

2.1.49 *Rated Load (Lift)* — The maximum load for which the lift car is designed and installed to carry safely at its rated speed.

2.1.50 *Rated Speed (Lift)* — The mean of the maximum speed attained by the lift car in the upward and downward direction with rated load in the lift car.

2.1.51 *Retiring Cam* — A device which prevents the landing doors from being unlocked by the lift car unless it stops at a landing.

2.1.52 *Roping Multiple* — A system of roping where, in order to obtain a multiplying factor from the machine to the car, multiple falls of rope are run around sheave on the car or counterweight or both. It includes roping arrangement of 2 to 1, 3 to 1, etc.

2.1.53 *Safety Gear* — A mechanical device attached to the lift car or counterweight or both, designed to stop and to hold the car or counterweight to the guides in the event of free fall, or, if governor operated, of over-speed in the descending direction. Any anticipated impact force shall be added in the general drawing or layout drawing.

2.1.54 *Service Lift* — A passenger cum goods lift meant to carry goods along with people.

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NOTE — Typically in an office building this may be required to carry food or stationeries, in a residential building to carry luggage or accommodate a stretcher and in a hotel to be used for food trolleys or baggage. There is a need in such lifts, to take care of the dimensions of the car and the door clear opening in line with the type of goods that may have to be carried based on mutual discussion between the supplier and the customer. Also, such lifts shall have buffer railings in the car at suitable height to prevent damage to the car panels when the goods are transported. Typically such lifts, if provided with an automatic door, may use some means to detect trolleys and stretcher movement in advance to protect the doors against damage. The car floor load calculations and car area of such a lift is as in the case of a passenger lift except that these are not meant to carry heavy concentrated loads.

2.1.55 *Sheave* — A rope wheel, the rim of which is grooved to receive the suspension ropes but to which the ropes are not rigidly attached and by means of which power is transmitted from the lift machine to the suspension ropes.

2.1.56 *Slack Rope Switch* — Switch provided to open the control circuit in case of slackening of rope(s).

2.1.57 *Suspension Ropes* — The ropes by which the car and counter weight are suspended.

2.1.58 *Terminal Slow-Down Switch* — A switch when actuated shall compulsorily cut off the high speed and switch on the circuitry to run the lift in levelling speed before reaching on terminal landings.

2.1.59 *Terminal Stopping Switch Normal* — Switch for cutting off all the energizing current in case of car travelling beyond the top or bottom terminal landing or a switch that cuts off the energizing current so as to bring the car to a stop at the top or bottom terminal landing level in the respective direction of travel.

2.1.60 *Terminal Stopping Device Final* — A device which automatically causes the power to be removed from an electric lift driving machine motor and brake, independent of the functioning of the normal terminal stopping device, the operating device or any emergency terminal stopping device, after the car has passed a terminal landing.

2.1.61 *Total Headroom* — The vertical distance from the level of the top lift landing to the bottom of the machine room slab.

2.1.62 *Travel* — The vertical distance between the bottommost and topmost lift landings served by the lift.

2.2 Terms Relating to Performance Requirements for Lifts

2.2.1 *A95* — Values of acceleration or vibration within defined boundaries or limits, in which 95 percent of observed values fall. This value is used statistically to estimate typical levels.

2.2.2 *Acceleration* — Rate of change of z-axis velocity, attributed to lift motion control.

2.2.3 *Axis of Measurement* — Orthogonal reference axes for the measurements as follows:

a) *X-axis* — Axis perpendicular to the plane of the car front door (that is back to front),

b) *Y-axis* — Axis perpendicular to X and Z (that is side to side), and

c) *Z-axis* — Axis perpendicular to the car floor (that is vertical).

2.2.4 *Equivalent Sound Pressure Level* (L_{Aeq}) — Average A-weighted sound pressure level, using frequency weighting A and time weighing 'fast', determined within defined boundaries.

2.2.5 *Jerk* — Rate of change of z-axis acceleration, attributed to lift motion control. It is expressed in metre per second cube (m/s^3).

NOTE — The passenger perception of vertical ride quality during jerk is represented by the assessment of vertical vibration during non-constant acceleration.

2.2.6 *Lift Ride Quality* — Sound levels in the car, and vibration of the car floor, relevant to passenger perception, associated with lift motion.

2.2.7 *Peak to Peak Vibration Levels* — Sum of the magnitudes of two peaks of opposite sign separated by a single zero crossing.

2.2.8 *Sound* — A-weighted sound pressure level measured in decibels (dB).

2.2.9 *Sound Pressure Level* ($L_{p,A}$) — Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure measured (p_A) to the square of the reference sound pressure (p_0).

$$L_{p,A} = 10 \log (p_A^2/p_0^2) \text{ dBA}$$

NOTE — The reference sound pressure level (p_0) is 20 μPa (2×10^{-5} Pa). The measured sound pressure, p_A, is in Pascals, using frequency weighting A.

2.2.10 *V95* — Value of velocity within defined boundaries or limits, in which 95 percent of observed values fall. This value is used statistically to estimate typical levels.

2.2.11 *Velocity* — Rate of change of *z*-axis displacement, attributed to lift motion control.

2.2.12 *Vibration* — Variation with time of the magnitude of acceleration, when the magnitude is alternately greater and smaller than a reference level. It is expressed in m/s^2.

2.3 Terms Relating to Planning and Design of Lifts

2.3.1 *Door Closing Time* (t_c) — Time period measured from the instant that car doors start to close until the doors are locked.

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2.3.2 *Door Opening Time* (t_o) — Time period measured from the instant that car doors start to open until they are open 800 mm.

2.3.3 *Door-to-Door Time* (*T*) — Time period measured from the instant that car doors start to close to the instant that the car doors are open 800 mm at the next adjacent floor.

2.3.4 *Handling Capacity* (*HC*) — The number of passengers that a lift system can theoretically transport during the up-peak traffic condition with car occupancy of 80 percent of the actual capacity expressed as a percent of the total building population.

2.3.5 *Interval* (*INT*) — Time period between successive car arrivals at the main terminal floor with cars loaded to any value.

2.3.6 *Nominal Travel Time (NTT)* — The nominal travel time is defined as the time it would take to run a distance of the total travel at the rated speed of the lift without taking into account the acceleration and deceleration of the car or the intermediate stops of real runs.

2.3.7 *Passenger Arrival Rate* — Percentage of a building's population arriving within a 5 min period.

2.3.8 *Passenger Average Transfer Time* (t_p) — Average period of time required for a single passenger to enter or leave the lift car.

2.3.9 *Passenger Average Waiting Time* (*AWT*) — Average period of time from the instant a passenger registers a landing call or joins a queue, until the responding lift begins to open its doors at the boarding floor. AWT is not the same as INT.

2.3.10 *Round Trip Time* (*RTT*) — The average time taken by a single lift to make a trip from the main terminal back to the main terminal, starting from the time the car doors open at the main terminal until the car doors re-open at the main terminal after serving all demand along the way.

2.3.11 *Single Floor Flight Time* (t_{fl}) — Period of time measured from the instant that the car doors are locked until the lift is level at the next adjacent floor.

2.3.12 *Single Floor Transit Time* (t_v) — Period of time required to transit two adjacent floors at rated speed.

2.3.13 *Sky Lobby* — A sky lobby is the main floor for local groups in the upper part of a very tall building.

2.4 Terms Relating to Seismic Operation of Lifts

2.4.1 *Design Acceleration* (a_d) — The horizontal acceleration to be used for calculation of forces (moments acting on lift systems and arising from seismic events).

NOTE — The value of (a_d) shall be obtained by the lift manufacturer from the building engineer/structural engineer.

2.4.2 *Normal Operation* — Operation mode in which the lift performs when not in seismic mode or in seismic stand-by mode.

2.4.3 *Retaining Device* — Mechanical device securely fixed to a structural member of the lift car, counterweight frame designed to retain the lift car and counterweight within its guide rails during seismic activity.

2.4.4 *Seismic Mode* — Special mode in which the lift operates after detection of seismic trigger level.

2.4.5 *Seismic Stand-By Mode* — Special mode in which the lift operates after detection of primary earthquake wave without the activation of the seismic detection system.

2.4.6 *Seismic Trigger Level* — Seismic acceleration which is used to activate a seismic detection system.

2.4.7 *Snag Point* — The point of interference between flexible elements (for example, ropes, chains, travelling cable, etc) and fixed elements (for example, by guide rail brackets, guide rail clip bolts, fishplates, vanes, and similar devices).

2.5 Terms Related to Maintenance of Lifts

2.5.1 *Competent Maintenance Person* — Designated person, suitably trained, qualified by knowledge and practical experience, provided with necessary instructions and supported within their maintenance organization to enable the required maintenance operations to be safely carried out.

2.5.2 *Installation* — Completely installed passenger lift or good passenger lift or accessible goods only lift or service lift.

2.5.3 *Installer* — Natural or legal person who takes responsibility for the design, manufacture, installation and placing on the market of lifts.

2.5.4 *Maintenance Organization* — Company or part of company where competent maintenance person(s) carry out maintenance operation on behalf of the owner of the installation.

3 GENERAL

3.1 Conformity with Lifts Act and Rules

3.1.1 The installation shall generally be carried out in conformity with *Lift Acts* and *Rules*, wherever they are in force.

3.1.2 It is the responsibility of the owner of the premises where the lift will be installed, to obtain necessary permission from the Authority before and

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after the installation of lifts and for subsequent operation of lifts.

3.1.3 A licence for public use is a safety provision, issued by state authorities under *Lifts Acts* and *rules* wherever they are in force, and shall be obtained as per the laid down statutory requirement.

3.2 Conformity with *The Electricity Act,* 2003 and Rules/Regulations Thereunder

All electrical work in connection with installation of lifts shall be carried out in accordance with the provisions of *The Indian Electricity Act*, 2003 as amended up-to-date along with the rules and regulations framed thereunder and shall also comply with the other provisions of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

3.3 Conformity with Indian Standards

All materials, fittings, appliances, etc, used in electrical installation shall conform to Indian Standard specifications wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority. For detailed specification for lifts, reference shall be made to accepted standards [8-5A(2)].

3.4 Conformity to Accessibility Requirements

All lifts installed for public use shall meet the accessibility requirements in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

3.5 Conformity with Fire Regulations

The installation shall be carried out in conformity with Part 4 'Fire and Life Safety' of the Code and the state fire acts/local fire regulations, wherever they are in force.

3.6 Considerations for Selection of Lifts

The considerations for selection of lifts shall be based on the following criteria:

a) *Intended use of lift* — The number of lifts and their capacities (that is, load and speed) required for a given building shall be suitably decided to meet the intended requirement. The passenger lifts shall meet the requirements of handling capacity and waiting time for passenger, depending on the lift's expected usage and building type.

b) *System performance* — System performance criteria shall be based on building type (residential, commercial, hotel, hospital, etc).

c) *Accessibility requirements — see* **3.4**.

d) *Environmental conditions* — Lifts directly exposed to atmospheric conditions, that is, weather (for example, those meant for external applications), or any other adverse condition shall be appropriately designed and protected for that particular condition.

e) *Type of main drive for lift* — Whether electric traction, geared or gearless or hydraulic depending on speed, stops/travel height and capacity requirement.

f) *Civil engineering requirements* — Machinery location that is, machinery to be located in machine room or machinery to be kept inside lift well thereby eliminating conventional machine room.

g) *Seismic considerations* — Whether the lift is to be protected against seismic forces or whether the lift is to be rescued to a landing on detection of earthquake or both.

3.7 Maintenance

The considerations relating to maintenance shall be as follows:

a) The lift installation shall receive regular cleaning, lubrication, adjustment and adequate servicing by authorized competent persons at such intervals as per type of equipment and frequency of service demand. It is desirable and normal for the lift supplier to be entrusted with the servicing during the guarantee period of new lift.

b) In order that the lift installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the lift manufacturer and rigidly followed. The provision of a log book to record all items relating to general servicing and inspection is recommended for all lifts.

c) Any accident arising out of operation or maintenance of the lifts shall be duly reported to the authority in accordance with the rules laid down.

d) Lifts are required by statutory regulations to be examined at regular intervals as specified by lift acts, by a competent person.

e) The company entrusted with maintenance contract shall have valid licence to maintain the lifts. The persons assigned for maintenance work shall be appropriately qualified and experienced as required by *Lift Acts* and *Rules*.

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3.8 Energy Efficiency and Sustainability

Design options like space restrictions, reliability and safety, riding comfort have been the major market and technological driver. The following should be encouraged for reducing power consumption and promoting sustainability in buildings.

a) Energy efficient a.c. variable voltage variable frequency (VVVF) motor drive or equivalent. Lifts with 1-speed and 2-speed motor control are not recommended for passenger lifts because of high power consumption, poor passenger comfort and tripping hazard.

b) When the lift has answered the last call and stopped at a landing and no further landing call is registered, the car and landing doors shall close. If there is no further landing call after pre-determined period but not less than 90 s, the light and fan inside the car shall both be automatically switched off. Car lights and fan shall switch on automatically before the lift doors start to open or the lift is set in motion.

c) Under normal operating status, at least one lift car of a lift bank shall operate under a standby or sleep mode during off-peak period when the traffic demand on the vertical transportation system is low. During low demand periods, even completely shutting down one or more lifts within a group can be a good energy saving option, without compromising quality of service.

d) Where a number of lifts are installed together, their controls are interconnected to optimize their operation. By efficiently delivering passengers with the least amount of trips, starts and stops, the energy consumed is significantly reduced.

e) Energy saving LED lamps for car lighting in place of conventional lamps.

f) Gearless type machines to reduce transmission losses.

g) Improvement in total power factor of the motor drive of a lift at the isolator connecting lift to the building's electrical supply circuit.

h) Regenerative drives to recycle energy rather than wasting it as heat. The regenerated energy may be used for charging batteries, staircase lighting, lobby lighting, etc.

j) Use of high efficiency motors such as Permanent Magnet Synchronous Motors, or Induction motors having minimum efficiency class equivalent to IE2 as per accepted standard [8-5A(3)].

k) Adoption of materials and practices that are environmentally friendly and sustainable shall be promoted.

4 PLANNING AND DESIGN GUIDELINES

4.1 The planning guidelines, design considerations, and precautions to be exercised during design of passenger and goods lifts operated by electric traction are provided hereunder. Manufacturer may be consulted for other types of lifts such as hydraulic, home, automobile lifts, etc.

Design of lifts necessarily calls for coordination among various parties concerned, namely the client, the architect/engineer, the consulting engineers and the lift manufacturer. These guidelines give the information from the stage of planning till the design that should be exchanged between parties. It is essential that all the parties involved in the planning should have a clear understanding of the basis and the theory of planning. All parties involved need to recognize that it is highly impractical to correct badly planned lifts in a building as no changes can be carried out to the building core, if the number of hoist-ways is inadequate or of wrong size or wrongly positioned.

These provisions specify requirements for the architects/engineers, builders/ developers and tenderers while finalizing specification of lifts. Two basic considerations, namely, the quantity of service required and the quality of service desired, determine the number and type of lifts to be provided in a particular building. The quantity of service factor, that is, how many people might use the lift system over a defined period of time is represented by the handling capacity. The quality of service factor, that is, how well the lift system deals with its passengers is represented by passenger waiting time and lobby queuing. These factors are interrelated and depend, among other things, on the type of building and its use and on the type of occupier. Both these factors require proper study into the character of the building, extent and duration of peak periods, frequency of service required, type and method of control, type of landing doors, etc.

Figure 1 shows the flow chart to arrive at a reasonable vertical transportation solution for a building.

The adequacy of the lift group in a building is a major contributing factor to the success or failure of a building. Users of lifts would be intolerant of long queues and long waiting times. The planning and selection of the vertical transportation equipment is a specialized activity. Although the basic calculations are relatively simple, the theory on which they are based is complex. The difficulty in planning a lift installation is not only in calculating its probable performance but

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also in estimating the passenger demand and usage patterns. The architect/engineer doing the planning work should establish the lift system at a very early stage in consultation with the lift manufacturer/ consulting engineer and not after the rest of the building has been designed.

This Subsection defines the calculation approach for conventional two button dispatching and does not define calculation methods for destination control systems or hybrid systems. It also does not define an approach to simulation methods as consensus on how to apply simulation has not been established.

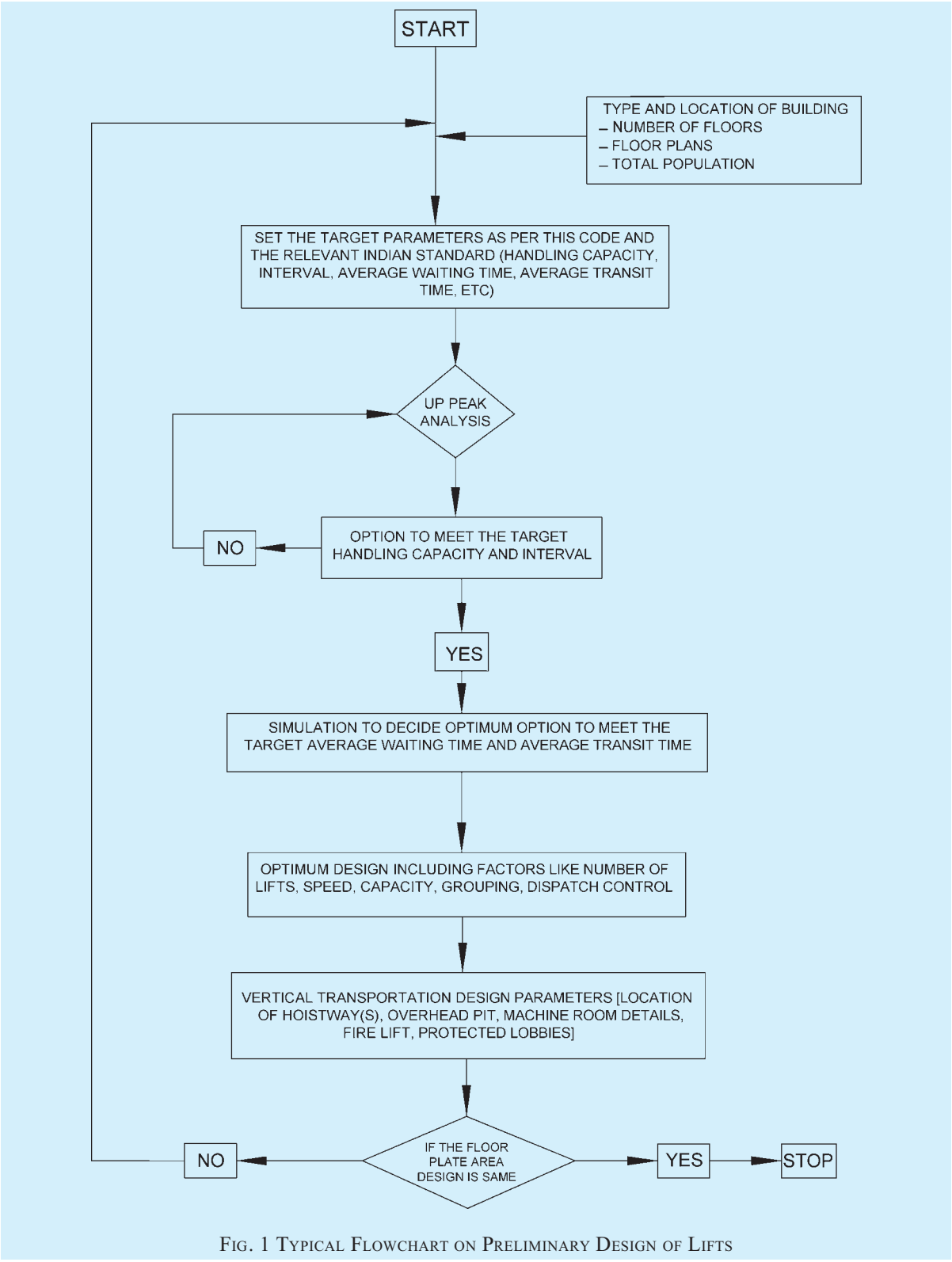


FIG. 1 TYPICAL FLOWCHART ON PRELIMINARY DESIGN OF LIFTS

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4.2 Preliminary Lift Planning

4.2.1 Two models can be used for lift traffic analysis and design:

a) The first model uses a calculation method based on mathematical formulae. This classical model uses the pure up-peak condition as this provides a well-defined, simple traffic pattern amenable to mathematical analysis. These calculations can be carried out manually, using a spreadsheet or by using computer based programme.

b) The second model is based on discrete digital simulation of the movement of lifts in a building and the passenger dynamics. This simulation model allows very complex situations to be analyzed and is generally capable of better evaluations. However, simulation approaches and algorithms vary with software ranging from crude to very sophisticated. With the varied approaches and lack of consensus on simulation approaches and how to apply simulation this standard does not define standards for simulation.

Generally, if a lift system (using a conventional landing call system) is sized correctly for the up-peak traffic pattern, all other traffic patterns should be adequately served. The notable exceptions to this, are:

1) Hotels where check-in/check-out clashes with meal times;
2) Hospitals;
3) Buildings that open at specified times (Example, stock exchanges, movie theatres, stadiums);
4) Buildings with 24×7 operation and shift changes (Example, BPO/ITES buildings);
5) Buildings with amenities located at higher floors (Example, roof top restaurant, cafeterias, health clubs);
6) Residential buildings (sometimes two-way traffic is considered);
7) Buildings with multiple entry levels;
8) Parking towers;
9) Schools where students change floors or buildings at the beginning and end of classes; and
10) Mixed-use buildings.

Methods of calculating the traffic handling capabilities of lifts were first devised for office buildings. In due course detailed modifications were devised to suit other applications without altering the basic principles. The application to office buildings is the most frequently used, and is outlined in **4.2.2** to **4.2.10** as a general approach to lifting.

Subsequently, traffic conditions other than up peak are examined as also building types other than office. It is recommended that calculations based on the classical model should be carried out in order to obtain an understanding of the various factors. A simulation may then be performed in order to cover special situations or to obtain information not provided by the calculation method.

4.2.2 *Population*

The first point to be ascertained from the owner/ developer or proposed occupier is the total building population. If a definite population figure is not available, then an estimation should be made using floor areas, more specifically, the net usable area (NUA). The NUA excludes circulation areas (stairs, corridors, foyers, etc), structural intrusions (columns, ducts, etc) and facilities (pantry, kitchens, toilets, conference rooms, training rooms, server rooms, storage areas, etc).

The number of people occupying the net usable area can vary according to the usage pattern or building type. Because of the criticality of establishing the population, it is recommended that the architect/engineer should prepare a typical test fit to establish an estimate of the population. The test fit estimates can be validated from population counts from buildings with similar usage patterns and types.

The designers need to understand the clear circulation and movement pattern of the occupants (and goods) of a building and design to facilitate the circulation and movement. Table 1 gives typical values for the density of population.

Table 1 Occupancy Area Per Person in Office Buildings
(*Clause* 4.2.2)

Sl No.	Building Type	Open Plan/ Hall Seating	Cellular Plan/ Cabins
(1)	(2)	(3)	(4)
i)	Premium	10 m^2	12 m^2
ii)	Regular	8 m^2	10 m^2
iii)	Low end	5 m^2	8 m^2

For certain specialized building functions such as BPO, areas ranging from 6 m^2 to 10 m^2 per person may be considered.

4.2.3 *Quantity of Service*

It is measured in terms of the total number of passengers handled during the peak 5 min period of the day. This is calculated by determining the number of trips made by the lifts over the peak 5 min period and then

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multiplying it by the average number of passengers carried in each trip. The target handling capacity as a percentage of the building population is usually the estimated value of passenger arrival rate for the 5 min up-peak period. The minimum recommended quantity of service is given in Table 2.

This would vary depending on various factors like starting time (fixed or flexi-time), nearness to fast access routes like mass rapid transport systems, express ways, major roads, etc.

Table 2 Recommended Quantity of Service in Office Buildings
(*Clause* 4.2.3)

Sl No.	Type of Occupancy	Quantity of Service Percent
(1)	(2)	(3)
i)	Multi tenancy	10 to 15
ii)	Single tenancy	15 to 25

4.2.4 *Quality of Service*

It is very difficult to get real indications of passenger waiting time and lobby queuing from the classic calculation models. Therefore, interval is considered as the measure. During pure up-peak traffic, the interval or the average time between successive arrivals of the lift cars at the main lobby is generally considered as an indicator of passenger waiting time. Table 3 gives the quality of service based on interval.

If interval is used as an indicator of quality of service, it should be noted that passenger average waiting time depends on the car occupancy, the handling capacity *vis-a-vis* the passenger arrival rates, the control systems, etc. The average waiting time approximates 75 percent to 85 percent of the interval for average car occupancy of 80 percent of the actual lift capacity provided the handling capacity is equal to or better than the peak arrival rate. Beyond 80 percent car loading passenger average waiting time increases exponentially and cannot be approximated from interval. Table 4 gives the recommended quality of service measured as average waiting time.

Table 3 Recommended Quality of Service in Office Buildings (Based on Interval)
(*Clause* 4.2.4)

Sl No.	Quality of Service	Interval s
(1)	(2)	(3)
i)	Excellent	Less than 25
ii)	Very good	25 to less than 30
iii)	Good	30 to less than 35
iv)	Fair	35 to less than 40
v)	Poor	40 to less than 45
vi)	Unsatisfactory	45 and above

Table 4 Recommended Quality of Service in Office Buildings (Based on Average Waiting Time)
(*Clause* 4.2.4)

Sl No.	Class of Building	Average Waiting Time s
(1)	(2)	(3)
i)	Premium	< 25
ii)	Regular	25 to 35

4.2.5 *Traffic Analysis Equations*

The classical method to size a lift installation requires the determination of the time, in second, that it takes for a single lift to make a round trip around the building during the up-peak traffic condition. This is called the round trip time and is given by:

$$RTT = 2Ht_v + (S+1)(T - t_v) + 2Pt_p$$

where

N = number of floors above main terminal floors,

H = average highest reversal floor

$$= N - \sum_{i=1}^{N-1} (i/N)^P ,$$

S = average no of stops

$$= N\left[1 - \left(1 - \frac{1}{N}\right)^P\right],$$

P = average passengers carried

= 0.8 × maximum actual car capacity,

t_v = single floor transit time = average inter floor distance/rated speed,

T = door operating time (t_c+t_o) + single floor flight time t_f(1), and

t_p = passenger transfer time.

The derivation of the round trip time equation assumes the following:

a) Traffic pattern corresponds to a pure up-peak.
b) Passengers arrive according to a rectangular probability distribution.
c) Lifts, on an average, fill to 80 percent of the actual car capacity by numbers irrespective of the weight of each passenger or the space that maybe occupied
d) All floors are equally populated.
e) Rated speed is achieved in a single floor jump.
f) Interfloor heights are equal.
g) Door dwell time does not exceed the calculated passenger transfer time.

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Interval, $INT = RTT / L$, where L is the number of lifts in a single group.

$$\text{5 min handling capacity, } HC = \frac{300 \times P \times L \times 100 / \text{Population}}{RTT}$$

or

$$\frac{300 \times P \times 100 / \text{Population}}{INT}$$

The down peak round trip time is estimated as:

$$RTT_{\text{downpeak}} = Nt_{\text{v}} + (0.5S + 1)(T - t_{\text{v}}) + 2Pt_{\text{p}}$$

The mid-day round trip time is estimated as:

$$RTT_{\text{mid-day}} = 2Ht_{\text{v}} + 2S(T - t_{\text{v}}) + 4Pt_{\text{p}}$$

An estimation of interfloor performance can be obtained using:

$$AWT_{\text{interfloor}} = INT_{\text{uppeak}} + \left(0.22 + 1.78 \frac{A_{\text{interfloor}}}{HC_{\text{uppeak}}} \right)$$

where $A_{\text{interfloor}}$ is the number of passengers arriving during the interfloor period.

4.2.6 *Configuration of Lifts: Number*

Determination of number of lifts depends on the required quality and quantity of service. It should be noted here that grouping of lifts and location should be given adequate attention.

If a bank of two lifts or more is required to meet the anticipated traffic requirements, they have to be oriented to facilitate grouping. Individual lifts will not achieve the required quantity and quality of service.

4.2.7 *Configuration of Lifts: Capacity*

Determination of car capacity depends on the required quality and quantity of service. A larger car, while improving the handling capacity might adversely impact the quality of service.

4.2.8 *Configuration of Lifts: Speed*

In addition to the speeds derived from the calculations for handling capacity and interval, the nominal travel time is used for selecting suitable rated speeds. The higher the building, the faster lifts are needed. The recommended values for nominal travel time in case of an office, commercial or hotel building are given in Table 5.

Table 5 Recommended Nominal Travel Time for Office, Commercial or Hotel Buildings
(*Clause* 4.2.8)

Sl No.	Level	Nominal Travel Time s
(1)	(2)	(3)
i)	Excellent	15 to 25
ii)	Good	> 25 to 35
iii)	Satisfactory	> 35 to 45

4.2.9 *Configuration of Lifts: Layout*

The shape and size of a passenger lift car bears a distinct relation to its efficiency in traffic handling. A study of the most suitable proportions for passenger lifts reveals that the width of the lift well entrance is the basic element in the determination of the best proportions. In other words, the width of the car is determined by the width of the entrance and the depth of the car is regulated by the loading per square metre permissible under this standard.

Centre opening doors are the most practicable and the most efficient entrance units for passenger lifts. Given the same door speed, the centre opening is much faster than the side opening type. For passenger lifts, wider cars are preferred as the ingress and egress efficiency is higher. For service/freight/ stretcher lifts deeper cars are preferred, so as to easily carry the stretcher/goods.

While sizing the hoist-ways, the possible construction inaccuracies have to be considered. Further where high speeds lifts are being considered the hoist-ways need to be designed to address the impact of the wind tunnel effect.

4.3 Planning for Specific Building Features

4.3.1 *Special Building Facilities*

Facilities like cafeteria, food courts, restaurants, gymnasia, etc, in the building impact the circulation patterns in a building and should be considered for lift traffic design.

4.3.2 *Basement Service*

Buildings are sometimes designed with car parks or other facilities at basement levels below the terminal floor. Such floors, if they are served by the main lifts have an adverse impact on the up-peak, down-peak and mid-day traffic patterns. During up-peak conditions, this may cause lifts to arrive at the main terminal already partly full causing confusion. In such a situation people have a tendency to push both up and down buttons resulting into deterioration of the lift service.

If basement floors are served by only a part of a lift group, passengers experience difficulty in selecting the correct lifts out of a group that will serve the basement. It is therefore better to provide basement service to the main lobby by a separate group of 'shuttle' lifts so as to avoid compromising the traffic handling capability of the main lift group.

4.3.3 *Multiple Entry Levels*

Some buildings have main entry points at more than one level. The effect of more than one main terminal is disruptive and adversely impacts effective circulation and movement. If there are more than one entrance

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levels, means should be provided to bring all the routes to a single terminal floor. If this is not possible, then the lift system planning should take into account the extra times incurred stopping and loading at multiple entry floors. Another difficulty is in deciding whether the building population will use each entrance equally. In the absence of any guidance, the solution is to assume an entrance bias with an additional 10 percent and size the lifts to meet the additional required handling capacity.

The loss of lift efficiency because of multiple entry levels could be as high as 15 percent per additional entry level. Both basement service and multiple entry level buildings with lifts serving all floors also can impact the security of the building.

4.3.4 *Non-Smoking Buildings*

When buildings are defined as non-smoking buildings, designers need to factor in the additional load put on the lifts on account of the additional trips that smokers make to go outside the building. It is appropriate to provide pressurized smoking zones at the floor level rather than require smokers to make additional trips.

4.3.5 *Reserved Lifts*

When lifts have to be reserved for VIP personal movement, designers should not consider these lifts as part of the lift group.

4.3.6 *Zoning (Vertical)/Sky Lobbies in Very Tall Buildings*

As the number of floors served increases, the values of H and S also increase, adversely impacting the round trip time and performance of the lift system. This has led to the concept of zoning in tall buildings. In stacked zoning, a tall building is effectively divided into horizontal layers or stacks. RTT, quality and quantity of service can be arrived at separately for each zone. The desired level of service can be attained by adjusting two parameters in this case — the number of lifts and the number of floors in the zone. The round trip time for each zone is given by:

$$RTT = 2Ht_v + (S + 1)(T - t_v) + 2Pt_p + 2[t_{express} - t_f(1)]$$

where $t_{express}$ is the flight time from the main terminal to the express zone terminal/sky lobby.

The round trip time for shuttle lifts serving only 2 floors — main terminal and sky lobby is given by:

$$RTT = 2T + 2Pt_p$$

4.4 Planning For Specific Building Types

4.4.1 *Residential Buildings*

The peak traffic condition occurs during the morning down-peak when many adults and children are leaving for work and school at the same time. Population assumptions would also need to consider the service staff, drivers of cars, etc. For high rise buildings the delivery of newspapers and milk and disposal of garbage are also required to be considered.

In the luxury housing segment, where the number of ratio of service staff to residents is fairly high, separate service lifts may be required for door deliveries and service staff. Typical average daily population for a residential building is given in Table 6.

The passenger handling capacity shall be as given in Table 7. The intervals shall be as per values in Table 8. Table 9 gives the recommended quality of service

Table 6 Typical Average Population for Residential Buildings
(*Clause* 4.4.1)

Sl No.	Type of Apartment	Number of Bedrooms Per Apartment				
		1	2	3	3 With Servant Quarters	4 With or Without Servant Quarters
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	High end apartments:					
	a) Residents	2 to 3	3 to 4	5	5	5 to 6
	b) Resident service staff	0	0	0	1	1
	c) Floating service staff	1	2 to 3	3 to 4	3 to 4	4 to 5
ii)	Mid end apartments:					
	a) Residents	3	4	5	5	5 to 6
	b) Resident service staff	0	0	0	1	1
	c) Floating service staff	1	1	2 to 3	2 to 3	3 to 4
iii)	Low end apartments:					
	a) Residents	4 to 5	5 to 6	NA	NA	NA
	b) Floating service staff	0.5	0.5	NA	NA	NA

NOTE — Unless separate lifts are provided for service staff, due consideration for service staff shall be given while calculating the required number of lifts.

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measured as average waiting time for residential buildings and Table 10 gives the nominal travel times.

Sizing of lifts should consider the requirement to shift the stretchers, heavy material, etc and it is recommended that at least one lift in each building should be a deep car which can accommodate a regular ambulance stretcher.

Table 7 Recommended Handling Capacity for Residential Buildings
(*Clause* 4.4.1)

Sl No.	Class of Building	Handling Capacity Percent
(1)	(2)	(3)
i)	High end building	> 8
ii)	Mid end building	6 to 8
iii)	Low end building	5 to 7

Table 8 Recommended Quality of Service for Residential Buildings (Based on Time Interval)
(*Clause* 4.4.1)

Sl No.	Class of Building	Interval s
(1)	(2)	(3)
i)	High end building	≤ 60
ii)	Mid end building	61 to 80
iii)	Low end building	81 to 100

Table 9 Recommended Quality of Service in Residential Buildings (Based on Average Waiting Time)
(*Clause* 4.4.1)

Sl No.	Class of Building	Average Waiting Time s
(1)	(2)	(3)
i)	High end building	≤ 30
ii)	Mid end building	31 to 45
iii)	Low end building	46 to 60

Table 10 Recommended Nominal Travel Time for Residential Buildings
(*Clause* 4.4.1)

Sl No.	Level	Nominal Travel Time s
(1)	(2)	(3)
i)	High end building	25 to 35
ii)	Mid end building	36 to 45
iii)	Low end building	46 to 60

NOTE — In case of super high rise buildings considering limit of lift speed as 10 m/s, the travel time may be longer than specified above.

4.4.2 *Hospitals*

Factors to be considered include number of staff and shift patterns, number of visitors and visiting hours, location of operation theatres, facilities, delivery of housekeeping supplies, waste disposal, evacuation procedures and segregation of sterile areas. When carrying out traffic analysis for hospitals, designers should consider establishing average car loading by volume rather than by weight. Arrival rates may approximate 10 percent to 15 percent and interval may be 30 s to 50 s.

The sizing of the lift car and doors should be such that a standard hospital stretcher and attendant can be easily accommodated. Where the hospital bed is likely to be moved the lift car should be able to accommodate the standard hospital bed including the auxiliary support equipment like oxygen cylinders, etc.

In large hospitals it is recommended that the lifts for the patients/hospital beds (or stretchers) should be separated from the lifts for staff/visitors.

NOTE — For hospital buildings, designers should also consider that in an emergency a number of patients would require to be evacuated on stretchers.

4.4.3 *Hotels*

The most demanding time is during the check-in and check-out period and two-way traffic occurs during this period with guests going to and from rooms and restaurants and in and out of the hotel. Calculations should be made assuming an equal number of up and down stops during this period. Average room occupancy may range from 1.5 to 2 persons and arrival rates from 10 to 15 percent. Security considerations need to be taken into account whilst establishing the circulation and lift requirements. Escalators should be employed for heavy short range movements such as from the lobby to banquet/ function level. Adequate number of service lifts need to be provided for service movement of housekeeping and room service staff as well as movement of material.

4.4.4 *Retail — Malls with Multiplexes*

Pedestrian movement in retail establishments like malls is generally centered on escalators, and lifts do not play a major part. However, provision should be made for movement of shopping trolleys, wheel chairs, perambulators and persons with limited mobility from one level to another. A commonly applied solution is the installation of inclined moving walks. Where lifts are provided, assumptions of lift car sizing should take into account space occupied by trolleys and shopping bags. Where multiplexes are located on the upper floors, the last movie of the day gets over after the mall is closed at which time the escalators might not be available. In such cases the lift provision has to be

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adequate to handle the egress of the total multiplex population.

4.4.5 *Airports/Railway Stations*

While moving walks and escalators greatly improve the building circulation, the use of lifts has to be considered for persons with limited mobility and for movement of baggage trolleys from one level to another. The RTT equation of **4.2.5** may be used, but care may need to be taken in the assumptions of lift car occupancy levels taking into account space occupied by trolleys.

4.4.6 *Multi-Level Car Parking*

Multi-level car parks may be standalone public car parks or attached to office, retail or residential complexes. These car parks may be fully automated where drivers would leave the cars inside or on a trolley at the entry floor and the car is parked and retrieved automatically. The other alternative would be for the use of car lifts and/or ramps.

When the movement of the cars is dependent on car lifts, detailed study has to be carried out to establish the required number of car lifts ensuring that average car retrieval/parking time does not exceed 2 min. The sizing of the car lifts has to be adequate to fit the largest vehicle that is intended to be transported as well as adequate space to enable opening of the doors to enable evacuation of passengers in the eventuality of an entrapment. Designers will also need to take into account the probability of queues developing and provide for holding lanes.

4.4.7 *Multi-Level Car Parking Passenger Traffic*

When car lifts or ramps are the means for parking the cars, then means would need to be provided for the movement of passengers from and to the parking floors. If the main building lifts also serve the parking floors, it is to be noted that, performance will be adversely impacted due to multiple entry floors. Additional entry floors will also affect the security of the building. It is therefore recommended that separate lifts should be considered to move passengers. If separate parking lifts are provided, the basic RTT equation of **4.2.5** may be used. Average vehicle occupancy may be considered as 1.5 per car for office car parks, 4 for airports and retail and 2 elsewhere.

4.4.8 *Schools and Other Educational Institutions*

In schools and other educational institutions, the traffic flow would consist of peak demand for short duration that would exist just before the start or after finishing of a class or lecture. It is unlikely that an economical solution can be implemented for such high peak requirements. Therefore the design of the building has to be such that heavy stair usage is facilitated.

4.4.9 *Buildings with 24 × 7 Operations*

In buildings operating 24 × 7 (round the clock), the peak traffic conditions would not be a typical up peak but will occur during shift changes. The handling capacity should take into account the incoming as well as outgoing traffic. Calculations shall be made assuming both up and down stops during this period. Particular attention should be paid while designating the drop off points, these should be assigned to a level so as to not increase the burden on the system. Designers need to consider that the lifts in such buildings would have a significantly higher number of starts/stops per hour than a conventional building.

4.4.10 *Observatory*

The height at which the observatory is located and the number of people expected at the observatory level shall decide the speed and the number of lifts. The circulation logic is crucial in locating the observatory lifts. Also, if the observatory is connected with lounge/café/souvenir shops, etc, separate service lifts may need to be provided.

4.5 Other Considerations

Designers need to be aware that the door opening and closing times, acceleration and deceleration times, etc, would vary between the suppliers and equipment types and can impact the overall lift performance. The dispatch algorithms and controller responses would also vary between the suppliers and the equipment types and can impact the actual operational results.

Lifts will breakdown as well require to be shut-down for regular maintenance and repairs. Lift availability might be hampered during renovation of the building as a lift might be taken up for movement of material and debris. Designers should take into consideration the impact of such non-availability of lifts. The provision of well-located and easily accessible stairs can considerably lessen the demands on the lifts and therefore architect/engineer should consider this aspect in the layout.

4.5.1 *Lift Speed*

For passenger lifts in a building, the general recommendations as given in Table 11 may be followed.

4.5.2 *Quiet Operation of Lifts*

Every precaution should be taken with passenger lifts to ensure quiet operation of the lift doors and machinery. The insulating of the lift machine and any motor generator from the floor by rubber cushions or by a precast concrete slab with rubber cushions, prevents transmission of most of the noise. In this connection, see also good practice [8-5A(4)] and Part 8 ‘Building Services, Section 4 Acoustics, Sound Insulation and

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Noise Control' of the Code for some useful recommendations.

Table 11 Lift Speed
(*Clause* 4.5.1)

Sl No.	No. of Floors	Speed m/s
(1)	(2)	(3)
i)	Up to 6	0.6 to 1.0
ii)	7 to 15	1.0 to 1.5
iii)	16 to 20	1.5 to 1.75
iv)	21 to 30	1.75 to 2.5
v)	31 to 45	3.0 to 4.0
vi)	46 to 60	4.0 to 6.0
vii)	Above 60	6.0 and above

NOTES
1 Above table is considering buildings with average floor height of 3.0 m.
2 For office buildings average floor height is 4.2 m (*see* Table 5 and Table 10).
3 Finalizing the lift speed for any building depends on detailed traffic analysis because number of floors, area per floor, area per person and class of building are crucial factors, which serve as inputs for such traffic analysis.
4 Finalizing the speed for hotel depends on the number of keys per floor and similarly for an observatory depends on the number of expected footfall.
5 For any building, the speed of the lifts will have to be validated against the total population and travel height of the building.

5 LIFT ARRANGEMENTS AND PLANNING DIMENSIONS

The appropriate aspect of lift installation shall be discussed during the preliminary planning of the building with all concerned parties, namely, client, architect, consulting engineer and/or lift manufacturer. This enables the lift manufacturer to furnish the architect and/or consulting engineer with the proposed layout or *vice-versa*.

5.1 Exchange of Information

5.1.1 The guidelines laid down together with Fig. 2 will enable the preliminary scheme for the installation to be established. Figure 2 shows only some of the typical arrangements and variations are possible with respect to number of lifts and the layout of lifts especially when destination control system (DCS) is used instead of conventional group control system

Although the recommended outline for the various classes of lifts enable the general planning details to be determined by the architect/engineer, these should be finally settled at the earliest possible stage by detailed investigation with the purchaser's representative reaching agreement with the lift manufacturer (where necessary) before an order is finally placed. This will enable a check to be made and information to be exchanged on vital matters such as:

a) Number, capacity, speed and disposition of the lifts necessary to give adequate lift service in the proposed building;
b) Provision of adequate access to the machine room;
c) Loads which the lift will impose on the building structure, and the holes to be left in the machine room floor and cut-outs for wall boxes for push-buttons and signals;
d) Necessity for and type of insulation to minimize the transmission of vibration and noise to other parts of the building;
e) Special requirements of local authorities and other requirements set out in the 'planning permit';
f) Need for the builder to maintain accuracy of building as to dimensions and in-plumb;
g) Periods of time required for preparation and approval of relevant drawings for manufacturing and the installation of the lift equipment;
h) Requirements for fixing guide brackets to the building structure;
j) Time at which electric power will be required before completion to allow for testing;
k) Requirements for electrical supply feeders, etc;
m) Requirements for scaffolding in the lift well and protection of the lift well prior to and during installation of equipment; and
n) Delivery and storage of equipment.

5.1.2 *Information to be provided by Architect or Engineer*

As a result of preliminary discussions, the drawings of the building should give the following particulars and finished sizes:

a) Number, type and size of lifts and position of lift well;
b) Particulars of lift well enclosure;
c) Size, position, number and type of landing doors;
d) Number of floors served by the lift;
e) Height between floor levels;
f) Number of entrances;
g) Total headroom;
h) Provision of access to machine room;
j) Provision of ventilation and, if possible, natural lighting of machine room;
k) Height of machine room;
m) Depth of lift pit;
n) Position of lift machine, above or below lift well;

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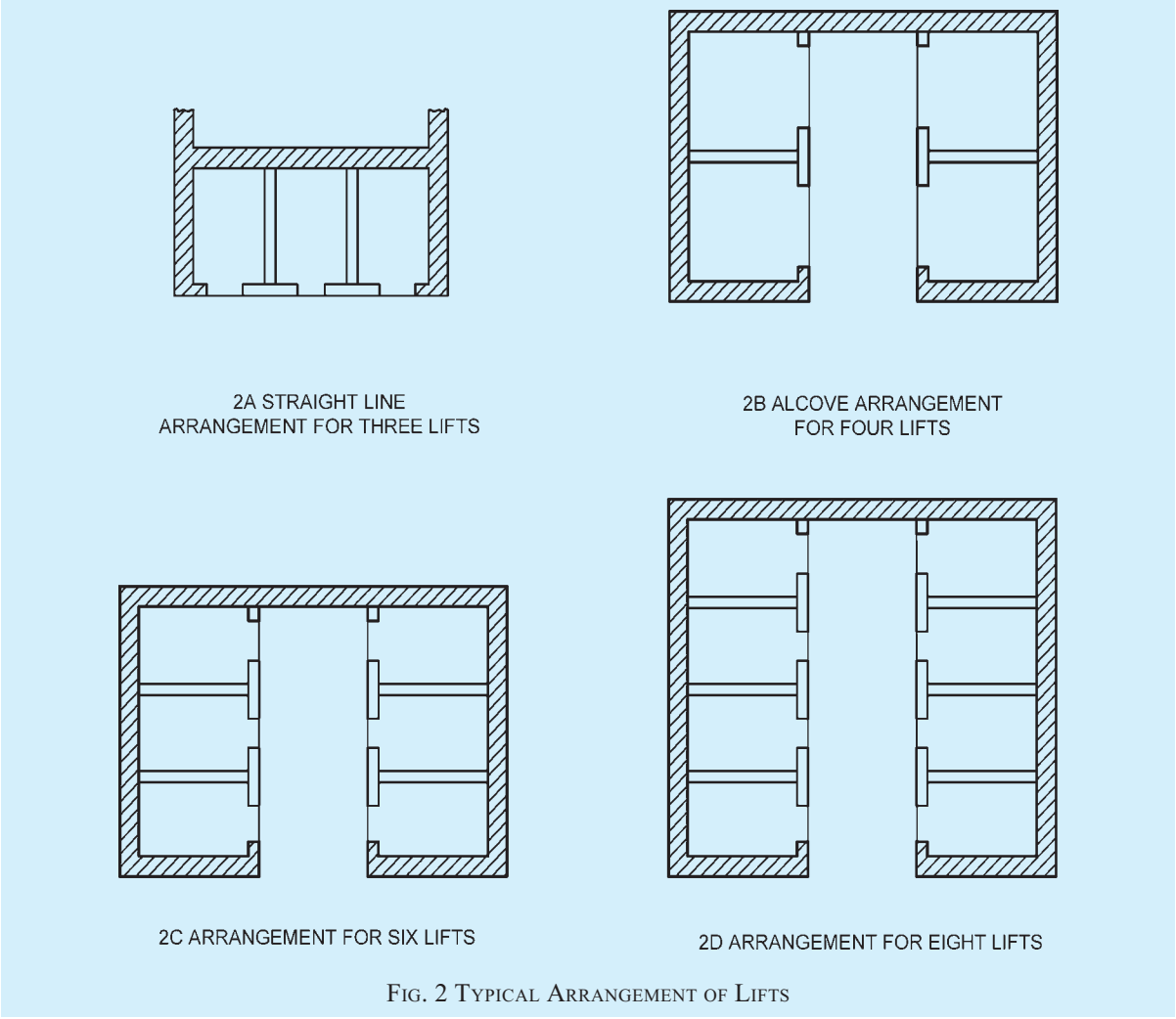


FIG. 2 TYPICAL ARRANGEMENT OF LIFTS

p) Size and position of any trimmer joists or stanchions adjacent to the lift well at each floor;

q) Size and position or supporting steel work at roof levels;

r) Size and position of any footings or grillage foundations, if these are adjacent to the lift pit; and

s) In the case of passenger lifts whether the lift cage is required to carry household luggage, such as refrigerator, steel almirah, etc.

5.2 The lift lobby should be designed appropriately since this has bearing on the traffic handling especially when more number of lifts are involved. In a dual line arrangement (lifts opposite to each other) the lobby should be between 1.5 times and 2.5 times the depth of one car. Typically, the greater the number of lifts, the bigger the multiplier to be used. As an example, a quadruplex may use 1.5 to 2, where as an octoplex will need 2 to 2.5. For in-line (single line) arrangements, the lobby can be typically half of the above recommendations.

It is preferable that the lift lobby is not used as a thoroughfare. If unavoidable the lift corridor shall take into account space for people who are moving.

5.3 The architect/engineer should advise the lift manufacturer, if the Authority has any special requirements regarding lifts in buildings in the administrative area concerned.

5.4 The architect/engineer should inform the lift manufacturer of the dates when the erection of the lift may be commenced and is to be completed so that sufficient time is allowed for the manufacture and erection of the lift.

5.5 When submitting application for a building permit to the local Authority, the building plans shall include the details of lifts (number of lifts duly numbered, location, type, type of doors, passenger capacity and speed).

5.6 Positioning of Lifts

A thorough investigation should be made for assessing the most suitable position for lift(s) while planning the

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building. It should take into account future expansions, if any. Though each building has to be considered individually for purposes of location of lifts, factors influencing the locations of passenger and goods lifts are given in **5.6.2** to **5.6.4.**

5.6.1 *Arrangement of Lifts*

The lifts should be easily accessible from all entrances to the building. For maximum efficiency, they should be grouped near the centre of the building. It is preferable not to have all the lifts out in straight line and, if possible, not more than four lifts should be arranged in this manner. If more than 4 lifts have to be grouped together in a straight line, then destination control systems would require to adopted. Further, the corridor should be wide enough to allow sufficient space for waiting passengers as well as for through passengers.

In some cases when there are more than three lifts, the alcove arrangement is recommended. With this arrangement, the lift alcove leads off the main corridor so that there is no interference by traffic to other groups or to other parts of the ground floor. This arrangement permits the narrowest possible corridors and saves space on the upper floors. Walking distance to the individual lift is reduced and passenger standing in the centre of the group can readily see all the lift doors and landing indicators. The ideal arrangement of the lifts depends upon the particular layout of the respective building and should be determined in every individual case. Some typical recommended arrangements are given in Fig. 2.

5.6.2 *Passenger Lifts*

5.6.2.1 *Low and medium class flats*

Where a lift is arranged to serve two, three or four flats per floor, the lift may be placed adjoining a staircase, with the lift entrances serving direct on to the landings. Where the lift is to serve a considerable number of flats having access to balconies or corridors, it may be conveniently placed in a well-ventilated tower adjoining the building.

5.6.2.2 *Office buildings, hotels and high class flats*

In general the arrangement as recommended in **5.6.1** should be followed. However, in case this is not possible, it is desirable to have at least a battery of two lifts at two or more convenient points of a building. If this is not possible, it is advisable to have at least two lifts side by side at the main entrance and one lift each at different sections of the building for inter-communication. When two lifts are installed side by side, the machine room shall be suitably planned with sufficient space for housing the machine equipment. The positioning of lifts side by side gives the following advantages:

a) All machines and switch gear may be housed in one machine room,
b) Lifts can be inter-connected more conveniently from an installation point of view, and
c) Greater convenience in service owing to the landing openings and each floor being adjacent.

5.6.2.3 *Shops and departmental stores*

Lifts in shops and stores should be situated so as to secure convenient and easy access at each floor.

5.6.2.4 For buildings with more than 12 floors, where passenger and service lifts are provided in one lobby, it is recommended to have group control for all the lifts.

5.6.3 *Goods Lifts*

The location of lifts in factories, warehouses and similar buildings should be planned to suit the progressive movement of goods throughout the buildings, having regard to the nature of position of the loading platforms, railway sidings, etc. The placing of a lift in a fume or dust laden atmosphere or where it may be exposed to extreme temperatures, should be avoided, wherever possible. Where it is impossible to avoid installing a lift in an adverse atmosphere, the electrical equipment should be of suitable design and construction to meet the conditions involved.

Normally goods lifts have lower speeds than passenger lifts for the same travel because traffic conditions are less demanding, and more time is required for loading and unloading. As loads for goods lifts increase in size and weight, so the operation of loading and unloading becomes more difficult. Therefore, it is usual to require greater accuracy of levelling as the capacity of the goods lift increases.

A large capacity goods lift operating at high speed is often a very uneconomical solution. The inherent high cost is enhanced due to the very small demand for such equipment, much of which is custom made. The high capital cost of the lift, building work and electrical supply equipment usually shows a much smaller return as an investment than more normal sizes of lifts.

5.6.4 *Hospital Bed Lifts*

Hospital bed lifts should be situated conveniently near the ward and operating theatre entrances. There shall be sufficient space near the landing door for easy movement of stretcher/bed. It is convenient to place the passenger lifts in a hospital, near the staircases.

5.7 General Arrangement Drawings (GAD)

The general arrangement drawings should be prepared

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by the lift manufacturer. The lift manufacturer requires sufficient information for the preparation of working drawings and is usually obtained from architect's drawings supplemented by any information obtained from the site and by collaboration with the other contractors.

General arrangement drawings showing the layout of lifts duly numbered, details of builders work, for example, holes in walls for guide fixing, holes in machine room floor for ropes and conduits, recesses for landing sills, supports for lift machine and loads imposed on the building should be submitted by the lift manufacturer to the architect/engineer for written approval.

5.8 Additional Requirements for Passenger, Goods and Service Lifts

5.8.1 *Bottom Car Clearance*

When the car rests on its fully compressed buffer there shall be a vertical clearance of not less than 600 mm between the pit floor and the buffer striker plate or the lowest structural or mechanical part equipment or device installed. The clearance shall be available beneath the whole area of the platform except for,

a) guide shoes or rollers, safety jaw blocks, platform aprons, guards of other equipment located within 300 mm measured horizontally from the sides of the car platform; and

b) compensating sheaves.

Provided that in all the cases, including small cars, a minimum clearance of 600 mm is available over a horizontal area of 800 mm × 500 mm.

Provided also that in all the cases, when the car rests on its fully compressed buffers, there shall be a vertical clearance of not less than 50 mm between any part of the car and any obstruction of device mounted in the pit.

5.8.2 *Top Car Clearance*

The vertical clearance between the car cross-head and the nearest overhead obstruction within 500 mm measured horizontally to the nearest part of the crosshead when the car platform is level with the top landing, shall be not less than the sum of the following:

a) Bottom counterweight run-by.
b) Stroke of the counterweight buffer used.
c) One-half of the gravity stopping distance based on,
   1) 115 percent of the rated speed where oil buffers are used and no provision is made to prevent the jump of the car at counterweight buffer engagement; and
   2) Governor tripping speed where spring buffers are used.

   NOTE — The gravity stopping distance based on the gravity retardation from any initial velocity may be calculated according to the following formula

   $$S = 51\ V^2$$

   where

   S = free fall, in mm (gravity stopping distance), and

   V = initial velocity, in m/s.

d) 600 mm.

Where there is a projection below the ceiling of the well and the projection is more than 500 mm, measured horizontally from the centre line of the cross-head but over the roof of the car, a minimum vertical clearance not less than that calculated above shall also be available between the roof of the car and the projection.

Provided that the vertical clearance between any equipment mounted on top of the car and the nearest overhead obstruction shall be not less than the sum of the three items (a), (b) and (c) as calculated above plus 150 mm.

5.8.3 *Bottom Run-by for Cars and Counterweights*

The bottom run-by of cars and counterweights shall be not less than the following:

a) 150 mm, where oil buffers are used.
b) Where spring-buffers are used;
   1) 150 mm for controls as in **2.1.11.4** to **2.1.11.8,** and
   2) Not less than the following for controls as in **2.1.11.1** to **2.1.11.3**:

Rated Speed m/s	*Run-by* mm
Up to 0.125	75
0.125 to 0.25	150
0.25 to 0.50	225
0.50 to 1	300

5.8.4 *Maximum Bottom Run-by*

In no case shall the maximum bottom run-by exceed the following:

a) 600 mm for cars; and
b) 900 mm for counterweights.

5.8.5 *Top Counterweight Clearances*

The top counterweight clearance shall be not less than the sum of the following four items:

a) Bottom car run-by.

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b) Stroke of the car buffer used.
c) 150 mm.
d) One-half the gravity stopping distance based on,
   1) 115 percent of the rated speed where oil buffers are used and no provision is made to prevent jump of the counterweight at car buffer engagement; and
   2) governor tripping speed where spring buffers are used.

5.9 Additional Requirements for Dumb Waiters

5.9.1 *Top Car Clearance*

The top car clearance shall be sufficient to avoid any protruding part fixed on the top of the car coming in direct contact with the ceiling or diverting sheave.

The clearance shall be calculated taking into account the following and shall not be less than the sum of the following four items:

a) Bottom counterweight run-by.
b) Stroke of the counterweight buffer used.
c) Dimensions of the portion of the diverting sheave hanging underneath the ceiling in the lift well.
d) 150 mm for compensating for gravity stopping distance and future repairs to the rope connections at counterweight and at the car or at the suspension points.

5.9.2 *Bottom Car Clearance*

The bottom car clearance shall be maintained in such a way that the counterweight shall not come in contact with the ceiling or any part hanging underneath the ceiling, when the car completely rests on fully compressed buffers, provided the buffers are spring type mounted on solid concrete or steel bed.

In case of wooden buffers the bottom car clearance shall be maintained in such a way that the total downward travel of the car from the service level of the immediate floor near the pit, shall not be more than the top counterweight clearance, when the wooden buffers are completely crushed.

5.9.3 *Top Counterweight Clearance*

The top clearance for the counterweight can be calculated taking into account the following and shall not be less than the sum of the following three items:

a) Car run-by.
b) Compression of the buffer spring or height of the wooden block used as buffer.
c) 150 mm to compensate for gravity stopping distance for counterweight and any future repairs to rope connections at the counterweight at the car ends or at the suspension points.

5.9.4 *Run-by for Cars and Counterweights*

a) *Minimum bottom run-by* — The bottom run-by for cars and counterweights shall not be less than 150 mm.

b) *Maximum bottom run-by* — In no case shall the maximum bottom run-by exceed 300 mm.

5.10 Planning for Dimensions

5.10.1 *General*

The dimensions of lift well have been chosen to accommodate the doors inside the well which is the normal practice. In special cases, the door may be accommodated in a recess in the front wall, for which prior consultation shall be made with the lift manufacturer.

5.10.2 *Plan Dimensions*

All plan dimensions of lift well given hereunder, are the minimum clear plumb sizes. The architect/engineer, in conjunction with the builder, shall ensure that adequate tolerances are included in the building design so that the specified minimum clear plumb dimensions are obtained in the finished work.

NOTE — The words 'clear plumb dimensions' should be noted particularly in case of high rise buildings.

Rough opening in concrete or brick walls to accommodate landing doors depend on design of architrave. It is advisable to provide sufficient allowances in rough opening width to allow for alignment errors of opening at various landings. When more than one lift is located in a common well, a minimum allowance of 150 mm for separator beams shall be made in the widths shown in Tables 1 to 4.

Where the governor operated counterweight safety is required under conditions stipulated in good practice [8-5A(5)], the tabular values should be revised in consultation with the lift manufacturer.

For outline dimensions of lifts having more than one car entrance, lift manufacturers shall be consulted.

5.10.3 *Outline Dimensions*

5.10.3.1 The outline dimensions of lift shaft, machine-room, pit depth, overhead and raw door opening size for lifts to which this Subsection applies are specified in Tables 12 to 23 as indicated below:

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a) Machine room lifts:

1) Recommended dimensions of passenger lifts and service lifts	:	Table 12
2) Recommended dimensions of hospital bed/stretcher lifts	:	Table 13
3) Recommended dimensions of goods lifts with machine room	:	Table 14
4) Recommended dimensions of machine room height, overhead, pit depth for passenger, goods, stretcher/hospital lifts with machine room	:	Table 15
5) Recommended dimensions of automobile lifts with machine room — Through type car	:	Table 16
6) Recommended dimensions of dumbwaiter lifts	:	Table 17

b) Machine room-less lifts:

1) Recommended dimensions of passenger lifts MRL	:	Table 18
2) Recommended dimensions of stretcher/hospital lifts MRL	:	Table 19
3) Pit depth for passenger/ stretcher/hospital lifts MRL	:	Table 20
4) Overhead height for passenger and stretcher/hospital lifts MRL	:	Table 21
5) Recommended dimensions of goods lifts MRL	:	Table 22
6) Recommended dimensions of automobile lifts MRL	:	Table 23

5.10.3.2 *Minimum floor to floor height*

Minimum floor to floor height for landings on same side for horizontally sliding door is *f* +750 mm, where '*f*' is clear entrance height, in mm.

6 CIVIL AND ELECTRICAL REQUIREMENTS FOR LIFTS

6.1 Civil Requirements

Lift well enclosures, lift pits, machine rooms and machine supports besides conforming to the essential requirements given below should form part of the building construction and comply with the lift manufacturer's drawings.

6.1.1 *Requirements of Lift Well Enclosure*

The requirements of lift well enclosures are as given hereunder:

a) *Totally enclosed well* — Lift wells shall be totally enclosed by imperforate walls, floor and ceiling, constructed for protection against all weather and of dust free surface material or should be painted to minimize dust circulation on to moving apparatus and from being pumped by the car movement in to machine room or on to landings and shall be 120 min fire-resistant.

The lift well may have openings for landing doors, inspection and emergency doors, vent openings for escape of gases and smoke in case of fire, ventilation openings, openings in the machine room floor for connecting lift components such as ropes, cables, etc.

b) *Partially enclosed well* — In case of partially enclosed lift wells used for applications for example, observation lifts in connection with galleries or atriums, etc, the well does not need to be totally enclosed, provided the height of the enclosure at places normally accessible to persons is sufficient to prevent such persons:

1) being endangered by moving parts of the lift; and
2) interfering with the safe operation of the lift by reaching lift equipment within the well either directly or with hand held objects.

The height of the enclosure shall be minimum 3.5 m at the landing door side. The height of enclosure at other sides shall be 2.5 m minimum when the horizontal distance between the moving parts of the lift and enclosure is 0.5 m minimum. The height of enclosure at other sides may be reduced to 1.1 m progressively if the horizontal distance between the moving parts of the lift and enclosure increases to 2 m. The enclosure shall be located within 150 mm of the edge of the floor. The enclosure shall be imperforate and made of non combustible material.

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Table 12 Recommended Dimensions of Passenger Lifts and Service Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.

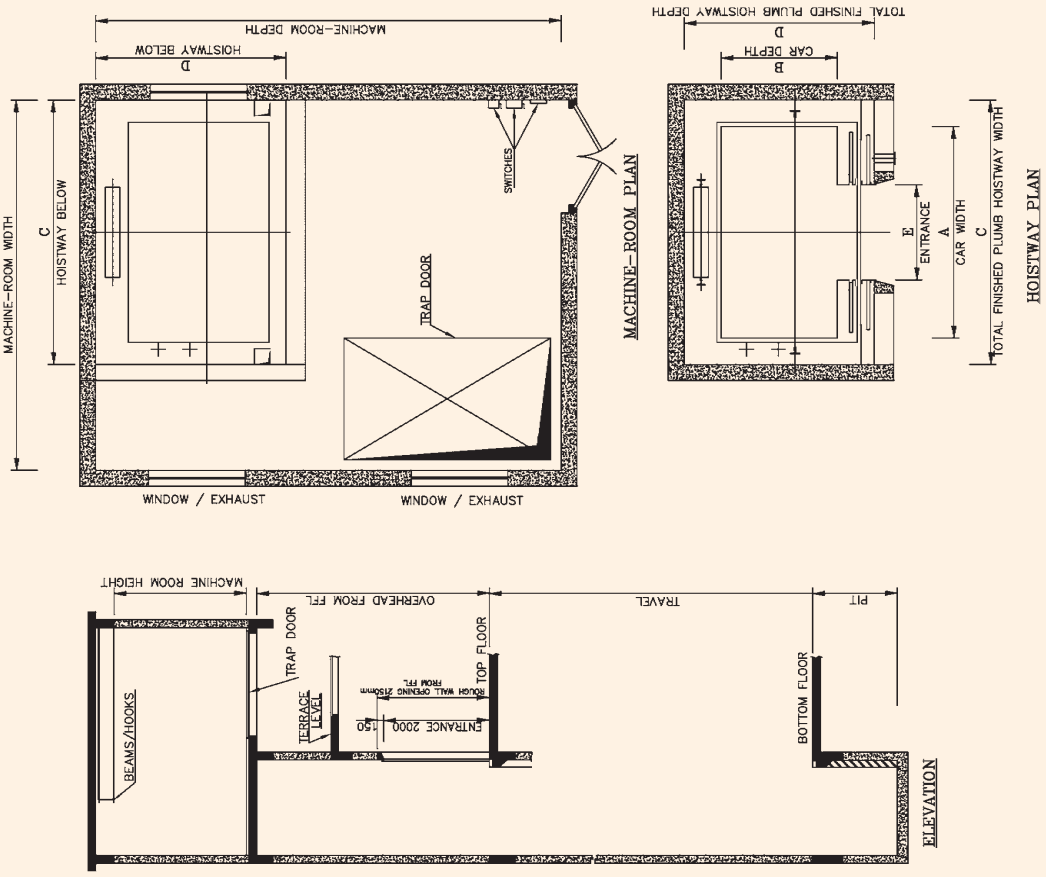


Table 12 — (*Concluded*)

Sl No.	No. of Passengers	Rated Load	Car Size		COPD Door	Passenger and Service Lifts with Machine Room: Shaft Sizes													
						Rated speed < 1 m/s		1.0 m/s ≤ Rated Speed ≤ 2.5 m/s		3.0 m/s ≤ Rated Speed ≤ 3.5 m/s		4.0 m/s ≤ Rated Speed ≤ 5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s ≤ Rated Speed ≤ 8.0 m/s		9.0 m/s ≤ Rated Speed ≤ 10.0 m/s	
						Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
		kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
i)	4	272	1 100	700	800	1 900	1 300	1 900	1 300										
ii)	6	408	1 100	1 000	800	1 900	1 700	1 900	1 700										
iii)	8	544	1 300	1 100	800	1 900	1 900	1 900	1 900										
iv)	10	680	1 300	1 350	800	1 900	2 150	1 900	2 150										
v)	13	884	2 000	1 100	900	2 600	1 900	2 600	1 900										
vi)	14	952	1 600	1 400	900	2 200	2 100	2 200	2 100	2 200	2 150	2 250	2 150	2 250	2 250	2 300	2 300	2 300	2 450
vii)	16	1 088	1 600	1 600	1 000	2 300	2 300	2 300	2 300	2 300	2 350	2 300	2 350	2 300	2 450	2 300	2 500	2 300	2 650
viii)	18	1 224	2 000	1 400	1 100			2 600	2 100	2 600	2 150	2 600	2 150	2 600	2 250	2 700	2 300	2 700	2 450
ix)	20	1 360	2 000	1 500	1 100			2 600	2 100	2 600	2 250	2 600	2 250	2 600	2 350	2 700	2 400	2 700	2 550
x)	22	1 496	2 100	1 600	1 100			2 700	2 300	2 700	2 350	2 700	2 350	2 700	2 450	2 800	2 500	2 800	2 550
xi)	26	1 768	2 350	1 600	1 200			3 000	2 300	3 000	2 350	3 000	2 350	3 000	2 450	3 050	2 550	3 050	2 550
xii)	29	1 972	2 350	1 700	1 200					3 000	2 500	3 000	2 500	3 000	2 550	3 050	2 600	3 050	2 700

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at rear, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed between the manufacturer and the purchaser are permitted. However, variation in,

a) car inside dimensions shall be within the minimum and maximum area limits specified in accordance with accepted standards [8-5A(6)].

b) entrance width on higher side is permitted.

c) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 The minimum size of the lift car and all other requirements relating to accessibility, in all public buildings shall be in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

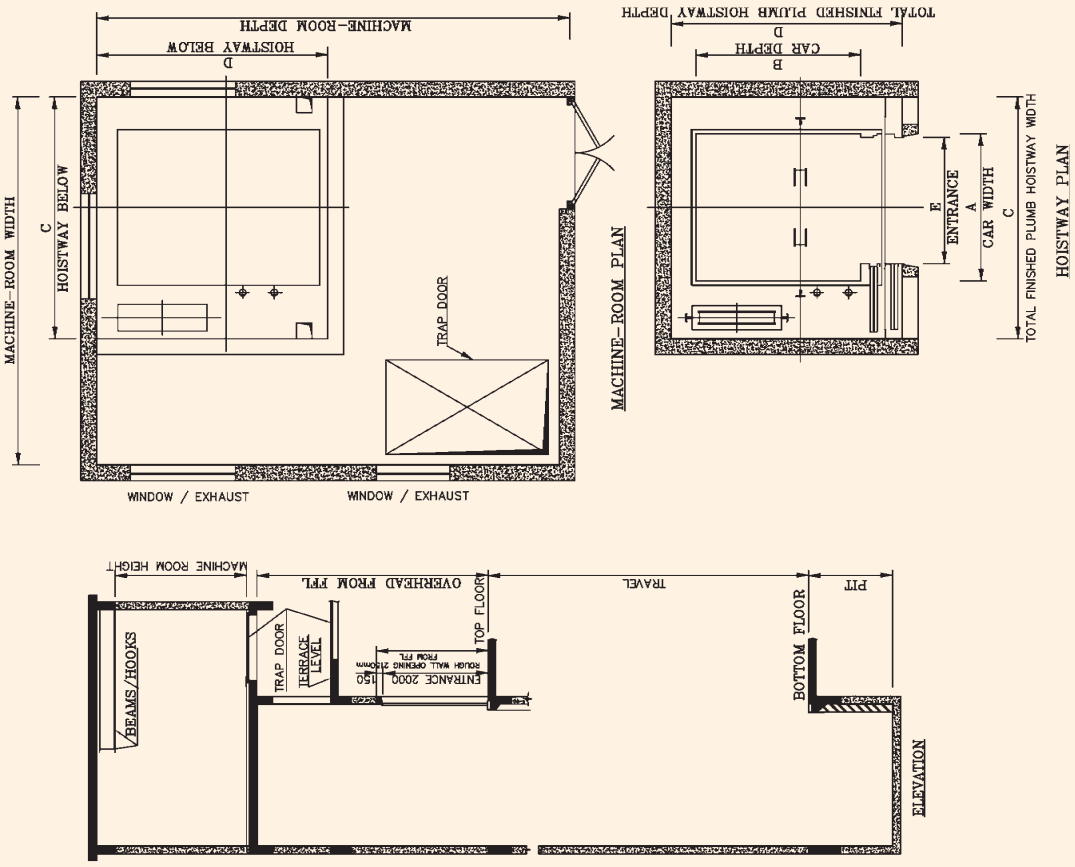
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Table 13 Recommended Dimensions of Stretcher/Hospital Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.



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Table 13 — (*Concluded*)

Sl No.	No. of Passengers	Rated Load	Rounded off Rated Load	Car Size		2P TSPD Door	Hospital Bed / Stretcher Lifts with Machine Room: Shaft Sizes													
							Rated Speed ≤ 1 m/s		0.6 m/s ≤ Rated Speed ≤ 2.5 m/s		3.0 m/s ≤ Rated Speed ≤ 3.5 m/s		4.0 m/s ≤ Rated Speed ≤ 5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s ≤ Rated Speed ≤ 8.0 m/s		9.0 m/s ≤ Rated Speed ≤ 10.0 m/s	
							Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
		kg	kg	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
i)	15	1 020		1 000	2 400	800	1 800	3 000	1 800	3 000										
ii)	20	1 360		1 300	2 400	1 200			2 300	3 000	2 350	3 000	2 350	3 000	2 350	3 000	2 500	3 000	2 500	3 000
iii)	26	1 768	1 800	1 400	2 550	1 200			2 500	3 050	2 500	3 050	2 500	3 050	2 500	3 050	2 600	3 150	2 650	3 150
iv)	29	1 972	2 000	1 500	2 700	1 400			2 650	3 200	2 600	3 200	2 600	3 200	2 600	3 200	2 700	3 200	2 700	3 200
v)	36	2 448	2 500	1 800	2 700	1 400			2 800	3 150	2 900	3 200	2 900	3 200	2 900	3 200	3 000	3 200	3 000	3 200

NOTES

1 All dimensions given above for lifts having two panel telescopic doors (2P TSPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, variation in:

a) car inside dimensions shall be within the maximum area limits specified in accordance with accepted standards [8-5A(6)].

b) entrance width on higher side is permitted.

c) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

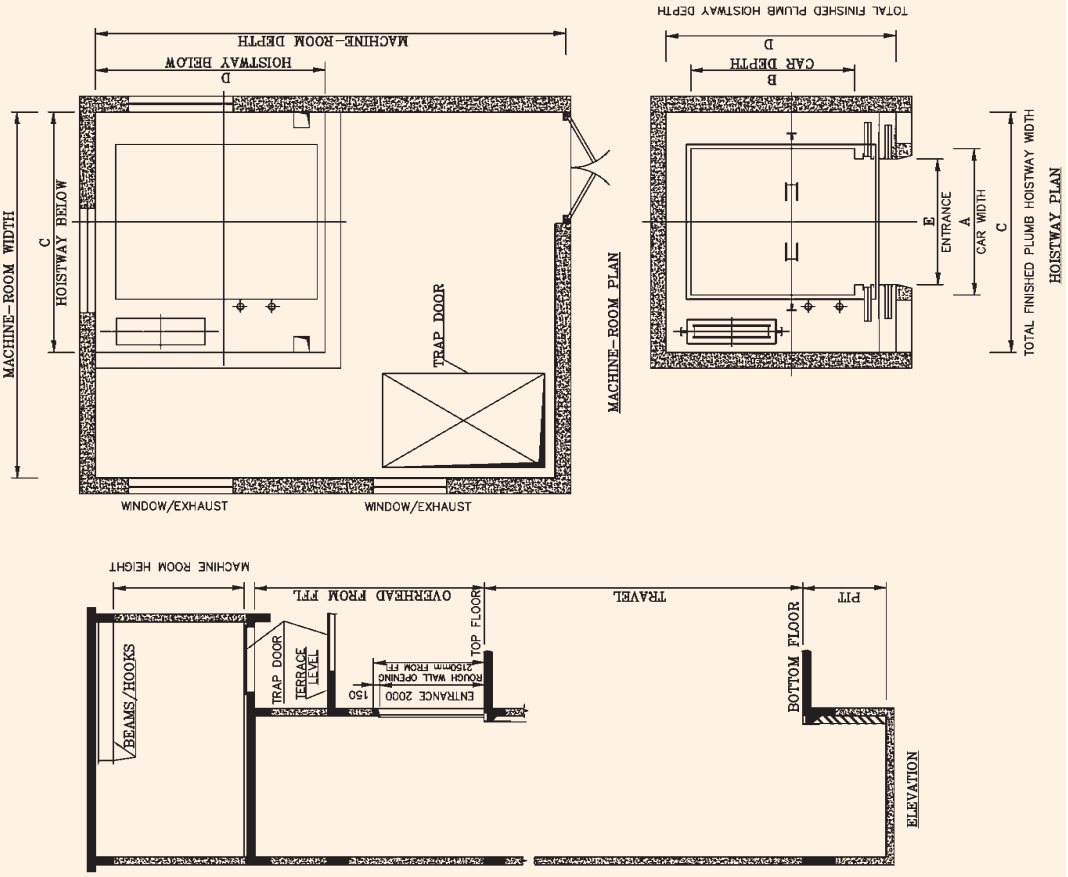
2 Car depth of 2 100 mm may be considered in residential/commercial buildings, where use of only ambulance stretcher is envisaged. The hoist-way depth maybe reduced accordingly.

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Table 14 Recommended Dimensions of Goods Lifts with Machine Room

(*Clause* 5.10.3.1)

All dimensions are in millimetres.



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Table 14 — (*Concluded*)

Sl No.	Rated Load	Car Size		COPD Door	0.6 m/s ≤ Rated Speed ≤ 2.5 m/s		3.0 m/s ≤ Rated Speed ≤ 3.5 m/s		4.0 m/s ≤ Rated Speed ≤ 5.0 m/s		Rated Speed = 6.0 m/s		7.0 m/s ≤ Rated Speed ≤ 8.0 m/s		9.0 m/s ≤ Rated Speed ≤ 10.0 m/s	
					Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size		Shaft Size	
	kg	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width	Depth	Width
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
i)	1 000	1 400	1 800	2P-tel-1200	2 300	2 350										
ii)	1 500	1 700	2 000	4P-1500	2 750	2 550										
iii)	2 000	1 700	2 500	4P-1500	2 800	3 050	2 800	3 050	2 900	3 050	3 000	3 050	3 000	3 050	3 000	3 050
iv)	2 500	2 000	2 500	4P-1700	3 000	3 050	3 000	3 050	3 100	3 050	3 200	3 050	3 200	3 050	3 200	3 050
v)	3 000	2 000	3 000	4P-1700	3 000	3 550	3 000	3 550	3 100	3 550	3 200	3 550	3 200	3 550	3 200	3 550
vi)	4 000	2 500	3 000	6P-2100	3 700	3 650	3 700	3 650								
vii)	5 000	2 500	3 600	6P-2100	3 850	4 250	3 850	4 250								

NOTE — All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the goods lift shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

Table 15 Recommended Dimensions of Machine Room Height, Overhead, Pit Depth for Passenger, Goods, Stretcher/Hospital Lifts with Machine Room

(*Clause* 5.10.3.1)

All dimensions in millimetres.

For speed up to 3.5 m/s

Sl No.	No. of Passengers	Rated Load	Dimensions of Pit Depth, Overhead Height (HR) and Machine Room Height (MR)																				
			0.7 m/s			1.0 m/s			1.6 m/s			2 m/s			2.5 m/s			3 m/s			3.5 m/s		
		kg	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
i)	4	272	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500									
ii)	6	408	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500									
iii)	8	544	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500									
iv)	10	680	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500									
v)	13	884	1 350	CH + 1 900	2 500	1 500	CH + 1 950	2 500	1 600	CH + 2 400	2 500	2 200	CH + 2 800	2 500									
vi)	14	952				1 500	CH + 1 950	2 500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 000	CH + 3 000	3 000	4 500	CH + 3 450	3 000
vii)	16	1 088 / 1 000				1 500	CH + 1 950	2 500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 000	CH + 3 000	3 000	4 500	CH + 3 450	3 000
viii)	18	1 224				1 500	CH + 1 950	2 500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	2 500	3 000	CH + 3 000	3 000	4 500	CH + 3 450	3 000
ix)	20	1 360				1 500	CH + 1 950	2 500	1 800	CH + 2 400	2 500	2 200	CH + 2 800	2 500	2 500	CH + 3 000	3 000	3 000	CH + 3 000	3 000	4 500	CH + 3 450	3 000
x)	22	1 496 / 1 500				1 500	CH + 1 950	2 500	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 000	CH + 3 000	3 000	4 500	CH + 3 450	3 000
xi)	26	1 768				1 500	CH + 1 950	3 000	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 000	CH + 3 450	3 000	4 500	CH + 3 450	3 000
xii)	29	1 972 / 2 000				1 600	CH + 1 950	3 000	1 800	CH + 2 400	3 000	2 200	CH + 2 800	3 000	2 500	CH + 3 000	3 000	3 000	CH + 3 450	3 000	4 600	CH + 3 450	3 000
xiii)		2 500				1 800	CH + 1 950	4 000	1 800	CH + 2 400	4 000	2 200	CH + 2 800	4 000	2 500	CH + 3 000	4 000	3 000	CH + 3 450	4 000	4 600	CH + 3 450	4 000
xiv)		3 000				1 800	CH + 1 950	4 000	1 800	CH + 2 400	4 000	2 200	CH + 2 800	4 000	2 500	CH + 3 000	4 000	3 200	CH + 3 450	4 300	4 600	CH + 3 600	4 300
xv)		4 000				1 800	CH + 2 200	4 300	1 800	CH + 2 400	4 300	2 200	CH + 2 800	4 300	2 500	CH + 3 000	4 300	3 200	CH + 3 450	4 300	4 600	CH + 3 600	4 300
xvi)		5 000				1 800	CH + 2 200	4 500	1 800	CH + 2 400	4 500	2 200	CH + 2 800	4 500	2 500	CH + 3 000	5 000	3 200	CH + 3 450	5 000	4 600	CH + 3 600	5 000

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Table 15 — (*Concluded*)

For speed from 4 m/s to 10 m/s

Sl No.	No. of Passengers	Rated Load	Passenger, Goods, Stretcher/Hospital Lifts With Machine Room: Dimensions of Pit Depth, Overhead Height (HR) and Machine Room Height (MR)																				
			4 m/s			5 m/s			6 m/s			7 m/s			8 m/s			9 m/s			10 m/s		
		kg	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR	Pit Depth	HR	MR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
i)	14	952	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
ii)	16	1 088/ 1 000	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
iii)	18	1 224	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
iv)	20	1 360	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
v)	22	1 496/ 1 500	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 000	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
vi)	26	1 768	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 300	5 500	CH + 3 800	4 300	5 900	CH + 5 000	4 300	6 500	CH + 5 800	4 300	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
vii)	29	1 972/ 2 000	4 600	CH + 3 450	4 000	4 700	CH + 3 450	4 300	5 500	CH + 3 800	4 300	5 900	CH + 5 000	5 000	6 500	CH + 5 800	5 000	7 100	CH + 6 500	5 000	7 500	CH + 6 900	5 000
viii)		2 500	4 600	CH + 3 450	4 300	4 700	CH + 3 450	5 000	5 500	CH + 3 800	5 000	5 900	CH + 5 500	5 000	6 500	CH + 6 300	5 000	7 100	CH + 7 000	5 000	7 500	CH + 7 500	5 000
ix)		3 000	4 600	CH + 3 600	4 300	4 700	CH + 3 600	5 000	5 500	CH + 4 000	5 000	5 900	CH + 5 500	5 000	6 500	CH + 6 300	5 000	7 100	CH + 7 000	5 000	7 500	CH + 7 500	5 000

CH — Car clear inside height measured from car finished floor level to false ceiling.

NOTES

1 Recommended dimensions for pit depth, overhead and machine-room for different lift speeds are given in the table above. These dimensions may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5A(7)].

2 In case of goods lifts minimum pit depth required is 1 600 mm.

3 In case of lift speeds 3.5 m/s and 4 m/s with rear counterweight the pit depth requirement could be less by about 500 mm to 1 000 mm.

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Table 16 Recommended Dimensions of Automobile Lifts with Machine Room — Through Type Car (Rated Speed = 0.6 m/s or 1.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

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Table 16 — (*Concluded*)

Sl No.	Rated Load	Car Size		COPD Door	Shaft Size		Car Height	Overhead Height	Pit Depth	Machine Room Height
		Width	Depth	Width	Width	Depth	CH	HR	PH	MR
	kg									
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
i)	2 500	2 500	5 300	4P-2 400	4 000	6 100			1 800	4 000
ii)	3 000	2 700	5 400	4P-2 400	4 000	6 200				
iii)	4 000	3 000	5 800	6P-3 000	4 300	6 700	2 400	5 200		4 500
iv)	5 000	3 000	6 000	6P-3 000	4 300	6 900			2 000	

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the automobile lift shall be based on a load of not less than 1.45kN/m^2 of the net inside car area.

2 Dimensions of machine room height, pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5A(7)].

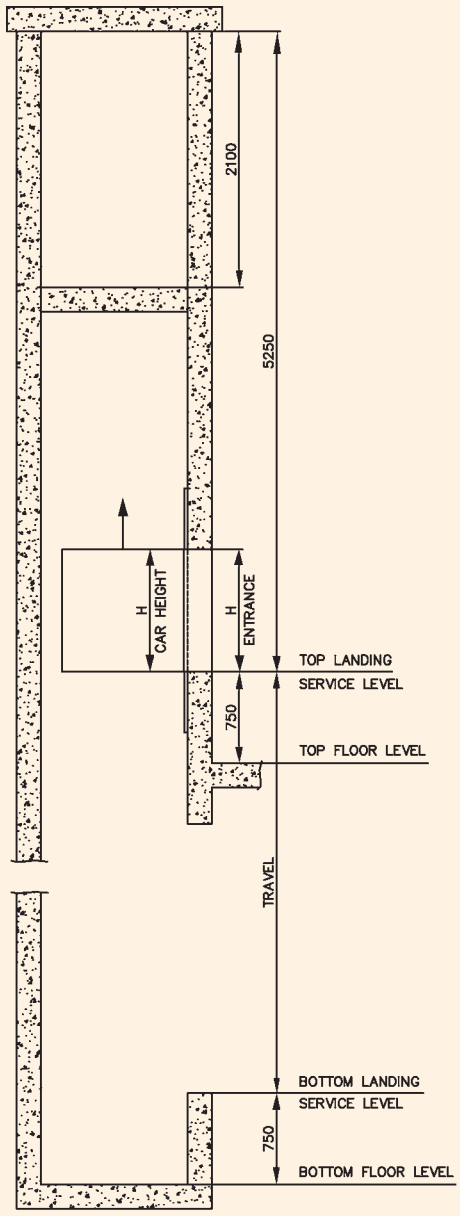
3 The lift car width should be selected such that in case of emergency while the automobile is in the car-lift the driver should be able to open the automobile door and come out of the automobile.

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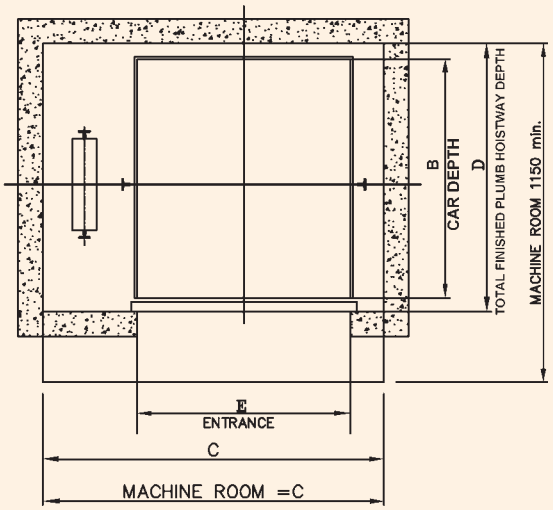
Table 17 Recommended Dimensions of Dumbwaiter Lifts

(*Clause* 5.10.3.1)

All dimensions in millimetres.



ELEVATION



HOISTWAY PLAN

Sl No.	Load	Car Inside			Lift Well		Entrance
	kg	*A*	*B*	*H*	*C*	*D*	*E*
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	100	700	700	800	1 200	900	700
ii)	150	800	800	900	1 300	1 000	800
iii)	200	900	900	1 000	1 400	1 100	900
iv)	250	1 000	1 000	1 200	1 500	1 200	1 000

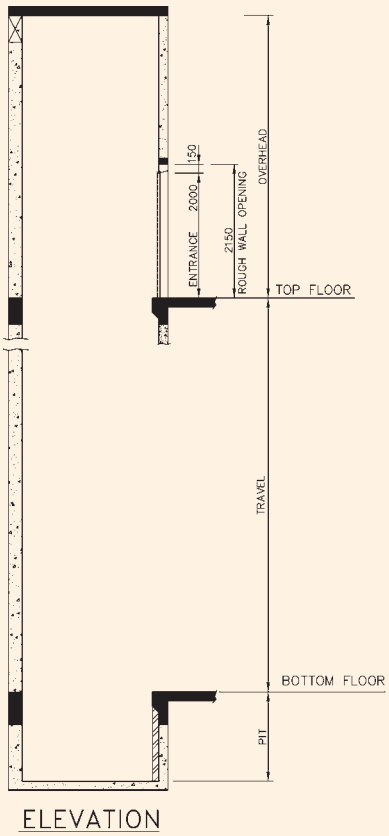
NOTE — Entrance width '*E*' is based on assumption of provision of vertical biparting doors (no car door is normally provided).

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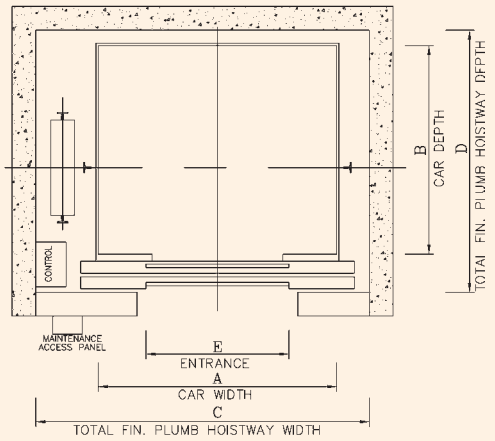
Table 18 Recommended Dimensions of Passenger Lifts MRL COPD

(*Clause* 5.10.3.1)

All dimensions in millimetres.



ELEVATION



HOISTWAY PLAN

Sl No.	No. of Passengers	Rated Load	Car Size		2 P COPD Door	1.0 m/s ≤ Rated Speed ≤ 2.0 m/s		Rated Speed = 2.5 m/s		Rated Speed = 3.0 m/s	
						Shaft Size		Shaft Size		Shaft Size	
		kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
i)	4	272	900	850	700	1 600	1 550				
ii)	6	408	1 000	1 100	800	2 000	1 700				
iii)	8	544	1 300	1 100	800	2 150	1 800				
iv)	10	680	1 350	1 300	800	2 150	1 900				
v)	13	884	1 600	1 400	1 000	2 550	1 950	2 550	2 050	2 550	2 250
vi)	15	1 020	1 600	1 550	1 000	2 550	2 050	2 550	2 150	2 550	2 250
vii)	16	1 088	1 600	1 600	1 000	2 550	2 100	2 550	2 200	2 550	2 300
viii)	20	1 360	1 800	1 700	1 100	2 700	2 300	2 700	2 350	2 700	2 350
ix)	22	1 496	1 800	1 900	1 100	2 700	2 400	2 750	2 450	2 750	2 450
x)	26	1 768	1 900	2 000	1 100	2 800	2 450	2 850	2 450	2 850	2 500
xi)	29	1 972	2 350	1 700	1 200	3 100	2 200	3 100	2 200		

NOTES

1 All dimensions given above for lifts having centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, variation in,

a) car inside dimensions shall be within the maximum area limits specified in accordance with accepted standards [8-5A(6)].

b) entrance width on higher side is permitted.

c) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 The minimum size of the lift car and all other requirements relating to accessibility, in all public buildings shall be in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

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Table 19 Recommended Dimensions of Stretcher/Hospital lifts MRL (2P Telescopic Door/4P COPD, Speed 1.0 m/s to 2.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load		Car Size		Door Size	Shaft Size	
	Persons	kg	Width	Depth		Width	Depth
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	15	1 020	1 100	2 400	900	2 150	2 950
ii)	20	1 360	1 300	2 400	1 200	2 350	2 950
iii)	23	1 600	1 400	2 400	1 300	2 450	2 950
iv)	29	2 000	1 500	2 700	1 300	2 450	3 250

NOTES

1 All dimensions given above for lifts having 2 panel telescopic or 4 panel centre opening power operated doors (4P COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, variation in,

i) car inside dimensions shall be within the maximum area limits specified in accordance with accepted standards [8-5A(6)].

ii) entrance width on higher side is permitted.

iii) entrance width on lower side is permitted up to 100 mm subject to minimum of 700 mm.

2 Car depth of 2 100 mm may be considered in residential/commercial buildings where use of only ambulance stretcher is envisaged. The hoist-way depth maybe reduced accordingly.

Table 20 Pit Depth for Passenger/Stretcher/Hospital Lifts MRL

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	Pit Depth for Speed					
		1 m/s	1.6 m/s	1.8 m/s	2 m/s	2.5 m/s	3 m/s
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	4	1 600	1 800	2 000	2 200		
ii)	6	1 600	1 800	2 000	2 200		
iii)	8	1 600	1 800	2 000	2 200		
iv)	10	1 600	1 800	2 000	2 200		
v)	13	1 600	1 800	2 000	2 200	2 500	3 100
vi)	15	1 600	1 800	2 000	2 200	2 500	3 100
vii)	16	1 600	1 800	2 000	2 200	2 500	3 100
viii)	20	1 800	1 800	2 000	2 200	2 500	3 100
ix)	22	1 800	1 800	2 000	2 200	2 500	3 100
x)	26	1 800	1 800	2 000	2 200	2 500	3 100
xi)	29	1 800	1 800	2 000	2 200	2 500	

NOTE — Recommended dimensions for pit depth for different lift speeds are given in the table. These dimensions may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5A(7)].

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Table 21 Overhead Height for Passenger and Stretcher/Hospital Lifts MRL

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	No. of Passengers	For Speed			
		1 m/s	1.6 m/s ≤ Rated Speed ≤ 2 m/s	2.5 m/s	3 m/s
(1)	(2)	(3)	(4)	(5)	(6)
i)	4	CH + 1 900	CH + 2 400		
ii)	6	CH + 1 900	CH + 2 400		
iii)	8	CH + 1 900	CH + 2 400		
iv)	10	CH + 1 900	CH + 2 400		
v)	13	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
vi)	15	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
vii)	16	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
viii)	20	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
ix)	22	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
x)	26	CH + 1 900	CH + 2 400	CH + 2 600	CH + 2 800
xi)	29	CH + 1 900	CH + 2 400	CH + 2 600	

NOTE — Recommended dimensions for overhead for different lift speeds are given in the table. These dimensions may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5A(7)].

Table 22 Recommended Dimensions of Goods Lifts MRL (Speed 1.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load	Car Size		Door Size	Telescopic Door Shaft Size		4P COPD Shaft Size		2P COPD Shaft Size		Overhead Height	Pit Depth
	kg	Width	Depth	Width	Width	Depth	Width	Depth	Width	Depth	HR	PH
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
i)	500	1 300	1 100	800					1 950	1 800	CH + 1 900	1 600
ii)	1 000	1 600	1 550	1 000					2 250	2 050	CH + 1 900	1 600
iii)	1 600	1 400	2 400	1 300	2 550	3 000	2 500	3 000			CH + 1 900	1 800
iv)	2 000	1 500	2 700	1 300	2 550	3 300	2 550	3 300			CH + 1 900	1 800
v)	2 500	1 800	2 650	1 700			3 150	3 250			CH + 2 100	1 800
vi)	3 000	2 000	2 700	1 800			3 350	3 300			CH + 2 100	1 800
vii)	4 000	2 100	3 400	1 800			3 400	4 000			CH + 2 100	2 100
viii)	5 000	2 500	3 500	2 200			3 800	4 100			CH + 2 400	2 200

NOTES

1 CH is the clear car height from car finished floor level to car roof (goods lifts will normally not have any false ceiling).

2 Normal range for CH is 2 100 mm to 2 400 mm.

3 Door height is less than or equal to the car height CH.

4 In case counterweight safety is applicable check for dimensions with lift manufacturer.

5 All dimensions given above for lifts having telescopic or centre opening power operated doors (COPD) with counterweight at side, are recommended dimensions primarily for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the goods lift shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

6 Recommended dimensions for overhead and pit depth for different lift speeds are given in the table. These dimensions may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the overhead and pit depth shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8-5A(7)].

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Table 23 Recommended Dimensions of Automobile Lifts MRL COPD (Speed 0.5 m/s to 1.0 m/s)

(*Clause* 5.10.3.1)

All dimensions in millimetres.

Sl No.	Rated Load kg	Car Size		6P COPD Door Size: Opposite Entrances	Shaft Size		Overhead Height	Pit Depth
		Width	Depth	Width	Width	Depth	HR	PH
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	3 000	2 500	5 500	2 200	3 800	6 450	4 850	2 500
ii)	4 000	3 000	6 000	2 700	4 300	6 950	4 850	2 500

NOTES

1 Car height normal range is 2 100 mm to 2 700 mm.

2 Overhead height shown is required for all values of car height CH shown above.

3 In case counterweight safety is applicable check for dimensions with lift manufacturer.

4 All dimensions given above for machine room less lifts with 6 panel centre opening power doors (6P COPD) used for automobiles are recommended dimensions for architects and building planners. Any variations mutually agreed to between the manufacturer and the purchaser are permitted. However, the minimum rated load for the automobile lift shall be based on a load of not less than 1.45kN/m^2 of the net inside car area.

5 Dimensions of pit depth and overhead may differ in practice as per individual manufacturer's design depending upon load, speed and drive. However, the pit depth and overhead shall be such as to conform to the requirements of bottom clearance and top clearance in accordance with the accepted standards [8 5A(7)].

6 The lift car width should be selected such that in case of emergency while the automobile is in the lift car the driver should be able to open the automobile door and come out of the automobile.

c) *General requirements related to the lift well* — The well shall be exclusively used for lifts. It shall not contain cables or devices, etc other than for the lift. Permanently installed adequate lighting shall be provided comprising sufficient number of lamps fixed throughout the lift well such that the illumination level 1 m above the car roof within its vertical projection at any position of the car in the well and 1 m above pit floor everywhere a person can stand, work and/or move between the working areas shall be at least 50 lux and at least 20 lux at remaining locations, even when all the doors are closed.

NOTE — Additional lamps may be fixed on the car top as a part of the well lighting system to achieve this.

Well lighting switch shall be located in the machine room close to the main switch and pit lighting switch in lift well close to lower landing door.

Should a lift entrance open out in to an area exposed to the weather, the entrance should be protected by a suitable canopy and the ground level sloped up to the lift entrance to prevent rain or drainage water entering the lift well through the clearances around the landing doors. Any push buttons exposed should be of weatherproof type.

The approach of the landing door on each floor shall be kept lighted during the whole time the lift is available for use at night, and during the day time if so required due to insufficient natural light.

When the distance between consecutive landing door sills exceeds 11 000 mm, intermediate emergency landing(s) with lift landing door(s) shall be provided such that the distance between any two consecutive landings is not more than 11 000 mm. Rescue through these landings is permissible in case of automatic rescue device operation.

No counter-weight shall be allowed to travel in any lift well, or part of any lift well other than that to which it belongs.

In the case of a lift well which is common to more than one lift and where the lift car or the counterweight of one lift is working in juxtaposition to the lift car or counterweight of another lift, such lift cars or counterweights shall be guarded carefully and adequately in order to protect persons working in the lift well or on the lift cars from accidental contact with such cars or counterweights in any part of their travel.

d) *Construction of the lift well* — The side walls of the lift well may be made of reinforced cement concrete at least 150 mm thick; or brick or similar fire resisting materials

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provided tie beams are made available for lift guide rail fixings at such heights as specified by the lift manufacturer, so as to provide satisfactory anchoring arrangement for fixing guide rails and other equipment to the lift well.

The inner surface of the lift well and its enclosure facing any lift-car entrance shall, so far as practicable, be kept smooth and flush devoid of projections or recesses. Where any projections or tops of the recesses cannot be rendered flush, they shall be levelled on the underside to an angle not less than 60° from the horizontal, by means of metal plates, cement rendering or other fire resisting material.

Where a lift car levelling device is operative with the lift car door open, such interior surfaces shall always form a smooth and flush surface below each landing level for a depth to at least the depth of the car-levelling zone plus the distance through which the lift car may travel of its own momentum when the power is cut-off.

The distance between the lift well enclosure on the sides facing any lift-car entrance and the sill edge of the car shall not be more than 30 mm in the landing zone below the landing gate. If such distance is more than 30 mm in the lift well enclosure, the same shall be finished with suitable and smooth plaster work or fascia plates so as to make the surface thereof devoid of all projections and recesses. In case the enclosure wall on the sides facing the lift-car entrance is more than 130 mm from the sill edge of the lift-car platform, the lift-car door of such lift shall be provided with means to prevent it from being opened except when the lift-car is at the landing served by such car entrance.

Sufficient space shall be provided between the guides for the car and the side walls of the lift well enclosure to allow safe and easy access to the parts of the safety gears for their maintenance and repairs.

All landing openings shall be protected by gates or doors which shall extend to the full height and full width of the landing openings. These openings shall not be less than 2 000 mm in clear height and 700 mm clear in width when the gates or doors are fully opened. There shall not be any common wall between lift well and water tank.

e) *Strength of the walls of the well* — The structure of the well shall be able to support at least the loads which may be applied by the machine, by the guide rails at the moment of safety gear operation, by eccentric load in the car, by the action of buffers, by the application of anti-rebound devices, by loading and unloading the car, etc.

The walls of the well shall withstand a force of 1 000 N, being evenly distributed over an area of 900 cm^2 in round or square section and applied at right angles to the wall at any point on either face,

1) without permanent deformation greater than 1 mm; and
2) without elastic deformation greater than 15 mm.

Glass panels, plane or formed shall be made of laminated glass. Such panels and their fixings shall withstand horizontal static force of 1 000 N applied on an area of 900 cm^2 at any point, from either side, without permanent deformation.

f) *Partition walls between lifts in a common lift well* — In case of common lift well for multiple lifts, the partition wall(s) of the common lift well may be either be RCC or brick or steel or glass which may be provided with openings for escape of air displaced due to movement of lift in the adjacent well. For high speed lifts the partition between the lifts maybe of suitable wire grill / expanded metal of following specifications:

1) It shall be made of at least 2.2 mm thick steel wire or expanded metal.
2) A ball of 25 mm diameter shall not pass through the wire grill.
3) It shall be so fixed as not to deflect more than 15 mm when subjected to a force of 450 N applied horizontally at any point from either side.

6.1.2 *Requirements of the Pit*

Pit shall be soundly constructed and maintained in a dry (water proofed) and clean condition. Where necessary, provision shall be made for permanent drainage. The floor of the pit shall be able to support beneath each guide rail, force due to mass of guide rails plus the reaction due to safety gear operation. The floor of the pit shall be able to support beneath the car buffer supports, force in Newton, equal to 4 times the static load being imposed by the mass of fully loaded car:

$$4.g\,(P + Q)$$

where

P = mass of empty car and components supported by the car, that is part of travelling

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cable, compensating rope/chain, if any, etc, in kg;

Q = rated load, in kg; and

g = acceleration due to gravity.

The floor of the pit shall be able to support beneath the counterweight buffer support, force in Newton, equal to 4 times the static load being imposed by the mass of the counterweight:

$$4.g\ (P + q.Q)$$

where

P = mass of empty car and components supported by the car, that is part of travelling cable, compensating rope/chain, if any, etc, in kg;

Q = rated load, in kg;

g = acceleration due to gravity; and

q = live load balancing factor (normally, $q = 0.5$).

The floor of the pit shall be able to support upward thrust of the tied down rope compensation device, if provided. If accessible spaces do exist below the well, the base of the pit shall be designed for an imposed load of at least 5 000 N/m^2 and the counterweight shall be equipped with safety gear. In addition, it is recommended to provide double slab for the lift pit.

NOTES

1 Lift wells should preferably not be situated above a space accessible to persons.

2 Enclosing projected area of the lift shaft under the pit in accessible spaces will not nullify above provisions.

There shall not be any common wall/slab between lift pit and any water reservoir.

The pit shall be accessible by an access door. A permanent ladder inside the well may be provided close to the last landing *in-lieu* of access door, if the pit depth does not exceed 2.5 m.

NOTE — In case of structural limitations for providing pit access door at pit floor level, alternative arrangement to access pit may be provided which shall allow access to pit with complete safety.

A physical means of protection shall be provided to prevent accidental contact with the counterweight.

The pit shall be equipped with a stop switch which is easily accessible from the lowest landing and the pit floor. If more than one switch is required, they shall be wired in series.

6.1.3 *Requirements Associated with Machine Room and Pulley Room*

Generally lifts have machine rooms immediately over the lift well, and this should be arranged, whenever possible without restricting the overhead distance required for normal safety precautions. In case where machine room provision on top is a limitation, either machine room less lift or basement drive or side drive lift can be considered. The spaces and tolerances shall be in accordance with the following:

a) *Requirements associated with machine room and pulley room (where lift machinery is placed in the machine room)*

1) The lift machine, controller and all other apparatus and equipment of a lift installation, except such apparatus and equipment having functional location in the lift well or other positions, shall be placed in the machine room which shall be adequately lighted and rendered fire-resistant and weather-proof.

   If parts of different lifts are present in one machine and/or pulley room each lift shall be identified with a number, letter or colour consistently used for all parts (machine, controller, over speed governor, switches, etc).

2) Machine room should be considered as plant space, and conditions provided to permit reliable operation of electrical switchgear and rotating machinery, and be conducive to good maintenance. The machine room shall be either air conditioned or adequately ventilated so as to maintain the ambient temperature therein between +5°C and +40°C. The machine room shall be such that the motors and equipment as well as electric cables etc are protected as far as possible from dust and humidity. Machine room should also be protected from all weather and if ventilation louvers are provided, they should be designed and located to prevent entry of rain water in the machine room.

   The well, machinery spaces and pulley rooms shall not be used to provide ventilation of rooms other than those belonging to the lift.

3) Rescue instructions with required tools and tackles, if any, shall be made available in the machine room.

4) Machine room floor shall be provided with a trap door, if necessary. The size of the trap door shall be as per manufacturer's recommendation. Since the purpose of the trap door is to lift or lower the machinery, controller, etc, between machine room and the top landing, it may be necessary to provided similar trap door in the terrace slab as well depending on the design of the building.

   The trap door when closed shall be able to support 2 000 N on an area of 0.20 m × 0.20 m

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at any position. The trap door shall not open downwards. Hinges, if any, shall be of a type which cannot be unhooked. Trap doors shall be locked. When the trap door is in the open position, precautions shall be taken to prevent the fall of persons (for example, a guardrail) and prevent the trapdoor from closing such as to cause a crushing hazard (for example by counterbalance).

5) Lighting shall be provided to give at least 200 lux around the controller and machine. At least one plug socket point per lift shall be provided in the machine room. The switch for the machine room light shall be fixed near the entrance of the machine room. The machine room walls, ceiling and floor should be finished in dust-resisting materials, tiles, etc, or painted as a minimum to stop dust circulation, which otherwise could damage rotating machinery and cause failure of switchgear.

6) The machine room shall be so designed as to allow free and easy access to all parts of the equipment and the width of the clear space around the machine from any two sides shall in no case be less than 600 mm. Provision shall be made to allow the removal and replacement of various units. The entrance of the machine room shall be minimum 1 m wide and 2 m high to allow removal and replacement of machinery therein. The floor of the machine room shall be designed and constructed to carry safely at any point the heaviest part of the equipment and withstand the loads and forces to which they are intended to be subjected to. If the floor does not extend to the enclosing wall, the open sides shall be adequately guarded by suitable means for example, rails, guards.

7) The height of the machine room shall be sufficient to allow any portion of the equipment to be accessible and removable for repairs and replacement and shall not be less than 2 000 mm clear from the floor of the access area and working area. There shall be a clear vertical distance of at least 300 mm above the rotating parts of the machine.

8) The machine room shall be locked and shall be accessible to those who are concerned with the operation and maintenance of the machinery or equipment. Approach way to machine room from top landing level shall be direct, easy and safe to walk by way of stairs. If stairs are not possible, sufficiently wide and deep permanent structural steps may be used. These structural steps shall be provided with adequate hand holds and shall not be too steep.

9) A danger notice board shall be displayed permanently on the outside of the machine room door and near the machinery.

10) There shall not be any common wall/slab between machine room and any water reservoir.

11) The machine room shall not be used as a store room or for any purpose other than housing the machinery/components connected with the lift installation. The machine room shall not act as a passage to any other room or utility.

    The lift well, machine and pulley rooms may, however contain,

    i) equipment for air conditioning or heating of these spaces, excluding steam heating and high pressure water heating. However, any control and adjustment devices of the heating apparatus shall be located outside the well.

    ii) fire detectors and/or suppression system, with a high operating temperature, appropriate for the electrical equipment and suitably protected against accidental impact.

    When sprinkler systems are used, activation of the sprinkler shall only be possible, when the lift is stationary at a landing and the electrical supply of the lift and lighting circuits are automatically switched off by the fire or smoke detection system.

    NOTE — Such smoke, fire detection and sprinkler systems are the responsibility of the building management.

12) Machine room floor shall be designed to carry an imposed (live) load of not less than 10 kN/m^2 over the whole area and also any load which may be imposed thereon by the equipment used in the machine room or by any reaction from any such equipment both during periods of normal operation, maintenance and repair.

13) One or more beams or hooks with the indication of the safe working load, as appropriate, shall be provided in the machinery spaces, and conveniently positioned to permit the hoisting of heavy equipment.

14) The total load on overhead beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

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15) The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with (14) shall be not less than the following:

i) For steel : 5
ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

16) The place in which the overhead pulleys, over speed governors and similar machinery are fixed shall be easily accessible for maintenance and repair purposes. It shall be lighted adequately and safe working procedure shall be established for maintenance and repair works.

17) It is recommended that emergency exit is provided in case of large machine rooms having four or more lifts.

18) Where the machine room occupies a prominent position on roof of a building, provision should be made for lightning protection in accordance Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code and applicable standards.

b) *Requirements associated with machine spaces (where machinery is placed in the well)*

1) Access to the interior of the machinery and pulley spaces shall be capable of being properly lit by a permanent electric light fixture(s) and easy to use in complete safety in all circumstances without necessitating entry into private premises.

2) Machinery spaces inside the well shall be designed and constructed to withstand the loads and forces they are subjected to.

3) In the case of partially enclosed wells located at the exterior of the building, the machinery shall be suitably protected against environmental influences.

4) Provision should be given to access the machine for maintenance purpose either from car top or otherwise

5) The clear height for movement shall not be less than 2 m.

6) The machinery spaces shall be suitably ventilated. The electric equipment of the machinery shall be protected as far as it is reasonably practicable from dust, harmful fumes and humidity.

7) The working area and machinery spaces shall be provided with permanently installed electric lighting on the basis of at least 200 lux at floor level.

8) One or more beams or hooks with the indication of the safe working load, as appropriate, shall be provided in the machinery spaces, conveniently positioned to permit the hoisting of heavy equipment.

9) The total load on overhead beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

10) The factor of safety for all overhead beams and supports based on ultimate strength of the material and load in accordance with (9) shall be not less than the following:

i) For steel : 5
ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

c) *Requirements associated with machine spaces (where machinery is placed outside of the well)*

1) Machinery spaces outside of the well shall be constructed to withstand the loads and forces to which they are subjected.

2) The total load on beams used for supporting machinery shall be assumed as equal to all equipment resting on the beams plus twice the maximum load suspended from the beams.

3) The factor of safety for all beams and supports based on ultimate strength of the material and load in accordance with (2) above shall be not less than the following:

i) For steel : 5
ii) For reinforced concrete : 7

The deflection of the overhead beams under the maximum static load calculated in accordance with above shall not exceed 1/1 500 of the span.

4) Access to the interior of the machinery and pulley spaces shall be,

i) capable of being properly lit by a permanent electric light fixture(s); and
ii) easy to use in complete safety in all circumstances without necessitating entry into private premises.

The clear height for movement shall not be less than 2 m.

5) The machinery shall be located inside a

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cabinet consisting of imperforate walls, floor, roof and lockable door(s).

6) The machinery cabinet shall be suitably ventilated. It shall be such that the machinery is protected as far as it is reasonably practicable from dust, harmful fumes and humidity.

7) The inside of the machinery cabinet shall be provided with permanently installed electric lighting on the basis of at least 200 lux at floor level. The switch placed inside close to the door(s), at an appropriate height, shall control lighting of the cabinet.

d) *Dimensional tolerances*

1) *Lift well dimensions* — Plan dimensions of lift wells given by the lift manufacturer represent the minimum clear plumb sizes. The purchaser's representative, in conjunction with the builder, should ensure that adequate tolerances are included in the building design so that the specified minimum plumb dimensions are obtained in the finished work. Dimensions in excess of these minimum plumb dimensions for lift well and openings (but not less) can be accommodated by the lift manufacturer up to certain maximum values beyond which changes in design may be necessary involving additional expense or work by the builder. The purchaser's representative should take these factors into account when specifying the lift well structural dimensions on the basis of the constructional tolerance appropriate to the building technique.

2) *Landing door openings* — It is very important that finished landing openings should be accurate to design size and plumb one above the other for the full travel of the lift. In constructing the structural openings in concrete walls to lift wells it is not possible to achieve a degree of accuracy vertically which will allow doors and frames to be inserted in the opening without some form of masking or packing to overcome inaccuracies. Provisions should therefore be made in design by increasing the nominal height from design finished floor level and width of openings to each jamb and head. In addition, the alignment of the outer face of the front wall of the lift well is of importance when architrave of fixed dimensions are called for, and in this case the alignment of the outer face from floor to floor should not vary to a greater extent than can be accommodate by the subsequent front wall finish, the architrave being set accurately plumb.

3) *Structural limits for lift wells at any level* — If the net plumb well (dimensions *A* and *B* in Fig. 3) and the nominal structural entrance openings (dimensions *C* and *D* in Fig. 3) are defined by plumb lines, the actual wall should not encroach on these dimensions.

Dimension *K* (inside face of wall of Fig. 3) should fall within the following limits:

i) For wells up to 30 m : 0 - 25 mm
ii) For wells up to 60 m : 0 - 35 mm
iii) For wells up to 100 m : 0 - 50 mm
iv) For wells taller than 100 m : 0 - 50 mm for any 100 m portion of the well.

When architraves are to be supplied by the lift manufacturer dimension *L* (side of structural opening of Fig. 3) should fall within the limits of 0 and 25 mm and dimension *M* (outer face of the front wall of Fig. 3) should not vary to a greater extent than can be accommodated by the subsequent front wall finish, the architrave being set accurately plumb. When the entrance linings are supplied by the builder, corresponding provision should be made for the finished openings to be accurately plumb one above the other for the full travel of the lift end to design size.

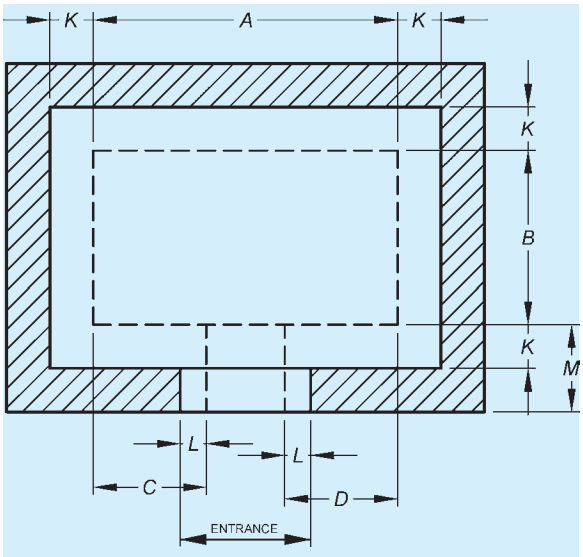


FIG. 3 LIFT WELL TOLERANCE

6.2 Electrical Installation Requirements

The lift manufacturer should specify, on a schedule, particulars of full load current, starting current, maximum permissible voltage drop, size of switches

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and other details to suit requirements. The main power cable and lighting cable shall be routed through respective lift shaft for every lift. It is important that the switches at the intake and in the machine room which are provided by the electrical contractor are of correct size. No form of 'NO VOLT' trip relay should be included anywhere in the power supply of the lift.

6.2.1 *Main Switches*

For each lift, a main switch capable of breaking the supply to the lift on all the live conductors shall be provided. This switch shall be capable of interrupting the highest current involved in normal conditions of use of the lift.

This switch shall not cut the circuits feeding the following:

a) Car lighting and ventilation
b) Socket outlet on the car roof;
c) Lighting of machinery spaces;
d) Socket outlet in the machinery and pulley spaces and in the pit;
e) Lighting of the lift well including pit;
f) Alarm device; and
g) Automatic rescue device.

The switch shall be located,

1) in the machine room, where it exists;
2) where no machine room exists, in the control cabinet; and
3) at the emergency and test panel, when control panel is mounted in the well.

If the emergency panel is separate from test panel, the switch shall be at emergency panel. If the main switch is not easily accessible from the controller cabinet, then the cabinet shall be provided with an isolating switch.

The main switches shall have stable open and closed positions, and shall be capable of being locked-off in the open position with the use of a padlock or equivalent, to ensure no inadvertent operation takes place.

For a single lift, this switch should be fixed adjacent to the machine room entrance in the machine room. In a machine room common to more than one lift, each main switch should be conveniently situated with respect to the lift it controls.

The supply to the car light should be from a separate circuit, and controlled by a switch in the machine room. For multiple lifts with a common machine room a separate supply should be provided for each car. The car lighting supply should be independent of the power supply mains

Any capacitors to correct the power factor shall be connected before the main switch of the power circuit.

6.2.2 *Residual Current Device*

Residual current device (RCD), if provided, right type and sensitivity shall be selected.

The RCD shall,

a) have 10 times the maximum leakage current (300 mA maximum) as tripping current and be suitable for frequency converters with a 3-phase supply.
b) be sensitive for sinusoidal currents up to 1 000 Hz, insensitive for currents more than 1 000 Hz.

NOTE — This kind of RCDs are generally classified as 'Type B'.

Three-phase power supply for the lift should never be protected with a 30 mA residual current device (RCD). The 30 mA RCD trips easily when the lift starts to drive and prevents the lift to run. If the construction-time power supply is for some reason protected with a 30 mA residual current device (RCD), suitably sized isolation transformer needs to be provided by the electrical contractor.

6.2.3 *Supply Cables Wiring and Apparatus*

The main power supply cables providing the electricity supply to a lift installation shall be flame retardant type PVC or XLPE insulated armoured cables. The cable should be terminated in the main switch. For each lift, one $415\ ^{+6\ \text{Percent}}_{-10\ \text{Percent}}$ V , 3-phase, 4-wire, 50 Hz and one single phase $230\ ^{+6\ \text{Percent}}_{-10\ \text{Percent}}$ V , 2-wire, 50 Hz supply shall be independently provided. Other than this, power circuit at $230\ ^{+6\ \text{Percent}}_{-10\ \text{Percent}}$ V percent for power and lighting sockets in the lift machine room and the lift shaft shall be provided. This is to facilitate maintenance and other related works with lighting and socket outlets while the lift is switched off.

No cables which are not part of lift installation shall be run in the lift well. The lift cables shall be run in respective lift wells.

Fixed electrical wiring for circuit voltage up to 250 V located in lift wells shall be one of the following:

a) PVC wires encased in rigid metal conduit or trunking.
b) PVC insulated PVC sheathed cables.
c) PVC wires in flexible metallic or plastic conduits not exceeding 1 500 mm in length for limit switches, interlocks, push buttons and similar devices.

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Control cables on lift cars shall be run in rigid metallic conduit or trunking. Short runs of flexible conduits may be used, where they are securely fastened in place and not exposed to oil and grease. Short runs of flexible cord may be used as flexible connections between fixed wirings on the car and the switch on car door provided that chord is securely fastened in position and so located as not to be subjected to mechanical damage.

Wiring in machine room shall be run in rigid metallic trunking. The trunking in machine room floor shall be flush with the finished floor to avoid trip hazard. The following additional requirements may also be taken care of:

1) The lift sub-circuit from the meter room should be separate from other building services. Each lift should be capable of being isolated from the mains supply. This means of isolation should be lockable. The electric supply cables shall run in a route safe from fire, subsequently within the respective lift shafts to the machine room.
2) For banks of interconnected lifts, a separate sub-circuit is required for the common supervisory system, in order that any car may be shut down without isolating the supervisory control of the remainder lifts.
3) When the alarm system is connected to a transformer or trickle charger, the supply should be taken from the machine room lighting.
4) All electrical supply lines and apparatus in connection with the lift installation shall be so constructed and shall be so installed, protected, worked and maintained that there may be no danger to persons therefrom.
5) All metal casings or metallic coverings containing or protecting any electric supply lines of apparatus shall be efficiently earthed.
6) No bare conductor shall be used in any lift car as it may cause danger to persons.
7) All cables and other wiring in connection with the lift installation shall be of suitable grade for the voltage at which these are intended to be worked and if metallic covering is used it shall be efficiently earthed.
8) Suitable caution notice shall be affixed near every motor or other apparatus in which voltage used exceeds 250 V.
9) A single trailing cable for lighting control and signal circuit shall be permitted, if all the conductors of this trailing cable are insulated for maximum voltage running through any one conductor of this cable.
10) *Emergency signal or telephone* — The lift car shall be provided either with an emergency signal that is operative from the lift car and audible outside the lift well or with a telephone.
11) When an alarm bell is to be provided, each car is fitted with an alarm push button which is wired to a terminal box in the lift well at the ground floor by the lift manufacturer. This alarm bell, to be supplied by the lift manufacturer (with indicator for more than one lift) should be fixed in an agreed position and wired to the lift well. The supply may be from a battery (or transformer) fixed in the machine room or, when available, from the building fire alarm supply.
12) When a telephone is to be provided in the lift car the lift manufacturer should fit the cabinet in the car and provide wiring from the car to a terminal box adjacent to the lift well. Alternatively, a hands-free unit may be provided. The type of telephone should be stated in the enquiry.

6.2.4 *Earthing*

There shall be separate exclusive earth pit for the lift or a group of lifts or the same shall be connected to equipotential bonding system. There shall be two separate and distinct earth conductors provided from the earth pit to the machine room as per good practice [8-5A(8)]. The cross-sectional area of copper earthing conductor shall be not smaller than half that of the largest current-carrying conductor subject to an upper limit of 65 mm^2.

In case of buildings having earthing through earth mats or earth grids, it is permissible to earth the lift equipment with separate conductors from these earth mats/grids. Separate earth pits shall not be a requirement in this case.

The terminal for the earthing of the frame of the motor, the winding machine, the frame of the control panel, and similar electric appliances which normally carry the main current shall be at least equivalent to a 10 mm diameter bolt, stud or screw.

The terminal for the earthing of the metallic cases and covers of door interlocks, door contacts, call and control buttons, stop buttons, car switches, limit switches, junction boxes and similar electrical fittings which normally carry only the control current shall be at least equivalent to 5 mm brass screw (such terminal being one specially provided for this purpose), and the earth conductor size shall be at least equivalent to 0.5 mm^2 copper.

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The earth conductor shall be secured to earthing terminal in accordance with the recommendations made in good practice [8-5A(8)] and also in conformity with the latest provisions of *The Indian Electricity Act*, 2003 and the Rules framed thereunder from time to time.

The exposed metal parts of electrical apparatus installed on a lift car shall be sufficiently bonded and earthed.

Where screwed conduit screws into electric fittings carrying control current making the case and cover electrically continuous with the conduit, the earthing of the conduit may be considered to earth the fitting. Where flexible conduit is used for leading into a fitting, the fitting and such length of flexible conduit shall be effectively earthed.

7 FIRE PROTECTION REQUIREMENTS FOR LIFTS

7.1 Fire Protection Requirements of Lifts in High Rise Buildings

7.1.1 *Buildings of Height 15 m and Above*

Following requirements over and above those specified in **6** and **8** and in Part 4 'Fire and Life safty' of the Code are applicable to all lifts provided in buildings having height more than 15 m:

a) All materials of constructions in load bearing elements, stairways and corridors and facades shall be non-combustible.

b) The interior finishing materials shall be of very low flame spread type.

c) Walls of the lift bank well enclosure for a lift or group of lifts shall have a fire rating of 120 min. The lift well shall have a vent at the top, of area not less than 0.2 m^2 per lift.

d) *Landing doors* — Lift landing doors shall be imperforate. Collapsible doors shall not be permitted. Lift landing doors provided in the lift enclosure shall have a minimum fire resistance rating of 60 min.

e) *Lift car door* — Lift car doors shall be imperforate. Collapsible car doors shall not be permitted.

f) Telephone or other communication facilities shall be provided in the lift car and the lift main lobby. Communication system for lifts shall also be connected to the fire control room of the building if provided. For lifts for use by persons with disabilities, the facilities shall be provided in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

g) Photo luminescent safety signs shall be posted and maintained on every floor at or near the lift indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall have the plan of the respective floor showing location of the stairways. The plan shall also indicate the direction to and the level of refuge area. All signs posted and maintained on every floor of buildings open to and used by the public shall comply with the requirements of accessible signage given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

h) All lifts (fireman's lifts/non fireman's lifts) shall be provided with Phase I operation as per **7.1.1**(k)(x) (grounding operation).

j) The grounding operation may be initiated by individual switches for lifts or a common switch for a group of lifts or by a signal from fire alarm system of the building if available.

k) *Fireman's lift* — The fireman's lift is provided in a building for the purpose of aiding firefighters in evacuating trapped persons in the building and to take the equipment for fighting fire to upper levels with minimum delay. Some lifts out of all the lifts shall be identified as fireman's lifts.

The number of required fireman's lifts and their locations in a building will vary depending on the size, design, complexity of the building. Some considerations are as follows:

1) There shall be at least one fireman's lift per building.

2) If there are multiple wings in the building, there shall be at least one fireman's lift per wing.

3) If there are multiple banks of lifts in the building there shall be at least one fireman's lift per bank of lifts.

4) If the building height is up to 600 m and it is zoned height-wise and it does not have single fireman's lift serving every floor of the building, then there shall be at least one fireman's lift per zone which shall serve the main level/fire access level and shall serve all the landings in the respective zone.

5) If the building height is more than 600 m and it does not have any single firman's lift serving all the floors, that is, it has all lifts serving only respective zones,

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the fireman's lift shall be provided in each zone separately, serving all landings in respective zone, with a transfer landing for transferring from one zone to another.

Considering all the above, the fireman's lift(s) shall be identified on the building plan and duly displayed in Fire Command Centre.

To be effective in firefighting operation, the fireman's lift shall have following requirements:

i) The fireman's lift may be used by the occupants in normal times.

ii) The fireman's lift shall be provided with a fireman's switch. The switch shall be a two position (ON/OFF) switch fixed at the evacuation floor (normally main entrance floor) for enabling the lift to be put into fireman's mode. The switch shall be situated in a glass-fronted box with suitable label and fixed adjacent to the lift at the entrance level. When the switch is on, landing call-points shall become inoperative and the lift shall be on the car control only or on a priority control device. When the switch is off, the lift will return to normal working.

iii) The fireman's lift shall be provided with an audio and visual signal in the car.

iv) The fireman's lift shall have a floor area of minimum 1.43 m^2. It shall have loading capacity of not less than 544 kg (8 persons lift).

v) The fireman's lift shall be provided with power operated (automatic) doors of minimum 0.8 m width.

vi) The speed of the fireman's lift shall be 1.0 m/s or more such that it can reach the top floor from main floor/firefighter access level within 1 min. In case the building is zoned, the fireman's lift shall operate from the lowest served landing to the topmost served landing in 1 min.

NOTE — Notwithstanding the above, the speed of lifts shall be established based on **4**.

vii) Reliable alternative source of power supply should be provided for all fireman lifts through a manually/automatically operated change-over switch. The route of wiring shall be safe from fire.

viii) Suitable arrangements such as providing slope in the floor of lift lobby shall be made at all the landings to prevent water used during firefighting from entering the lift shafts.

ix) The words 'Fireman Lift' shall be conspicuously displayed in fluorescent paint on the lift landing.

x) *Operational requirements of fireman's lift* — The lift shall be provided with the following operational controls, phase I and phase II.

a) *Phase I — Return to evacuation floor* — Shall start when the fireman's switch at the evacuation floor is turned to the 'ON' position or the signal from smoke detector (if provided by the Building Management System) is on. All lifts controlled by this switch shall cancel all existing car calls and separate from landing calls and no landing or car calls shall be registered. The audio and visual signal shall be turned on. All heat and smoke sensitive door reopening devices shall be rendered inoperative.

If the lift is travelling towards the evacuation floor, it shall continue driving to that floor.

If the lift is travelling away from the evacuation floor, it shall reverse its direction at the nearest possible floor without opening its doors and return non-stop to the evacuation floor.

If the lift is standing at a floor other than the evacuation floor, it shall close the doors and start travelling non-stop to the evacuation floor.

When at the evacuation floor, the lift shall park with doors open.

The continuous audio signal is turned off after this return drive.

NOTE — If the building is designed for alternative evacuation floor, in case of fire at main floor the lifts shall park at the alternative evacuation floor with doors open.

b) *Phase II — Operation of the lift shall be as defined below* — The phase 2 is started after phase 1, if the fireman's switch is 'ON'.

If the lifts are grounded by the smoke detector signal, for phase II to begin it shall be necessary to turn the fireman's switch 'ON'.

The lift does not respond to landing calls but registers car calls. All heat and smoke sensitive door reopening devices are rendered inoperative.

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When the car call button is pressed, the doors start closing. If the button is released before the doors are fully closed, they re-open. The car call is registered only when the doors are fully closed.

After registering a car call the lift starts driving to the call. If more than one car call is registered, only the nearest call is answered and the remaining calls will be cancelled at the first stop.

At the floor the doors are opened by pushing the door open button. If the button is released before the doors are fully open, they re-close.

The lift returns to normal service when it stands at the evacuation floor with doors open and the switch is turned 'OFF' thereafter.

The operation of fireman's lift shall be by means of a full set of push buttons in the car. Other operating systems shall be rendered inoperative.

7.1.2 *Buildings of Height 60 m and above*

The following requirements over and above those specified in **7.1.1** are applicable to the lifts and lift enclosures provided in buildings having height more than 60 m.

a) *Fireman's lifts* — Following additional requirements apply to all fireman's lifts in the building.
   1) The fireman's lift shall have loading capacity of not less than 1 000 kg and floor area not less than 2.35 m^2.
   2) Electrical equipment within the fireman's lift well and on the car, located within 1.0 m of any wall containing a landing door, shall be protected from dripping and splashing water or provided with enclosures classified to at least IPX3 according to good practice [8-5A(9)].
   3) The electrical switchgear placed less than 1 m above lift pit floor shall be protected to IP 67 as per to good practice [8-5A(9)]. The socket outlet and lowest lamp shall also be located at least 0.5 m above the highest permissible water level in the pit.
   4) Suitable means shall be provided in the lift pit to ensure that water will not rise above the level of the fully compressed car buffer.
   5) Means shall be provided to prevent the water level in the pit from reaching equipment which could create a malfunction of the fireman's lift.
   6) Alternative source of power supply shall be provided for all fireman's lifts through automatically operated changeover switch. In case of failure of normal electric supply, it shall automatically trip over to alternative supply. The route of wiring shall be safe from fire.

b) There shall be Fire Command Centre (FCC) and/or Building Management System (BMS) room in the building. CCTV cameras shall be fixed in the lift lobbies and the display screen(s) shall be placed in the FCC or BMS room.

7.2 Evacuation Lifts

Buildings, particularly super high rise (height more than 200 m) buildings, may be designed for a systematic evacuation of persons in case of emergencies that are relevant to a specific building. There are many reasons why a building may need to be evacuated, for example, a fire, explosion, chemical or biological attack, flooding, storm damage, earthquake, etc. Not all of these are relevant to every building hence those which are not relevant can be disregarded. Designers of buildings shall determine, if a particular hazard is sufficiently great as to require addressing. This clause deals primarily with fire situation although similar logic can be used in case of other situations as well.

The lifts may be planned only supplementary to, not as a replacement of, exits. In fact, using lifts instead of stairs may well increase evacuation times in many building designs, especially low and medium rise buildings. However, lifts may be allowed to play a positive role in assisting and improving efficiency of the building evacuation strategy especially for persons with disabilities. The building designers should decide, if they want to use lifts for evacuation purpose. It may be noted that in general a fireman's lift may be suitable as an evacuation lift.

7.2.1 *Pre-requisites to Using Lifts for Evacuation in Case of Fire*

7.2.1.1 *Detecting fire, smoke, and temperature*

Methods of fire detection are well established. If the lifts are to operate a safe evacuation service, good monitoring of the fire in relation to lift equipment is essential.

To ensure the safety of users and lift equipment; the lift machine room, lift well (including lift pit and overhead areas) and landing areas shall be provided with means to detect and monitor for the presence of smoke and heat. Temperature in any safe area provided for persons to wait (lobby, refuge, etc) and the lift well, machine room, etc, should be continuously monitored to

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determine if it is safe and remains safe for persons and equipment. When an unsafe temperature or presence of smoke is detected the information should be sent to the BMS or FCC. The BMS or FCC should determine what is to be done next and send appropriate signals to the lift, for example remove lift from service at floor *x* with doors parked open or closed as required. The equipment used for this sensing and monitoring of heat and smoke should be specified by those responsible for the design of the building fire and smoke detection system.

7.2.1.2 *Location of an event in relation to lifts*

In detecting an event like fire it will be important to know its location in relation to any lift intended for evacuation use. The more the level of sophistication of detection system employed, the more precise will be the level of information available to make decisions and more meaningful these decisions will be. The designer shall determine the degree of sophistication required taking into account the importance of the building, type of occupancy, etc.

7.2.1.3 *Emergency power provisions*

Secondary (emergency) power shall be provided that has sufficient capacity to run all the evacuation lifts at full speed for the required evacuation time. The route of the cabling shall be safe from fire.

7.2.2 *Operational Decisions for Evacuation*

7.2.2.1 *Types of evacuation*

The evacuation strategy developed should lead to an obvious evacuation type. Lifts will not be able to evacuate all floors at once, so to some degree a systematic evacuation will be governed by the capacity of lifts and the number of persons to be evacuated. Lift engineers can calculate the number of persons that can be moved for a given set of circumstances but the first thing to determine is the number of persons to be evacuated within the required evacuation time. Fire engineers/experts shall determine these figures. It shall also be determined what proportion of wheel chair and others with impaired mobility may be there and if there is likely to be a floor or building area with a particular concentration of them.

In many instances some sort of phased evacuation will be desirable while at other times a full evacuation may be essential. Phased evacuation involves the evacuation of certain areas first, usually those floors areas at greatest risk followed by other key areas. Also, there could be horizontal evacuation, partly or fully, for example, in case of hospitals.

7.2.2.2 *Decide, if evacuation is required (building management)*

This is a decision to be made by other experts and those responsible for building management. In large buildings, evacuation may take some time and it shall not be assumed that continued use of a particular lift or lifts is guaranteed. Serious thought shall be given to how information will be displayed to those managing the building especially where the BMS system is capable of providing a large amount of information. It should be possible to see at a glance if lifts are operating correctly and what services they are running. There shall always be provision made to allow the building management or authorities to override any automatic evacuation signal that is generated by a BMS. Irrespective of the systems employed the evacuation decision cannot be made by a lift system and therefore other experts in this field shall determine what risks will constitute the need for evacuation and the type of evacuation (partial or full).

7.2.2.3 *Decide, if lifts are to be used for the evacuation*

If for some reason a significant number of lifts are not available for use then it may be prudent to remove all lifts from automatic evacuation service rather than have too few. If too few lifts are in service, delays will result that could be dangerous or cause panic. In such circumstances it is probably desirable to run a limited service for the evacuation of those who have difficulty in negotiating stairs. Any such service needs to be managed by lift attendants who will drive the lift, manage possible crowding and assist those who need it. The decision to operate some form of service when not all lifts are available shall be taken by those managing the building evacuation.

7.2.2.4 *Building evacuation information*

When evacuation is required, updated information shall be provided through the building systems informing persons concerned including those in waiting areas which lifts to use during the particular emergency. This information shall be in both audible and visual format. Any safe areas/waiting areas should also have an emergency communication system.

7.2.3 *Specifications of Automatic Evacuation Lift*

7.2.3.1 *Determining the number and size of lifts*

To calculate the number and size of lifts required for an adequate evacuation service, the handling capacity of a given lift or group of lifts shall be determined considering possibility that a lift or lifts may not be available for some reason such as planned maintenance, repairs. Also due consideration shall be given to the requirement of accommodating a wheel chair in the lift car.

7.2.3.2 *Protection of lift equipment*

Lift shafts and machine rooms or machinery spaces located outside the shaft should be fully enclosed. The temperature in the enclosures should be monitored and maintained to acceptable levels for the equipment, as

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determined by the lift supplier in consultation with the building management. Protection from water may be considered, if required as per overall evacuation strategy.

7.2.3.3 *Removal or suspension of lifts from evacuation service*

Where a lift receives a command from a BMS or manual signal to stop or suspend service to a floor or area of the building, any stop shall be a controlled stop at a safe area. A controlled stop means allowing the lift to slow down and stop at a floor in the normal manner. Where a lift or lifts are instructed to suspend service, the lift(s) shall communicate with the FCC and any BMS once it is no longer available for service.

7.2.3.4 *Remote lift car surveillance*

At times of emergency it is vital to be able to see that lifts do not contain trapped passengers who may be incapacitated. A means to display the entire floor area of the car shall be provided with information to the occupants that the lift car is under surveillance. At least one viewing terminal shall be located in the FCC and clearly marked 'LIFT CAR SURVEILLANCE' with the lift designation identified.

7.2.3.5 *Communication system requirements*

As a minimum, a 3-way communication system shall be available for passenger use to permit direct communications between the lift car and safe area and FCC. Operation of the communication device in the lift car shall be simply by means of a single button, operation of which shall connect the system to the FCC. Further operation of the device in the lift car shall be hands free.

7.2.3.6 *Initiation of evacuation service*

Evacuation service can be initiated by a device such as a button or lever, key, etc, located near the lift shaft at the evacuation landing, or from a signal sent by a BMS or hazard detection system. Where a button or other manual activated device is used it shall be protected against unauthorized use. Its purpose shall be clearly marked with a symbol and/or the words 'LIFT EVACUATION SERVICE'.

The evacuation service shall be operational between the floors as decided by the building designer. The logic of operation shall be mutually agreed to between the building designer and the lift designer. However, any lift will be automatically removed from evacuation service if, where provided, it is turned to fire-fighters service.

7.2.3.7 *Cancellation of evacuation service*

On cancellation of a signal from the device that initiated the service and receipt of a signal from an evacuation service cancellation switch, all lifts which are not at the main landing shall complete any allocated task and return to the main landing.

On arrival at the main landing the doors shall open and then the lift evacuation for that particular lift shall be cancelled. Any lift already at the main landing shall on opening its doors cancel its evacuation service.

7.2.4 *Information to be Provided to the Building Owner*

Detailed instructions shall be provided to the building operator by the building designer in the form of a manual. The manual shall explain the evacuation strategies to be used, how any detection systems operate, how they shall be maintained and how the lift will operate on evacuation service. It should also provide advice on periodic checks the owner can make to ensure the system is working correctly and explain the importance of a suitable testing and maintenance system being in place. Training being very important aspect of this new concept, the manual shall include such details of training as who should be covered by training, how the training should be carried out, what should be the frequency, etc.

8 MINIMUM TECHNICAL AND SAFETY REQUIREMENTS

8.1 General Requirements

The following general requirements shall be adhered to:

a) Passenger and goods lifts shall comply with the safety requirements and/or protective measures of the following clauses. In addition the passenger and goods lifts shall be designed according to good practices [8-5A(2)].

b) All labels, notices, markings and operating instructions shall be permanently affixed, indelible, legible and readily understandable (if necessary aided by signs or symbols). *See also* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code. They shall be of durable material, placed in a visible position, and written in the accepted language(s).

c) The minimum factor of safety for any part of the lift shall not be less than five. Higher factor of safety for various parts shall be applicable in accordance with accepted standards [8-5A(5)] and [8-5A(6)].

d) All passenger, goods, stretcher, automobile, dumbwaiter lifts shall have conformity with *Lifts Acts and Rules* in force, *Indian Electricity*

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Act, 2003 and *Rules*, all relevant and applicable Indian Standards, applicable fire regulations, fire prevention act and rules in force.

e) *Notices* — The following notices shall be placed at respective places:

1) A notice (*see* Fig. 4) bearing the following (typical) minimum inscription shall be fixed to the outside of doors or trap-doors (excluding landing doors and doors of emergency and test panels) giving access to machine and pulley rooms.

2) In the case of trap-doors, a permanently visible notice (*see* Fig. 5) shall indicate necessary warning to those using the trap-door.

3) Outside of the well, near the access doors and emergency doors, if any, there shall be a notice stating as shown in Fig. 6.

4) A notice board with following instructions as applicable, and/or other applicable instructions shall be placed in conspicuous position in the lift car:

i) Maximum capacity of lift ____ kg/ __ persons.

ii) Close the car and landing door/gate properly, on entering, or while leaving the lift car.

iii) Do not open the lift-car gate when the lift-car is moving. The gate should only be opened after the lift-car has stopped opposite a landing gate.

iv) In case of danger, press the alarm button, but do not try to open the car door. Wait inside, until the lift car is brought opposite a landing, and do not attempt to leave the lift car until the landing door is opened fully.

v) Children under 12 years of age shall not use the lift, unless accompanied by an adult.

5) The following is a typical list of Do's and Don'ts that should be displayed in the lift car, and in case of lifts open to public use, in an accessible format complying requirements of accessible information board/signage, given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code:

Do's	*Don'ts*
a) Press call button lightly	a) Do not overload the lift
b) Know your destination. Push lift call for direction you want to go	b) Do not press call button again and again
c) Stand aside for exiting passenger	c) Do not force-open the doors, it is dangerous
d) Pay attention to floor indicator	d) Do not stand in between the doors
e) Push and hold the door open button, if door needs to be held open	e) Do not fiddle with the equipment
f) Wait for the next car, if the lift is full	f) Do not step in until lift has stopped at landing and doors are fully open
g) Take the stairs, if there is a fire	g) Do not crowd in the middle of car
h) In, contact case of emergency, contact customer service cell for rescue operation	h) Do not lean against car panels
	j) Do not panic in case of power failure
	k) Do not attempt to jump out, if the lift has stopped out of floor level

NOTE — No distracting notice/advertisement should be fixed in the lift car.

8.2 Power and Control Systems

8.2.1 *Features Associated with Power Systems*

The features associated with power systems are listed below.

8.2.1.1 *Industrial switchgear*

Switchgear for controlling lift power systems is characterized by its high duty cycle and its high rupturing capacity. Switchgear shall be robust enough and shall be so designed as to withstand the high duty cycle and high rupturing capacity introduced during the operation of the lifts.

8.2.1.2 *Levelling accuracy*

The levelling tolerances in accordance with good practice [8-5A(7)] are those which can be reasonably expected between no load and full load in either direction. With the VVVF drives good leveling accuracy can be expected.

8.2.1.3 *Corrective levelling*

This should only be used, when it is impossible otherwise to achieve the required levelling tolerances or on long travel lifts to maintain the required levelling tolerances during loading and unloading.

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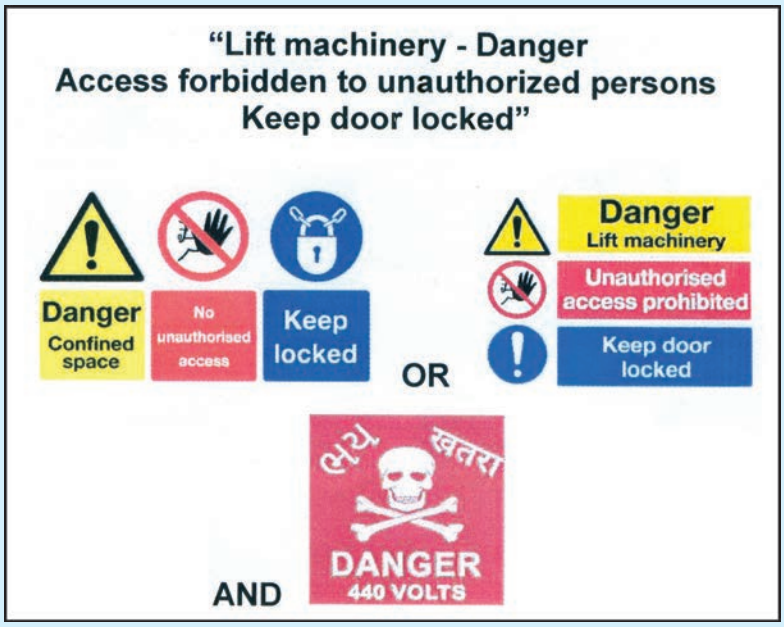


FIG. 4 TYPICAL INSCRIPTION ON DOORS



FIG. 5 TYPICAL NOTICE ON TRAP DOORS



FIG. 6 TYPICAL NOTICE ON ACCESS DOORS AND EMERGENCY DOORS

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8.2.1.4 *Levelling with variable voltage*

A variable voltage system is one using continuous regulation which minimizes speed differences due to load variation. Therefore, the actual levelling speed is of less importance than the general refinement of its regulation control. In fact no levelling speed as such may be identifiable.

8.2.1.5 *Overload tests*

A lift is designed to operate and transport the contract load, at the required duty cycle, and should not by intention or habitually be used to carry overloads. During test as a safeguard to cover variable supply and temperature conditions a lift is checked for the car to complete one round trip with contract load plus 10 percent at nominal supply voltage and nominal ambient temperature. There is also a static test with contract load plus 25 percent to check that the brake will sustain the car. It is unnecessary to specify and additional overload test or capacity and in fact it is detrimental to the normal running efficiency and safety of the lift to do so.

8.2.1.6 *Occasional extra load*

It is not good practice to request that a lift should be designed to carry an occasional extra load. It is tantamount to specifying an excessive overload test which is detrimental to the normal running efficiency and safety of the lift.

8.2.2 *Description of Operation Systems*

The following description relates to the associated operating systems.

8.2.2.1 *Methods of control systems*

The methods of control systems are as follows [*see* **8.2.2.2** (a)]:

a) Attendant and dual control, and
b) Automatic push button operation.

8.2.2.2 *Types of control systems*

The features of control systems shall be as described below:

a) *Automatic push button operation* — Automatic control is a method of operation by which a momentary pressure on a push button sets the car in motion and causes it to stop automatically at any required lift landing. This is the simplest control system and it is sometimes referred to as push button control. A car answers a landing or car call, whichever is actuated first by momentary pressure provided the lift is not in use. Momentary pressure of a car push button will send the car to the designated floor. The car always responds to a car push button in preference to a landing push button. With this type of control, a red landing signal light or direction arrow indicates that the car is in use that is the lift is travelling. This type of control is recommended for single passenger lifts serving up to 4 floors and goods lifts.

   For special purposes, the following two systems may be considered:

   1) Dispatch from landings as an additional feature for a goods lift with manually operated doors. The call is registered by pressing the car push button and when the doors are closed the car will travel to the designated floor.
   2) Automatic with attendant control as an additional feature on goods lifts with a key operated switch in the car to transfer the control from normal automatic to attendant operation. There is also a visual call indicator with buzzer in the car to indicate to the attendant the landing floors at which push buttons have been pressed when the car is under attendant control.

b) *Collective control* — Collective control is a generic term for those methods of automatic operation by which calls made by pressing push buttons in the car and at lift landings are registered and answered by the car stopping in floor sequence at each lift landing for which calls have been registered irrespective of the order in which the calls have been made, and until all calls have had attention. Collective control of any form is usually not suitable for goods lifts except where loading is not expected to fill the car and additional loads can be taken at other stops.

c) *Single push button collective control* — Single push button collective control has a single push button at each landing. It is not recommended, as the direction in which it is desired to travel cannot be registered by the intending passenger.

d) *Down collective control* — Down collective is a control system where landing calls are registered from a single push button, irrespective of the car being in motion or the landing door being open and calls are stored until answered. Any number of car calls can be registered and the car will stop in sequence in the down direction at each of the designated floors. The car will travel in the up direction to the highest call registered stopping only in

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response to car calls. It will then travel downwards answering calls in floor sequence. If only one call has been registered the car travels to the floor of call.

This system is suitable where there is traffic between the ground and upper floors only and no inter floor traffic. Two or three car banks have interconnected control. With this type of control the following signals are included:

1) A landing signal light indicates that the call has been registered and will be answered.

2) Illuminated car position indicator above car entrance.

e) *Directional collective control for one car* — Directional collective control for one car is a control system having 'UP' and 'DOWN' push buttons at intermediate landings whereby the call is registered for the intended direction of travel. Calls from the car or landing push buttons are registered and stored until answered. The car will answer calls in floor sequence in one direction of travel. Calls for the opposite direction of travel are answered when the direction of travel is reversed.

This system is suitable for single lifts serving 4 or more floors with inter floor traffic, such as small office blocks, hotels and blocks of flats. With this type of control the following signals are included:

1) A landing signal light for each landing push button indicates that the call has been registered and will be answered.

2) Illuminated car position indicator above the entrance in the car.

3) Arrow shaped signal lights in the back of the car or on the landing to indicate to the entering person in which direction the car is going to depart.

f) *Directional collective control for two or three cars* — Directional collective control for two or three cars is a system covering a control in which the two or three cars in a bank are interconnected. One push button unit with 'UP' and 'DOWN' push buttons or floor buttons (in case of car control from floor) are required at each landing and the call system is common to all lifts. If for architectural balance, in the case of a three car bank, extra push button units are required, these should be specified. Each landing call is automatically allocated to the best placed car. The control is designed so that cars are effectively spaced and thus give even service. When a car reaches the highest floor to which there is a call its direction of travel is automatically reversed when it next starts. One or more cars will return to the parking floor. Automatically bypassing of landing calls when a car is fully loaded is an essential feature for three-car banks. It is also necessary for two-car banks in offices. Other cars will continue to provide service to all floors. When three-car banks serve 7 or 8 floors and over, some form of automatic supervisory control [*see* **8.2.2.2**(g)] is generally necessary in the interest of efficiency. With this type of control the following signals are included:

1) A landing signal light for each landing push button to indicate that the call has been registered and will be answered.

2) Illuminated car position indicator above the entrance in the car.

3) Arrow shaped signal lights in conjunction with an audible single stroke gong or an indication on the landing call push button station above each landing entrance to indicate to the waiting person(s) which car is going to stop and in which direction it will continue its course.

g) *Group supervisory control* — A bank or group of intensive traffic passengers lifts requires a supervisory system to coordinate the operation of individual lifts which are all on collective control and are interconnected. The very nature of intensive service calls for a sophisticated automatic supervisory control system so as to match the speed capacity of these lifts. The supervisory system regulates the despatching of individual cars and provides service to all floors as different traffic conditions arise minimizing such unproductive factors as idle cars, uneven service and excessive waiting time. The system will respond automatically to traffic conditions such as 'UP' and 'DOWN' peaks, balanced or light traffic and provides for other specialized features. If desired, a master station can be provided in the lift lobby which gives by indicators, visual information regarding the pattern under which the system is operating. Where the system is based on a definite programme, control means are provided for altering the type of traffic programme. There are other facilities, such as the removal of any lift from service.

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h) *Destination control system* — In case of a bank of lifts Destination Control System (DCS) may be provided. The passengers enter their destination floors on the Destination Operating Panels (DOPs) provided on the lift landings. The lift controller allocates a lift to every call registered which is displayed on the DOP. The passenger is expected to board the assigned lift and travel to his destination floor. He need not register his destination floor in the lift car operating panel (COP) again. In fact COP in the lift car may not be provided with floor buttons in case of DCS control system. The principle behind the DCS is to group passenger with same destinations together thus reducing the number of stops of the lift reducing round trip time thus boosting traffic.

The advantages of DCS system over conventional collective control are:

1) Enhanced passenger handling capacity,

2) Less transit time, few intermediate stops, and

3) Passengers do not have to struggle through crowd to book the calls.

In addition to the DOPs the lift landings are provided with lift identifier. The main landing may be provided with destination indicator displaying the floor designations the lift would stop at.

Hybrid Destination Control (HDCS) combines features of the DCS and conventional control system. The main floor is provided with DOPs, Lift Identifiers and the lift car is provided with the conventional COP as well. Thus while availing benefit of traffic boosting HDCS provides convenience of call booking from inside the lift car as well.

8.2.2.3 *Features of operation systems*

The features associated with the operating systems are as follows:

a) *Car preference* — Sometimes it is necessary to give a special personal service or a house service. When this service is required and for whatever purpose, it should be specified as 'car preference' is by a key operated switch in the car. The operation is then from the car only and the doors remain open until a car call is registered for a floor destination. All landing calls are bypassed and car position indicators on the landing for this lift are not illuminated. The removal of the key when the special operation is completed, restores the control to normal service.

b) *Landing call automatic bypass* — For collective operation, automatic bypassing of landing calls can be provided. This device will bypass landing calls when a car is fully loaded but the calls are not cancelled.

c) *Motor generator shut down* — Lifts controlled by variable voltage system automatically shut down when subject to an over-riding control which puts them out of service under certain conditions; for example, no demand for lift service. They are automatically put back into service as required.

d) *Basement service* — For lifts with collective control when service is required below the main parking floor, which is usually the ground floor, to a basement and/or a sub-basement, the lift manufacturer should be informed of the type of service required, as special technical considerations are then usually necessary.

e) *Hospital service* — Lifts for carrying beds and stretchers require a car preference switch so that an attendant can have complete control of the car when required. This requirement should be specified as 'car preference' and it will function as described in **8.2.2.1**. Otherwise such lifts can have the same control systems as for normal passenger lifts, the choice depending on the number of floors served, the service required and the number of lifts.

f) *Manually operated doors* (*without closers*) — A 'door open' alarm should be provided to draw attention to a car or landing door which has been left open.

g) *Automatically power closed doors* — For passenger operation when the car arrives at a landing the doors will automatically open and then close after lapse of a time interval. This time interval can be overruled by the pressure of a push button in the car to give instant door closing. An 'open door' push button is provided in the car to reverse closing motion of the doors or hold them open.

h) *Controlled power closed doors* — When there are conditions that particularly affect the safety of passengers or damage to vehicles or trucks, the closing of the doors should only be made by the continuous pressure of push buttons in the car or on landings. A 'door open' alarm should be provided to draw attention to a car

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or landing door which has been left open. This means of operation is required for some forms of goods lifts.

j) *Safe operation of doors* — The safety of passengers passing through lift entrances is fully covered by the provision of good practice [8-5A(6)]. No modification of these provisions should be specified.

k) *Directorial service* — There are many forms of giving special service for individuals, but they should always be avoided. They range from key operated switches at preferred landings to the complete segregation of one out of a bank of lifts. It is obvious that any preferential treatment of this nature can seriously jeopardize the efficiency of the service as a whole. When a bank of say three lifts is installed to meet the anticipated traffic requirements and then, when the building is occupies, one lift is detached permanently for directors' service, the traffic handling can be reduced by a half rather than a third. When preferential service is imperative, then the car preference feature should be available [*see* **8.2.2.3**(a)].

m) *Indication of car arrival* — As all lift cars are illuminated when available (in service). It is recommended that this illumination be used to signal the arrival of a car at a landing in preference to special signals such as 'LIFT HERE' signs since signal lamps can fail when the lift is still operating satisfactorily.

The following is the practice adopted for vision panels in doors:

1) For lifts with manually operated car and landing doors, vision panels are provided in all doors;

2) For lifts with power operated car doors and manually operated landing doors, vision panels are provided in the landing doors only;

3) For lifts with automatically opened car and landing doors, no vision panels are required; and

4) When vision panels are provided they should comply with the requirements of good practice [8-5A(7)].

n) *Service switches* — When switches are provided to take cars out of service, that is because the remaining cars in the group can cater for the required passenger traffic, it is essential that such switches should not stop the fireman's control from being operative in the event of the lift being designated as a fireman's lift. Service switches should not be confused with maintenance switches which are only used when it is dangerous to attempt to operate the lift because maintenance work is actually in progress. A control station fitted on top of the car is regarded as a maintenance switch.

p) *Fire switch* — When required by the fire authority a fire switch has to be provided, the function of which is to enable the fire authority to take over the complete control of one or more lifts in an installation.

q) *Push buttons and signals* — It is most important that the purpose of every push button and signal should be clearly understood by all passengers.

r) In public places where blind persons are expected to use the lifts it is recommended to provide Braille/tactile buttons.

8.3 Capacity and Loading

The minimum rated load of a passenger lift car corresponding to the net inside car area shall bear the relationship given in Fig. 7, the net inside car area being evaluated as shown in Fig. 8. The net inside car areas for various passenger capacities with corresponding minimum rated loads have been given in Table 24.

NOTES

1 The graph shown in Fig. 7 is based on the following formula:

$W = 35.05\ A^2 + 325.66\ A$

where

W = rated load, in kg; and

A = net inside area, in m^2.

2 For rated loads exceeding those covered by the graph, value may be evaluated from the formula given above.

3 To avoid the possibility of serious overloading of bed lifts, they shall be treated as passenger lifts.

4 The minimum rated load for goods lifts shall be based on a load of not less than 3.45 kN/m^2 of the net inside car area.

5 The minimum rated load for automobile lifts shall be based on a load of not less than 1.45 kN/m^2 of the net inside car area.

6 When the load in a goods lifts consists of pallets or similar single piece loads loaded by means of a power truck, it is necessary during loading and unloading to take into account the total load on the car platform the capacity of the brake, and the resistance to slipping of the ropes on the sheave of a traction machine. Similarly, guide rails, guide fixing, car frame and platform shall be designed to withstand the horizontal thrust imposed by power trucks, motor vehicles and the like.

7 For motor vehicle and other special purpose lifts for transportation of light weight and heavy volume loads, the lift car inside dimensions mutually agreed to between the manufacturer and the purchaser will be permitted with the provision of a device to prevent the lift from starting from a landing in case of overloading.

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8 A load plate giving the rated load of the lift shall be filled in each lift car in a conspicuous position. For passenger lifts, the rated load shall be given in number of person and kg. For goods lifts, the rated load shall be given in kg or other convenient units and in persons. For the purpose of this clause, a person shall be regarded as weighing 68 kg.

Table 24 Minimum-Maximum Net Car Areas for Various Rated Loads
(*Clause* 8.3)

Sl No.	No. of Passengers	Minimum Rated Load kg	Minimum Net Inside Car Area m^2	Maximum Net Inside Car Area m^2
(1)	(2)	(3)	(4)	(5)
i)	4	272	0.68	0.77
ii)	5	340	0.85	0.95
iii)	6	408	1.00	1.12
iv)	7	476	1.16	1.28
v)	8	544	1.31[1)]	1.45
vi)	9	612	1.46	1.60
vii)	10	680	1.61	1.76
viii)	11	748	1.77	1.91
ix)	12	816	1.92	2.05
x)	13	884	2.06	2.20
xi)	14	952	2.23	2.34
xii)	15	1 020	2.35	2.47
xiii)	16	1 088	2.48	2.61
xiv)	17	1 156	2.62	2.74
xv)	18	1 224	2.75	2.87
xvi)	19	1 292	2.88	3.00
xvii)	20	1 360	3.01	3.13
xviii)	21	1 428	3.14	3.25
xix)	22	1 496	3.26	3.38
xx)	23	1 564	3.39	3.50
xxi)	24	1 632	3.51	3.61
xxii)	25	1 700	3.62	3.73
xxiii)	26	1 768	3.74	3.85
xxiv)	27	1 836	3.86	3.96
xxv)	28	1 904	3.97	4.07
xxvi)	29	1 972	4.08	4.18

[1)] Minimum net car inside area for fireman lift is 1.43 m^2.

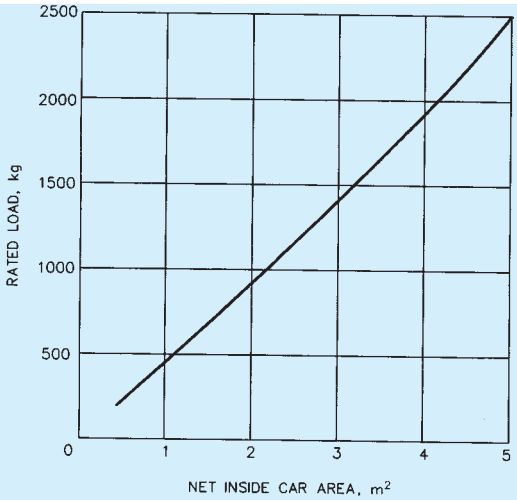


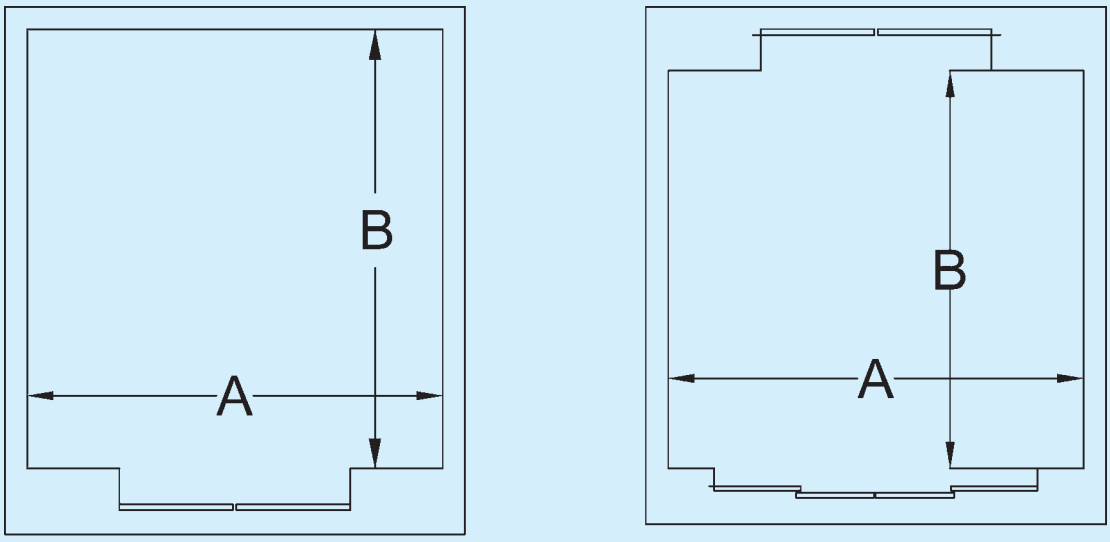
FIG. 7 MINIMUM RATED LOADS FOR PASSENGER LIFT CAR

8.4 Other Technical and Safety Requirements

8.4.1 Passenger lifts shall be provided with power operated doors which are imperforate.

8.4.2 Power operated car doors on automatically operated lifts shall be so designed that their closing and opening is not likely to injure a person. The power operated car door shall be provided with a sensitive device which shall automatically initiate reopening of the door in the event of a passenger being struck or is about to be struck by the door, while crossing the entrance during closing movement. The effect of the device may be neutralized,

a) during the last 58 mm of travel of door panel in case of side opening doors;



NET INSIDE CAR AREA = *A* × *B* **NET INSIDE CAR AREA = *A* × *B***

FIG. 8 NET INSIDE CAR AREA FOR PASSENGER LIFTS

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b) when panels are within 58 mm of each other in case of center opening doors; and
c) during emergency fire operation.

The force needed to prevent the door from closing shall not exceed 150 N and this measurement shall not be made in the first third of the travel of the door. In order to achieve this it is desirable that all power operated doors have a full length (covering at least 1 600 mm of car door height from bottom) infrared or equivalent light curtain safety to retract the door in the event of coming across any obstacle during closing of the door.

8.4.3 Single speed and two speed drives which are poor in levelling accuracy and energy consumption shall not be used for new lifts in view of availability of latest technology energy efficient variable voltage variable frequency (VVVF) drive systems with improved levelling accuracy.

8.4.4 For passenger lifts with car call button control in car, an additional car operating panel with call buttons shall be provided for ease of access to call buttons when the car is wider than 1 600 mm and/or the rated capacity of the lift is 16 passengers and more. This additional car operating panel shall be suitably located in the lift car.

8.4.5 Battery operated Automatic Rescue Device (ARD) shall be provided on all lifts to take lifts to the nearest possible landing in case of power failure, which includes power failure of one or more phases. In case of lifts equipped with backup generator with AMF (Automatic Mains Failure) panel, the provision of ARD is optional. For all lifts with ARD, an audio and visual indicator shall be provided inside the lift car to alert the persons trapped inside that they are being rescued. Capacity of batteries shall be such that minimum three rescue operations can be performed without recharging. Emergency light and at least one fan inside the lift car shall be operational till the end of rescue operation. Levelling accuracy of ±40 mm or better shall be achieved in the ARD Operation. The ARD should operate only when all safety circuits are operational. The safety circuits shall be checked and verified continuously during the rescue operation.

8.4.6 Minimum one stretcher lift shall be provided in each building having height more than 30 m so as to take care of medical as well as other emergencies. This lift shall have minimum car entrance width of 800 mm and car depth of 2 100 mm.

8.4.7 Every passenger lift shall be provided with an overload device which will prevent the lift from starting in case the lift car is loaded to 110 percent of the rated capacity of the lift or more. The lift shall remain stationery with door open. Audio and visual warning device shall be provided to alert the passengers in case of overload.

8.5 Painting at Works and on Site

Lift equipment will normally receive a protective coat of paint at works before dispatch to site. Further painting of lift equipment may be necessary and is normally in the form of a finishing coat and can take place on site. Alternatively, the further painting of the equipment may be carried out at works as a finishing coat with normal touching up after site erection as may be necessary. Any additional painting, due to site conditions during erection and/or final operating conditions in the premises, is subject to negotiation between the lift manufacturer and the purchaser. Decorative finishes are a subject for separate negotiation.

8.6 Emergency Manual Rescue

The emergency manual rescue operation with brake release should only be carried out in an emergency and by authorized persons who have received necessary instructions, because it is dangerous for any other persons to attempt to do so.

Before attempting to move the car, it is imperative that any person in the car be warned of the intention to move the car and that they shall not attempt to leave the car until they are advised that it is safe to do so. Any failure to carry out this precaution may render the person concerned guilty of negligence should an accident occur.

Before attempting to hand wind the lift machine, it is vital that the supply is switched off at the main switch. It is usually necessary to have two persons in the machine room: one to operate the brake release and the other to carry out the hand winding. The exceptions are small lift machines where the hand winding can be easily controlled by one man and larger machines which need two men to operate the hand winding alone with an additional man to control the brake release. In case of gearless machines especially, the brake shall be released and applied at very short intervals (of the order of 0.5 s to 1 s) so as to avoid the lift car attaining dangerously high speed due to the lift car and create unbalance in the absence of the gear box with large reduction ratio.

If the car is stuck in the lift well and cannot be moved when an attempt is made to move it in a downward direction, then no attempt at hand winding should be made because the car safety gear may have set. Any further procedure should be carried out under the instruction of a qualified lift mechanic. Provided the car is free to be moved in the downward direction, then it should be hand wound to the nearest floor. There is a preference to move the car in down direction. However, this may not always be practical owing to the distance involved and the time taken to complete the movement. In addition the amount of

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out of balance load on the counterweight side, due to the size of car and the small number of persons inside it, may make it necessary to wind the car upwards. In the case of high speed lifts the direction of hand winding will usually be governed by the effort required to move the car because of the absence of a large gear reduction ratio. It is essential that all detail operations be carried out according to the manufacturer's instructions for the lift concerned and these should be clearly stated and permanently displayed in the form of a notice in the machine room.

9 SPECIAL TECHNICAL REQUIREMENTS

The objective of this clause is to define some special type of lifts that are used currently in buildings such as lifts without conventional machine rooms (MRL lifts), lifts used in private apartments (home lifts), hydraulic type of lifts and lifts required for differently abled persons, etc.

9.1 Lifts Without Conventional Machine Rooms (MRL Lifts)

9.1.1 MRL lifts are a special type of lifts where hoisting machine is placed inside the lift shaft and control system may be inside and/or adjacent or at close proximity to top landing door, eliminating the need for conventional machine room.

9.1.2 The MRL lifts shall be in conformance with good practice [8-5A(10)] apart from other relevant provisions of this Section.

9.1.3 MRL lifts may be provided with emergency door on the top portion of the hoist-way which is equipped with electromechanical lock wired in series with lift safety chain and of size 700 mm × 700 mm minimum, so as to access the machinery space in case of emergency or safety device being activated on or above the top landing.

9.2 Lifts Used in Private Apartments/Houses/Villas (Home Lifts)

9.2.1 The home lift is designed especially for private home having up to 4 stops (maximum rise 12 m), where the usage of the lift is restricted primarily to the residents of the private home. Unlike conventional lifts which allow virtually unlimited access to members of the general public, in case of home lifts non-residents shall have limited access.

9.2.2 The rated capacity of the home lift shall be minimum 208 kg (3 persons) and maximum 272 kg (4 persons) and lift car speed shall not exceed 0.4 m/s.

9.2.3 The home lifts shall conform to good practice [8-5A(11)] apart from other relevant provisions of this Section.

9.2.4 Electric MRL type home lifts, shall in addition conform to the technical requirements specified in good practice [8-5A(10)].

9.2.5 Hydraulic type home lifts shall in addition conform to the technical requirements specified in good practice [8-5A(1)].

9.3 Hydraulic Lifts

9.3.1 The hydraulic lift is a special type of lift where the lift car is directly or indirectly driven by action of one or more hydraulic jacks.

9.3.2 The hydraulic lifts shall conform to good practice [8-5A(1)] apart from other relevant provisions of this Section.

9.3.3 These lifts should preferably be hole-less type of lifts.

9.4 Lifts Accessible for Persons with Disabilities

9.4.1 All lifts open to public shall adhere to the accessibility provisions in terms of size of the car, door width, control panel, flooring, finishes, handrails, communication systems and information, given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

9.4.2 Lifts for persons with disabilities shall conform to good practice [8-5A(12)] apart from other provisions of this Section.

9.5 Seismic Resistance in Lifts

When seismic protection of the passengers and equipment is a consideration, the safety requirements and protective measures given below may be adopted, the specified requirements being applicable when the units are subject to seismic conditions where the specified design acceleration (a_d) ≥ 1 m/s^2:

NOTE — The design acceleration is a function of ground acceleration, soil behaviour, importance factor, etc. Thus, the value of (a_d) applicable to the building and to be considered for lift design/installation shall be provided by the building architect or structural designer to the lift manufacturer.

a) *General* — Such lifts shall comply with the relevant safety requirements and/or protective measures of this clause to protect them when the lifts are subject to seismic conditions.

b) *Lift well* — In order to prevent that suspension ropes, governor ropes, travelling cables, compensation ropes and chains swaying in the well getting entangled with fixed equipment, snag points created by brackets, sills, devices and other equipment mounted in the well shall be protected according to Table 25.

c) *Machinery and pulley spaces* — Where buildings are designed with expansion joints

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Table 25 Protection of Snag Points
[*Clause* 9.5(b)]

Sl No.	Height of the Well	Horizontal Distance of Snag Points	Protected Equipment	Measures	Construction Scope
(1)	(2)	(3)	(4)	(5)	(6)
i)	≤ 20 m			Not necessary due to very small shake (displacement) of buildings	
ii)	> 20 m and ≤ 60 m	< 900 mm	Travelling cables	Install protection measure for example, a protection wire in the corner of the rail bracket or other snag points near the travelling cables	Required, if any portion of the loop is closer than 900 mm from a snag point
		< 750 mm	Compensating chain(s), compensating rope(s), counterweight governor rope	Install protection measure for example, a protection wire in the corner of the rail bracket or other snag points	Full travel in case of installing either of the compensating chain or compensating rope or counterweight governor rope
		< 500 mm	Car governor rope	Install a rope guide and protector. Otherwise use protection wire	Full travel
		< 300 mm	Suspension ropes	Install a tape guide and protector. Otherwise use protection wire	Full travel
iii)	> 60 m	Protect all snag points independent of horizontal distance	Travelling cables, compensating chain(s), compensating rope(s), counterweight governor rope, car governor rope, suspension ropes	Apply protection measures	Full travel

subdividing the structure into dynamically independent units, all the lift machinery including the landing entrances and the well of the lift shall be located on the same side of an expansion joint.

d) *Car*

1) *Mass of the car for lift design calculations* — For lift design calculations, the forces generated by the design acceleration (a_d) shall be calculated taking into account the following:

   i) For passenger lifts the mass of the car plus 40 percent of the rated load evenly distributed; and

   ii) For goods passenger lifts the mass of the car plus 80 percent of the rated load evenly distributed.

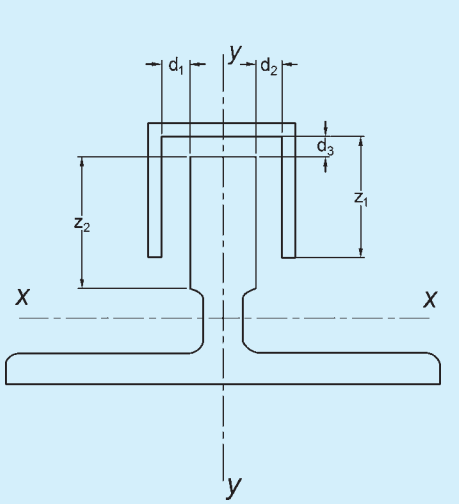
2) *Car retaining devices* — The retaining devices shall be placed in such a way to distribute loads in a similar way as the guide shoes. The retaining devices shall either be integrated or mounted close to the fixing of the guide shoes. When the car is center located between the guide rails the clearances d_1, d_2 and d_3 (*see* Fig. 9A) between the retaining device and the guide rail shall not exceed 5 mm and the dimensions chosen shall not cause accidental tripping of the safety gear during an earthquake.

The depth of the retaining device (z_1) shall be limited to avoid collision with guide rail attachments or other fixed devices, but long enough to guarantee a minimum required overlapping length between retaining devices and the guide rail blade during an earthquake.

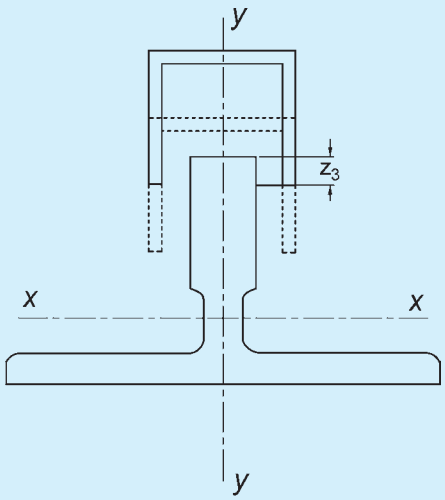
During an earthquake, the minimum required overlapping length between retaining devices and the guide rail blade shall be at least 5 mm (*see* Fig. 9B).

The car structure and retaining devices shall be sufficient to withstand the loads and forces imposed on them including forces generated by the design acceleration (a_d), without permanent deformation.

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9A NOMINAL POSITION AND CLEARANCE OF RETAINING DEVICE



9B MINIMUM REQUIRED OVERLAPPING LENGTH OF RETAINING DEVICE DURING EARTHQUAKE

Key

d_1, d_2 and d_3	clearances between the retaining device and the guide rail
x	guide rail x-axis
y	guide rail y-axis
z_1	depth of the retaining device
z_2	blade height
z_3	overlapping length of retaining device during earthquake (≥ 5 mm)

FIG. 9 RETAINING DEVICE

e) *Counterweight* — The counterweight shall be provided with upper and lower retaining devices able to hold the frame in between its guide rails. The retaining devices shall be placed in such a way to distribute loads in a similar way as the guide shoes. The retaining devices shall either be integrated or mounted close to the fixing of the guide shoes. The clearances d_1, d_2 and d_3 (*see* Fig. 9A) between the retaining devices and the guide rails shall not exceed 5 mm. When a safety gear is present, the dimensions chosen for the clearances d_1, d_2 and d_3 shall not cause accidental tripping of the safety gear. During an earthquake, the minimum required overlapping length between retaining devices and the guide rail blade side shall be not less than 5 mm (*see* Fig. 9B). The counterweight structure and retaining devices shall be sufficient to withstand the loads and forces imposed on them including forces generated by the design acceleration (a_d), without permanent deformation. The strength of the retaining devices and the counterweight frame frame shall be calculated taking into account the vertical mass distribution of its weight blocks. If the counterweight incorporates filler weights, necessary measures shall be taken to prevent their movement outside the frame considering the design acceleration value.

f) *Suspension and compensation*

1) *Protection for traction sheaves, pulleys and sprockets* — The devices for preventing the ropes from leaving the grooves of traction sheaves and pulleys shall include one retainer no more than 15° from the points where the ropes enter and leave the grooves and at least one intermediate retainer every 90° of the angle of wrap. The strength and stiffness of the retainers and their distance to the traction sheaves and pulleys compared to the diameter of the ropes shall be such that they are effective. The devices for preventing the chains from leaving the sprockets shall include one retainer at the points where the chains enter and leave the sprockets.

2) *Compensation chains* — Compensation chains or similar means shall be guided in the pit in order to limit them from swaying and reaching snag points.

g) *Precaution against environmental damage* — Hydraulic lifts shall be provided with a rupture valve. The rupture valve shall comply with the requirements of **12.2** of good practice [8-5A(1)]. The space in which the hydraulic power unit is situated and the pit shall be

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designed in such a way that it is impervious, so that all the fluid contained in the machinery placed in these areas will be retained if it leaks out or escapes.

h) *Guide rail system*

1) *General* — The guide rails, their joints and attachments shall comply with the requirements of good practice [8-5A(5)], and they shall also withstand the loads and forces generated by the design acceleration (a_d). Retaining devices shall be used as frame supporting points in the guide rail verification.

2) *Permissible stresses and deflections during seismic event* — With provision of retaining devices the requirements stated below shall be fulfilled. The safety factors for guide rails shall satisfy Table 26.

Table 26 Safety Factors for Guide Rails
[*Clause* 9.5 h(2)]

Sl No.	Elongation (A5)	Safety Factor
(1)	(2)	(3)
i)	$A5 \geq 12\ \%$	1.8
ii)	$8\ \% \leq A5 < 12\ \%$	3.0

For guide rails, the permissible stresses as given in Table 27 shall be used.

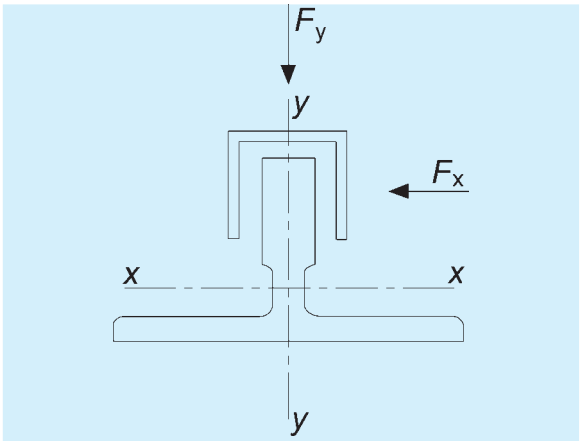
Table 27 Permissible Stresses, σ_{perm}
[*Clause* 9.5 h(2)]

***R*m (Tensile Strength of Guide Rail)**, N/mm^2	370	440	520
σ_{perm} (Permissible Stresses), N/mm^2	205	244	290

The maximum permissible deflection of car or counterweight guide rail in y-direction (*see* Fig. 10) shall be such that the overlapping length between the blade of the guide rail and the retaining devices is not less than 5 mm (*see* Fig. 9B). The maximum permissible deflection of the car guide rail, counterweight guide rail in x-direction (*see* Fig. 10) shall also be applied in y-direction. The maximum permissible deflection includes guide rail, its fixing bracket and separation beam, if used. For T-profile guide rails the maximum permissible deflection (in millimetre) (*see* Fig. 9A) is:

$$\delta_{perm} = z_1 - 2d_3 - 5$$

but never more than 40 mm.



KEY:
F_x = force exerted to the guide rail by the guide shoes or by the retaining devices in the x-axis.
F_y = force exerted to the guide rail by the guide shoes or by the retaining devices in the y-axis.

FIG. 10 GUIDE RAIL AXIS AND FORCES

j) *Machinery and other lift equipment* — All machinery including control cabinet(s) and drive system, lift machine, main switch(es), and means for emergency operations, cylinder and ram, pulleys and associated overhead beams and supports, rope attachments, over speed governor, tension pulleys and compensation rope tension devices shall be designed and anchored to prevent overturning and displacement as a result of the forces imposed on them including forces generated by the design acceleration (a_d).

Hydraulic lifts shall preferably use flexible pipe work but where the use of rigid pipe is essential it shall use flexible pipe at the end of each rigid length.

k) *Electric installations and appliances*

1) *Electric installations in the lift well* — The fixing of landing switch devices or final limit switches, vanes or similar devices fixed in the shaft shall be designed and installed to withstand the loads and forces imposed on them including forces generated by the design acceleration (a_d). In addition, the devices mentioned above shall be protected by guards against damage caused by ropes and cables swaying in the well.

2) *Behaviour of the lift in case of failure of the mains power supply* — In case of seismic events, in order to avoid people getting trapped in the car in case of failure of the normal power supply, the lift has to be able to move automatically, the car to the next landing in up or down direction.

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At landing, the lift shall operate as described below:

i) Lift with automatic power operated doors, when parked at a landing, shall open the doors, remove the lift from normal operation and keep the door open.

ii) For a lift with manually operated doors, when the car arrives at the designated landing, its door(s) shall be unlocked and the lift removed from normal operation.

Where local regulations do not permit the doors to remain open, a means shall be provided to open the doors (even with the electrical power on) enabling the rescue service to check whether the car is present and persons are not trapped.

The behaviour of the lift in case of failure of the normal power supply shall not override any of the following:

a) The electric safety devices.

b) Inspection operation.

c) Emergency electrical operation {*see* **9.5** of good practice [8-5A(6)]}.

d) The fireman's lift switch {*see* **8.3.14** of *see* good practice [8-5A(7)]}.

3) *Seismic detection system* — A seismic detection system shall be provided for lifts manufactured with design acceleration $a_d \geq 4$ m/s^2. For lifts manufactured with $a_d < 4$ m/s^2 the provision of seismic detection system is optional.

NOTE — The scope of supply for seismic detector and wiring from the detector to the lift control panel should be discussed between the building owner or his representative, and the lift manufacturer.

Where the seismic detection system is used exclusively to send information to the lift it may be placed in the pit of the lowest lift in the building. In case of expected interference with other vibration sources, alternative locations of the seismic detection system are allowed.

The seismic detection system shall comply with the following:

i) *Detection of tri-axial acceleration* — The seismic detection system shall be able to operate at all times when the lift is intended to be available to users.

ii) *Seismic trigger level* — It shall be less than or equal to 1.00 m/s^2 in any direction including vectors.

NOTE — 'Vector' relates to the resulting acceleration from combined reactions in x, y and z planes.

iii) *Frequency response* — It shall be between 0.5 Hz and 10 Hz.

iv) *System reaction time* — The system reaction time shall not exceed 3 s. The system reaction time describes the maximum allowed time period between the point in time when the seismic wave exceeds the selected seismic trigger level for the first time and the point in time when the lift switches into the seismic mode.

v) *Automatic system test* — The seismic detection function including interface between seismic detector system and the controller shall be tested automatically every 24 h. If a failure is detected during the test, the lift shall remove itself from normal operation on its next stop at a landing and park with its doors open.

vi) *Emergency electrical power supply* — The operation of the seismic detection system shall not be impeded or lost even in case of electrical power supply switching or mains power supply failure. When an emergency electrical power supply is used it shall be able to provide at least 24 h of power supply.

vii) *Resetting of the seismic detection device* — The resetting of the seismic detection device and the return of the lift to normal operation shall only be made by operation of manual reset devices. The manual reset device of the lift shall be placed outside of the well, clearly identified, and accessible to authorized persons only (maintenance, inspection and rescue), for example inside a locked cabinet.

4) *Behaviour of the lift in seismic mode* — After activation of the seismic detection system, the lift shall perform as described below:

i) All registered car and landing calls shall be cancelled. New calls shall be ignored. A lift in motion shall reduce the speed or stop and proceed to the next possible landing away from the counterweight or balancing weight with maximum 0.3 m/s car speed.

ii) When lift is at landing, a lift with automatic power operated doors shall

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open the doors, remove the lift from service and keep the doors open; and a lift with manually operated or non-automatic power operated doors shall remain in this condition and be removed from service with the doors unlocked.

Where local regulations do not permit the doors to remain open, a means shall be provided to open the doors (even with the electrical power on) enabling the rescue service to check whether the car is present and persons are not trapped. In case of failure of the normal power supply the lift shall operate as described in **9.5**(k)(2).

9.6 Automobile lifts

Where required, lifts suitable for moving passenger vehicles such as light motor vehicles (LMV), small utility vehicles (SUV), etc may be provided. The minimum requirements to be considered while providing such lifts are as given in **9.6.1** to **9.6.8**.

9.6.1 The minimum and maximum car area requirements for passenger lifts as defined in **6.1** of [8-5A(6)] may not be applicable for automobile lifts. For this class of loading, the rated load shall be based on not less than 1.45 kN/m^2 of inside net platform area.

9.6.2 Strengthening stiffeners may be added to car panels to have sufficient strength to avoid permanent or temporary deflection of car panels beyond limits in case the vehicle touches the lift car panels while moving in or out. Under no circumstance, it should result into unsafe condition.

9.6.3 The hall button for calling the lift may be provided in the approach way at such a location that the button is accessible to the vehicle driver in the driving position without having to get off the vehicle. Optional light ray detection system or card reader system may be provided for automatic detection of vehicles and calling the lift to the floor.

9.6.4 Minimum entrance width of such lifts may be 2 400 mm and entrance height of 2 300 mm. The minimum car inside dimensions may be 2 500 mm wide and 5 300 mm deep and typically with entrance doors on both sides of the lift. This will enable the car to be driven inside and can be taken out in the same direction, without any need to reverse the same. Minimum load carrying capacity shall not be less than 2 500 kg.

9.6.5 Barricades may be provided outside the lift entrance door(s), so as to limit the size of the vehicle and preventing oversized vehicles from entering the lifts and possibly damaging the equipment.

9.6.6 There shall be sufficient place on both sides of the vehicle, once the vehicle is inside the lift. The lift car width should be selected such that in case of emergency while the automobile is in the lift car the driver should be able to open the automobile door and come out of the automobile.

9.6.7 The car operating panel, where the car call can be given, may be provided at such a location that is accessible by the vehicle driver in the driving position without having to get off the vehicle. The time duration for which the door remains open upon arrival at landing floor or upon stopping at landing floor shall be sufficient enough so as to enable smooth movement of the vehicles in and out of the lift car. Lift car entrance door(s), shall be equipped with light curtain device in accordance with **19.1.4** of good practice [8-5A(5)].

9.6.8 Overload warning device shall be installed in accordance with **6.2** of good practice [8-5A(6)].

9.7 Air Conditioning System for Lift Cabin (Car)

Where the lift car is equipped with air conditioning system, following additional requirements are recommended:

a) The whole equipment, its container, condenser, etc, should be typically made of corrosion resistant material, with average designed life span of 10 years.

b) The air conditioning system should work on single phase electric power supply of maximum 230 V a.c. and should be well within the current carrying capacity of trailing cable cores provided for the air conditioning system. The power supply for the air conditioning system shall be provided from RCCB of suitable rating. This RCCB shall be located in the lift machine room with proper identification and lock out tag out facility.

c) The air conditioning system should be provided with suitable air filters which should ensure clean air inside lift car. The filters should be easily accessible and serviceable from top of the lift car in a safe and easy manner.

d) The lift air conditioning should typically include functions such as:

   1) Cooling, with adjustable temperature setting provided on the unit itself or through remote control unit, which may be maintained in the lift car.

   2) Heating, with adjustable temperature setting provided on the unit itself or through remote control unit may be maintained in the lift car.

   3) Ventilation, with adjustable air flow having less than 52 dBA noise level in the car.

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4) De-humidification, with effective condensation water management system.

e) The lift air conditioning should be equipped with effective condensation monitoring and condensed water recycling system so as to avoid water spillover or leakage on top of the lift car and other lift components.

1) Condensation water monitoring and dealing with it is a very important feature any lift air conditioner shall have. Condensation water leakage or spillover on the lift car top may cause damage to the lift and may lead to electrocution or even fire.

2) When the condensation water level in the reservoir reaches high level and remains at that or above that level for three minutes, the compressor should stop working and the air conditioner should go into ventilation mode. In the ventilation mode the air conditioner fan still works, water pump still runs, the water is pumped to the condenser for condensation water to be vaporized. When the water goes below 80 percent, the compressor may restart and the air conditioner may go into cooling mode.

3) When the condensation water level reaches 100 percent, and remains at that level for 1 min, to avoid the water spill over and damage to lift components, the air conditioner should power off by itself. All components of air conditioner should stop working. This air conditioning unit shut down should not be automatically resettable and should require manual intervention. Also it should be possible for this condensation water to be drained out by opening the drain plug provided. This facility of draining off excess condensation water shall be safely accessible either from lift car or lift pit.

f) It shall be possible to manually switch 'ON' and 'OFF' the lift air conditioning unit either by key switch provided in the lift car or by remote control.

9.8 Lift Interface with Building Management System (BMS)

Where required, a means to interface, monitor and control be provided by lift manufacturer, which should become the part of building management system. The following information and controls, but not limited to those, may be provided either through potential free contacts or building automation (BA) interface device suitable for providing necessary lift information over other accepted communication protocols. With potential free contacts only lift monitoring is possible. It shall not be possible to control the lift.

a) *Monitoring signals*

1) Floor position of the lift for each lift.

2) Direction of travel for each lift.

3) Load condition of each lift specially indicating overload status.

4) Lift door status of each lift, whether open or closed.

5) Lift modes such as attendant, automatic, independent operation, emergency fire service, seismic mode, emergency medical service and inspection mode for each lift.

b) *Control signals*

1) Bring the lift down to lobby floor in case of emergency or VIP movement.

2) Park and shutdown lifts based on building and traffic requirements, so as to save power.

3) Force the lift into emergency fire service, seismic mode or emergency medical service, etc through command from BA system based on respective sensor's such as smoke detectors, seismic sensor, etc, input to BMS.

c) *Reports* — Software tools may be developed to report out performance of each lift such as average response time, number starts per hour, average lift uptime, round trip time, etc. Flexibility to provide additional reports based on building requirements.

The above mentioned requirement for potential free contacts, other standard protocols, etc, may be optional, if the full-fledged lift management system software is provided by lift manufacturer for monitoring and control of lifts in the building. This software may be custom built providing above mentioned requirements. The wiring between lift machine room to Building Management Systems shall be planned and carried out by the builder along with other wiring in the building.

9.9 Closed Circuit Camera Inside Lifts for Monitoring (CCTV)

Where required, closed circuit camera is provided either by lift manufacturer or by third party supplier, inside the lift car for security purposes. Suitable warning mentioning 'You are under CCTV surveillance' shall be posted inside the lift car. These cameras may be located at ceiling level and at any location which cannot be easily accessed, noticed or tampered with.

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The cable used for connecting in car camera to monitoring system, provided by supplier, shall be of trailing grade. Ordinary co-axial or twisted pair wires shall not be lashed or tied along with trailing cables. Trailing cables are specialized cables used in lift applications. Wireless CCTV may also be considered alternatively.

If the camera signal is disconnected, either because of fault or intentionally, the lift monitoring system should get an alert indicating the same. Responsibility of monitoring, recording, organizing and maintaining CCTV shall be duly decided in advance.

9.10 Emergency Medical Service (EMS) for Hospitals

Optional emergency medical car operation may be provided especially for hospitals and operation theatre lifts and the lift behaviour in this mode is as described below. Activation of the emergency medical hall switch activates the in-car buzzer and illuminates a lamp in the car and hall. This forces the car to cancel car calls, reassigns hall calls, and return non-stop to the defined medical landing. Upon arrival, the door opens and the buzzer is deactivated.

The door remains open until the switch is turned off or the doors have been open for at least 60 s. If the medical switch is toggled, this operation remains in effect for additional 60 s. The second phase of EMS operation can only be activated when the doors are open at the medical landing. Once the car is on emergency medical operation fire service operation cannot be initiated, even though the fire service lamp and buzzer are activated.

If the car is performing fire service operations, emergency medical operations cannot be initiated, even though the medical lamp and buzzer are activated. The car automatically enters the emergency medical car operation after the doors are open at the medical return landing. If the emergency medical car switch is not activated within 60 s, the medical operation is cancelled.

To move the car, the emergency medical car switch needs to be activated. Prior to activation, the door cannot be closed and car calls cannot be registered. An active car switch allows car calls to be registered, which automatically closes the door and moves the car to the target landing. At the target landing the door opens and remains open until another car call is registered. The door close button has no effect on this operation.

If the car medical switch is deactivated away from the medical return landing with the doors open, the car remains at the landing not allowing car calls to be registered or the door to be closed. The car shall be returned to the medical landing and the emergency medical car switch deactivated to remove the car from emergency medical car operation.

9.11 Destination Control System (DCS)

The destination control system (DCS) uses passenger destination information to improve traffic flow and travel time in busy mid- and high-rise buildings. Instead of using standard hall call buttons, passenger enters specific floor number he wants to travel to — before entering the lift. The system groups passengers traveling to nearby floors to the same car.

Conventional Destination Control System requires keypads or touch screens at all floors to book the calls. This conventional DCS may be additionally provided the car operating panel (COP) in the lift car to improve passenger comfort. Alternatively, the COP in the lift car may be hidden. Traditional hall lanterns are no longer needed.

Hybrid Destination Control System requires keypads or touch screens only at the main floor allowing up-peak boosting of traffic. Traditional hall button stations and hall lanterns need to be provided at all other floors. A full COP is required in the lift. With both conventional and hybrid DCS provided with touch screens and/or keypads, hot button(s) may be provided to facilitate call booking to common floors as fast as possible.

Optional system features may be customized to meet building needs for special recognition to some passengers (VIP, special service, building service personnel). A security interface may be provided to allow for integration of building security and lift-dispatching systems.

Additional requirements for lifts required for persons with disabilities shall be according to requirements of good practice [8-5A(12)]. Fireman's lifts shall be provided with full car operating panel (COP) irrespective of configuration used.

9.12 Special Environments

Standard equipment is suitable for use inside normal residential, commercial and industrial buildings but when unusual environments are likely to be encountered, the advice of the lift manufacturer should be sought at the earliest possible stage to enable the most economic satisfactory solution to be found. Special mechanical protection and or electrical enclosures may be necessary as well as compliance with statutory or other regulations and with the purchaser's particular requirements, which should be fully considered at the time of enquiry.

Examples of situations which necessitate special consideration are:

a) Exposure to weather, for example, car parks.
b) Low temperatures, for example, cold stores.
c) High temperatures, for example, boiler plant.

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d) Hosing-down, for example, for hygiene or decontamination.

e) Corrosive atmosphere, for example, chemical works.

f) Dusty atmospheres, for example, gas plant.

g) Explosive and inflammable atmosphere, for example, gas plants, and petroleum and polyester industries.

h) Nuclear/heavy water plants.

10 PERFORMANCE REQUIREMENTS FOR LIFTS

10.1 It is necessary to have uniformity in the definition, measurement, processing and expression of vibration and noise signals that comprise lift ride quality. The aim of such uniformity is to benefit users by reducing variability in the results of lift ride quality measurements caused by differences in the methods of acquiring and quantifying the signals. Experience indicates that evaluation of vibration in terms of peak-to-peak levels is of particular relevance to passenger comfort. It is considered necessary to provide a dual form of expression, quantifying both the maximum peak-to-peak and A95 peak-to-peak vibration levels.

10.2 Measurement of Lift Ride Quality

Ride quality of all lifts shall be measured in accordance with accepted standards. The selection and calibration of measuring and test equipment shall also be in accordance with accepted standards.

Measurements shall be made during normal building conditions, after the lift has been running under normal daily operation for at least one hour. Vibration measurements shall be made at the geometric center of the car.

11 SPECIAL TECHNICAL REQUIREMENTS FOR SUPER HIGH RISE BUILDINGS

The provisions given hereunder describes the different physical phenomena that occur in super high rise buildings (> 200 m high) and have an effect on vertical transportation solutions.

Although there are no major differences with regard to suspension and guidance systems between high-rise and low-rise lifts, there are other aspects to be considered such as system technology and passenger comfort levels. Control system artificial intelligence levels, safety requirements, load-bearing component ratings, rope weight, energy consumption, and thus cost increase exponentially with the height of the building.

11.1 Air Pressure Effect

In high rise buildings, air pressure is different on ground level and on top of the building. Practically, pressure change on the ear becomes uncomfortable for some persons when lift is landing faster than 10 m/s. The thresholds are lower for small children, elderly persons and passengers having flu. Therefore, practically, lifts are offered as a standard solution up to 10 m/s maximum.

11.2 Piston Effect

If high speed lifts especially those having rated speed greater than or equal to 4 m/s, are housed in single shaft, the displaced air due to movement of the lift car tries to escape through the gaps between the lift car walls and the shaft walls in turbulent flow. This phenomenon known as piston effect causes the quality of ride in the lift car to deteriorate. Noise level in the lift car may increase along with vibrations which will be felt by the passengers. The air being displaced past the car generates whining and whistling noises inside the car. Buffeting when passing doors may be audible and passenger may feel uncomfortable. Both lift car doors and landing doors may whistle at high speeds.

Therefore, high speed lifts should preferably be housed in common shaft with ventilation holes in the common wall(s), if any. These holes allow the air displaced due to the movement of the lift car to escape in the adjoining hoist-way. Thus, the velocity of the escaping air which depends on the ratio of the lift car area to lift shaft area reduces which mitigates the piston effect ensuring good ride comfort for the passengers. The size of the vent and the pitch at which the vents need to be provided depend on lift car size in relation to lift shaft size, as well as the speed of the lift and the ride comfort expected.

In addition, high speed lifts especially those having rated speed more than 6 m/s may be provided cars with aerodynamically designed exteriors. This special construction of the car however increases the requirements of the overhead and pit for which lift manufacturer should be consulted. To reduce hammering sounds caused by the passage of the lift past the landing doors, shaft in front of the lift car door may be clad with facia plates of full shaft width between the landing door sill of the upper floor and door header of the lower floor door to create an even, flush surface. Lift cars also need to be specially constructed to absorb noise and thus reduce transmission of noise in the car.

It is advisable not to have common wall between the lift shafts. There should be shaft divider beams provided at every floor level and in between floors, if required, for the support of the guide rail brackets. Metallic wire mesh shall be provided for separation of shafts.

11.3 Stack Effect

Stack effect is defined as the vertical, natural air movement throughout a high rise building caused by the difference in temperatures between the inside air and the outside air. Positive stack effect is characterized

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by a strong draft from the ground floor to the roof. Positive stack effect is more significant in cold climates because of the greater difference in temperature between the inside and the outside of the building. The colder the weather and the taller the building, the greater will be the stack effect. Negative stack effect can also occur in the reverse direction in hot climates, but is not as significant because the difference in temperature is not as great.

The magnitude of stack effect is a function of,

a) building height;
b) air tightness of exterior walls;
c) air leakage between floors; and
d) difference in temperature between inside air and outside air.

The stack effect has following effects:

1) *Differential pressure on the lift landing doors* — The stack effect generates differential pressure on the landing doors. In case of buildings with airtight separation of each story the differential pressure on a particular landing door from inside and outside of the lift shaft is small however the pressure on the door of the first landing and that on the last landing varies a lot.

   In case of buildings with no air partitions the converse is true. The differential pressure on a particular landing is significant and is the maximum at the top most and bottom most landings which are farthest from the neutral pressure level. At the neutral pressure level, which occurs somewhere in the mid of the building height, the differential pressure on the landing door from inside and outside of the lift shaft is nil.

   The differential pressure on the landing door may cause difficulty in the operation of the door.

2) *Smoke movement* — The stack effect influences the smoke movement. In case of positive stack effect the air moves out from core of the building towards the exterior of the building above the neutral pressure level and it moves in from the exterior of the building to the core of the building below the neutral pressure level. In case of negative stack effect, reverse phenomenon occurs.

   This air movement naturally affects the smoke movement in case of fire and has to be taken into account.

   Since stairwells, lift shafts and lifts tend to contribute to the stack effect it is essential that all lift lobbies are well sealed and lifts parked with door closed to minimize stack effect. Especially in case of fire the stack effect needs to be controlled to prevent the spread of smoke in the building. On the other hand, the stack effect may be beneficially used to quickly drive smoke out of the building in case of fire.

11.4 Building Sway

The wind induced sway of the building may cause the lift suspension and/or compensation ropes and lift car travelling cables to sway. Buildings have natural frequencies of oscillations. Similarly lift ropes also have natural frequencies of oscillations which depend on the position of the car in the hoist-way amongst other parameters. When natural frequencies of the ropes and the building match, a large amount of energy is transferred to the ropes and they start swaying violently. This results into reduced ride comfort for the passengers in the lift and increases possibility of ropes getting stuck to snag points in the shaft and damaging shaft equipment. In general, the rope and travelling cable resonance phenomenon should be taken into account in the lift design for over 200 m in height buildings and slender buildings over 150 m in height, for example, TV towers. It is a fact that the resonance cannot be completely avoided in high rise buildings, hence the need for the solutions to cope with the phenomenon. If resonance is not taken into account in the lift design, it could increase the lift out-of-service time and decrease lift ride comfort.

The main purpose of the sway management is to improve lift safety and service time by reducing rope sway by optimizing compensations ropes tension, providing shaft protection equipment to prevent ropes from entangling and damaging the lift equipment. A sway detector may be used to control the lift operations. The output signals from the sway detector are used to reduce the speed of the lifts or park them at a safe floor.

In order that the sway analysis is done, the building designer should be in touch with the lift designer since early design stage of the building and share information on the building natural frequencies, maximum amplitude of building displacement with probability of occurrence, etc. The lift designer would then be in a position to calculate the rope/cable sway and decide on the preventive measures to be taken in the lift design.

11.5 Ride Comfort

A robust car guidance system with meticulously aligned guide rails is essential for reducing vibrations to an acceptable comfort level. Guide rails shall be rated for heavy-duty usage. Irregularity in the guidance system causes an unpleasant and uncomfortable transverse vibration within the car at high speeds. High-quality roller guidance system is required for smooth ride. In

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addition, the lift guidance system shall be able to withstand the effects of the building settling and the response of the building's structure to thermal and climatic changes.

11.6 Jump Lifts

In super high rise buildings there may be a need to start lift erection before the machine room is finished in order to compress total time required to complete the building. The self-climbing lift technique may be used to build the lift as the building construction progresses. Jump lift uses a temporary machine room that is moved upward as construction progresses. Typically, when the building construction reaches 7th floor, the jump lift may start operating and start serving lower floors. Exterior hoists can be removed sooner, enabling the façade to be enclosed. This means that lower floors are ready for finishing much earlier and the entire building can be completed sooner. Since all transportation takes place in a dry, windproof shaft, construction can continue safely and unhindered, even in bad weather. The change-over to final lift is very quickly done.

12 LIFT ENQUIRY OR INVITATION TO TENDER

12.1 General

A period of two to four weeks is normally sufficient for return of tenders. This should be extended, if large numbers of lifts or special requirements are involved.

The enquiry documents should be kept to the essential minimum, and should be strictly confined to material relevant to the lifts works and to the particular project concerned.

When enquiring for and ordering lifts, the particulars given below should be furnished:

1) Type of lift (passenger, goods, service or dumb waiter);
2) Number of lifts required;
3) Capacity/Load of lift (s): number of persons (in kg);
4) Rated speed (m/s);
5) Travel (in m) and building height;
6) Floors served (no. of regular openings, emergency openings, blocked openings);
7) Method of control (simplex or group control);
8) Position of machine room (if machine room-less, machine below, hydraulic);
9) Machine room height;
10) Clear overhead/Clear top clearance;
11) Pit depth;
12) Sizes of hoistway (width x depth), in mm;
13) Position of counterweight;
14) Car size (width x depth), in mm;
15) Construction, design and finish of car bodywork;
16) *Car entrances:*
    i) Number of entrances,
    ii) Size (width × height), in mm
    iii) Type of door (center opening, telescopic, 4 panel, vertical bi-parting), and
    iv) Whether through opening.
17) Car light;
18) Call indicator;
19) Position indicator in car;
20) *Lift landing entrances*:
    i) Number of entrances,
    ii) Size (width × height), in mm
    iii) Type of door or gates or shutters (for goods lifts) (centre opening, telescopic, 4 panel, vertical bi-parting), and
    iv) Whether through opening.
21) *Electric supply:*
    i) Power in volts a.c.,
    ii) Phase, and
    iii) Cycles (wire system).
22) Whether neutral wire available for control circuit;
23) Temporary guarding of hoist-way and car cabin;
24) Lighting volts a.c./d.c.;
25) Are premises subject to *Lifts Act* and *Rules;*
26) Disable friendly requirements [such as voice announcement of floor levels, accessible control panel (good contrast with the background wall, Braille, raised letter and font), railing on three sides, two way accessible communication system];
27) Earthquake protection requirements; and
28) Additional items.

12.2 Additional Items

The enquiry should state any additional items required beyond those specified in good practice, such as interface requirements, dismantling of existing lifts, fireman's control, seismic design consideration, sway/ deflection requirements, gravity distortion, etc.

12.3 Finishes

Finishes should be specified at the enquiry stage or provisional sums should be included for them. Finishes to be considered may include interior car finish, false ceiling design, false ceiling lighting, flooring material

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and weight, blower, ventilation details, car wall cladding details (weight to be considered), multimedia display details (like screen type, size, location, etc), door cladding details, transom details (flushed with the wall, material type, etc). *See also* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

12.4 Inclusions and Exclusions

A number of peripheral items are associated with lifts installation, of which some should always be provided by the builder and some are best included by the manufacturer. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

The lifts manufacturer should include such items mentioned in **12.1**.

The lifts manufacturer should exclude the supply and fixing of the items or as per the contract conditions as follows:

a) Builder's work such as forming lift well, pit and machine room, and building wall inserts.

b) Machine room floor including any reinforcement necessary for load bearing.

c) Hoisting hook/lifting beam fixing, where necessary.

d) Any necessary tanking, lining or reinforcement of the pit.

e) Diving beams for multiple wells and inter well pit screen (or as per the contract).

f) Trap door.

g) Intermediate beams for bracket fixing.

h) Door cladding (or as per the contract).

j) Cutting away and making good.

k) Working lights/permanent electricity supplies.

m) Site painting of steel work other than lift material (if any).

For more detailed discussion of the requirements for site preparation and work by other trades, reference should be made to good practice [8-5A(7)] and to other relevant clauses of this Section.

Facilities for the use of the main contractor's crane should be provided to assist in installing heavy equipment in addition to other unloading facilities on site in the course of erection.

The main contractor should be instructed to include these facilities in his own quantities.

Where the lift manufacturer agrees to use mobile platforms in place of lift well scaffolding, the general contractor should provide 400/440 V 3-phase and 200/220 V single-phase supply in the lift shaft to operate such equipment, the supply to terminate at the position in the lift well required by the lift manufacturer.

These mobile platforms are limited in use for erection personnel and the transportation of light equipment only, but use of crane will also be necessary to assist in the installation of the heavy machinery and also in the initial installation of the mobile platform equipment.

12.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the manufacturer, in particular the target date for completion, construction schedule, site preparedness, the availability of crane for hoisting, coordination details (with other contractors like BMS interfacing, CCTV interfacing, etc).

13 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

13.1 General

The procedure indicated below particularly relates to the most usual case, where the lift manufacturer is the sub-contractor.

13.2 Order

The building owner places an order with the selected contractor for supply and installation of lifts. If alternative schemes have been offered, the order should clearly indicate which has been accepted.

13.3 Programme

The contractor shall submit a detailed programme after acceptance of the order showing his intended method, stages of the works, together with the period of time that has been estimated for each and every stage of progress.

The programme shall cover each lift separately, including dates, such as:

a) Date of order of equipment and materials;

b) Date of commencement and completion of every stage of the works in line with the building construction programme;

c) Date of expected completion of builder's work requirements;

d) Date of delivery of equipment and materials to site; and

e) Date of requirement of temporary and permanent electricity supply, and date of completion, commissioning and testing.

The period between order and delivery of material falls into two stages: first the finalizing of details and secondly the actual production of the equipment which

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depends on the first stage. Within the first stage, other dates may need to be considered, such as:

1) All relevant building information available.
2) Submission of lift manufacturer's drawings.
3) Approval of drawings.
4) Final selection of finishes.

13.4 Drawings to be Submitted after Placing of Order

The lift manufacturer shall prepare layout drawings based on the civil/structure drawings, order requirements and submit to building owner within mutually agreed time frame. The same shall be briefed to building owner.

The drawings shall indicate clearly the position and sizes of all holes and cuttings, the loads on beams and structures, and all other requirements in relation to 'Lift Installation' namely:

a) Lift machine room and associated equipment, including sub-floor where appropriate.
b) All structural openings, such as landing entrances (including structural dimensions), ventilation openings, etc.
c) All bases, plinths, channels, holes, grouting-in of fixings, etc.
d) Lifting beams or other facilities for supporting lifting tackle in the machine room and lift well, permanent means of access to the lift pit.
e) Hoisting facilities and access required for delivery of equipment to the machine room, etc.
f) Details of structural steelwork for lift machinery in the lift machine room.
g) Details of shaft dividing steelwork for supporting guard brackets etc, and inter-well screens/wall for multiple wells.
h) Method of fixing guide rails.

13.5 Approval of Drawings

The building owner should go through the drawings submitted by lift manufacturer and ensure that it is prepared in line with civil/structural drawing and order requirements provided.

If any addition/alteration is noted in the drawing, the same shall be updated in the drawing by the lift manufacturer and resubmitted to the building owner for approval.

The drawing shall be approved by building owner, once it has been clearly understood.

13.6 Selection of Finishes

Where the contract provides for the purchaser's choice of decorative finishes, colours, etc, the decisions should be communicated by the purchaser's representative as early as possible, preferably not later than the time of approval of drawings.

13.7 Electricity Supply to Lift

Operation of the machine under power is required from a comparatively early stage of installation for the most efficient working, and power supply should be provided accordingly. Whilst temporary supply may be sufficient for erection purposes, final testing and setting up can only be carried out with the permanent supplies connected. For this reason the timely provision of the permanent supplies is important.

14 COORDINATION OF SITE WORK

14.1 Preparatory Work on Site

In accordance with the general arrangement drawing for the lift, the representative of the lift company would brief the building owner or his nominated representative about the preparatory work that is required to be carried out before commencement of the lift installation.

The building owner will ensure that the preparatory work is done in accordance to the general arrangement of lift and also the state *Lift Rules* are followed for the construction of the lift shaft as well as machine room. Once the preparatory work is completed, the building owner or his nominated representative, will ask the lift company to cross check and see that everything is in order.

The representative of lift manufacturer shall check the lift shaft and bring the shortfalls, if any, to the notice of the building owner till the preparatory work is completed in compliance with the requirement of lift supplier. The following works shall be completed by the building owner before commencement of lift erection.

a) Lift well pit floor and side wall of the lift shaft may be plastered and water proofed. Pit shall be free from any water leakage/seepage and debris. Building owner shall ensure the construction of the pit depth in accordance with the speed of the lift as specified by the manufacturer in the general arrangement drawing.
b) In general the thickness of lift walls should be minimum 230 mm in brick or 150 mm in RCC. However, the lift shaft walls shall be constructed in consultation with structural engineers or consultant to verify the suitability based on lift load/reactions.
c) In case of brick walls it would be recommended to have concrete block at locations where the guide rail brackets are to be installed. Similarly in case of structural shaft suitable ISMC/ISMB should be provided by the builder to fix guide rail brackets at all bracket fixing levels. The lift manufacturer

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will provide a drawing indicating the locations of brackets in the lift shaft.

d) Similarly for fixing the landing entrances, the builder has to provide RCC lintels/RCC beams for fixing landing door header and sill. In case of structural shaft suitable metallic channels have to be provided in the entrance area at lintel and floor level.

e) All the structural shafts have to be completely covered and finished in accordance to the local codes before the start of installation.

f) Suitable cut-outs near the entrance area as indicated in the lift general arrangement drawing have to be provided for fixing human interface system like landing operating panel, floor indicator, hall gong and lantern, emergency alarm, fireman switch and other devices like 'THIS CAR NEXT', group indicators, etc.

g) The building contractor shall provide load hooks/beams in machine room for machine room lift, one directly above the lift shaft and other directly on top of the trap door as specified in the lift general arrangement drawing. The same shall be provided in the slab in the overhead area for machine room less lifts, as specified by the lift manufacturer in their general arrangement drawing. The position of load hooks/beams provided by the building contractor shall be as specified by the lift manufacturer.

h) Machine room door shall be opening outside. It shall be minimum 1 m wide and 2 m in clear height with a platform outside.

j) Caution notice of 440 V and restricted entry shall be marked on the machine room door.

k) Fire extinguisher shall be provided by building contractor to prevent fire accidents.

m) The machine room shall be air-conditioned or adequately ventilated so as to maintain the ambient temperature between +5°C and +40°C.

n) The lift shaft in masonry shall be fully plastered. The shaft shall be given two coats of white-wash.

p) Scaffolding (bamboo/steel) shall be erected as required by the lift manufacturer with necessary safety measures. Adequate barricading needs to be provided on all the lift entrance opening to avoid mishap.

q) The building contractor shall provide proper illumination in the lift shaft, lift lobby, staircase and machine room.

14.2 Delivery of Material

The delivery of the material shall be made based on mutual agreement of the lift manufacturer and the building contractor. It is strongly recommended that the material should be delivered at site only when a suitable storage area is provided by the building contractor.

The scope of unloading and stacking materials shall be as per mutually agreed terms between the lift manufacturer and the building contractor. While unloading and shifting of materials due care shall be taken by both the parties to ensure safe unloading and shifting of materials.

Suitable equipment like hydra, fork lift, crane and trolleys shall be used for unloading and shifting of lift materials. Building contractor shall ensure safe passage for vehicles carrying materials, up to the storage area.

14.3 Storage

In order to enable efficient material distribution it is important that the material shall be unloaded from the delivery truck within a distance of 50 m of the storage/ unit location and have proper access from unloading area to storage area. The building contractor shall provide the storage area near the installation site, that is within 20 m distance from the installation site. The minimum storage space per lift shall be 35 m^2 per lift.

The storage room should be dry, well lit, weather protected and should have locking arrangement and provision of a 16 A power point is recommended. The storage area provided by the building owner should have PCC flooring. The storage room shall be kept ready before arrival of material at site and will remain in possession of installation engineer till the erection of lift is completed and handed over to the owner.

The material shall be stacked in sequential manner, in accordance with the planned activities. The storage area should be provided at a suitable location near the vicinity of the lift shaft preferably above the ground floor level and should remain in possession of the lift supplier till the installation and commissioning work is completed. It is strongly recommended that the location of the store is not changed to avoid material damages.

14.4 Site Meetings

For the successful progress of the work, full cooperation among all agencies is essential. In large sites, regular meetings of such agencies are beneficial for coordination of work efficiently. Programme for the constructional work in that part of the building

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containing the lift should be made in consultation among all parties concerned.

14.5 Service of Other Trades

The lift erector will require the services of architect, civil, and electrical contractors, and other agencies as the work proceeds, and it is essential that the lift erector should give due notice to the building contractor of the demands to be made on other trades, so that he can plan accordingly. Mutually agreed, periodic meeting to review work progress with agencies concerned would ensure better coordination and efficiency.

14.6 Scaffolding, Fencing, Wherever Provided

Scaffolds and stationary work platforms shall be erected in accordance with adequate safety under the supervision of a competent person. When used, wooden or synthetic planks shall be scaffold-grade or approved by a qualified person for scaffold and stationary work platform use, and the same shall be capable of withstanding 4 times the working load.

The assembly and disassembly of scaffolds and stationary work platforms shall be done using a safety harness and lifeline as required. All temporary lighting shall be so installed so as not to make any contact with the metal frames of the scaffold. Also the scaffolding shall be double earthed. Prior to carrying out any lift installation work, fencing and warning notices should be provided at all landings indicating that there are men at work.

14.7 System Building Sites

If the building programme allows insufficient time for lift erection in conventional fashion after the well is completely built special procedures are needed. This applies particularly to industrial and multi-storeyed buildings. The building contractor should provide a suitable portable cover to the completed portion of the lift well in order to protect the lift erectors working below against the weather and falling objects.

When the top of the well has been reached it is normal to cap it immediately with a precast load bearing floor slab on to which is lowered the pre-assembled machine room equipment. It then remains for the building contractor to complete and weatherproof the machine room as swiftly as possible. On all such projects the close cooperation between the building contractor and the lift manufacturer is essential.

14.8 Connecting to Power Supply

The lift manufacturer should give prior intimation to the building contractor of the date the power supply to the lift is required, so that suitable arrangements for connection can be made.

15 INSPECTION AND ACCEPTANCE PROCEDURE FOR LIFTS

15.1 Reference

This suggested procedure for inspection of lifts is based on good practice [8-5A(2)], [8-5A(10)] and [8-5A(13)] for the traction lift.

15.2 Purpose

To ensure safe operation of new lifts on their completion and before being placed in service, they need to be subjected to acceptance inspection and tests in the field to determine that installation shall conform to the requirements of applicable standards. An inspection and test shall also be carried out on an existing installation after a major alteration.

15.3 General Requirements

These requirements shall be as follows:

a) *Personal safety*
   1) Use of relevant personal protective equipment is mandatory by the inspector and his support staff at the time of inspection.
   2) Should stop work and arrange for correction, if unsafe conditions are noticed at the installation.

b) *Safety precautions during inspection*
   1) Inspectors should have a proper working knowledge of the lifts.
   2) They should always ensure that the car is in his control while working on car roof and pit
   3) They should at all times be alert for moving objects, and when on top of an lift car for moving counter weight, hoist-way projection such as beams, adjacent moving cars, cams and other equipment attached thereto or mounted in the hoist-way.
   4) The overhead clearance should always be noted as number of fatal accidents occurs due to cars running into limited overhead spaces while inspections are made from top of the lift cars.
   5) Inspector should never enter in lift pits containing water.
   6) When working in the lift pit the inspector should always note the position of car.
   7) Keeps clear distance from descending counterweight in the hoist-way of the lift being inspected and those in adjoining hoist-way.

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15.4 Description of Installation

The following provides a template of typical description of installation:

Site Name with details	Vendor
Length of travel (mm)	Job No:
Number of floors served Total: * Front: * Rear: *	Purchaser's identification number Power supply Permanent Temporary
Car door: Glass / SS Landing door: Glass / SS	
Rated load	Voltage *
Rated speed m/s *	Phase *
Lift type : Passenger / Goods Machine Room / Machine Room Less Location of Machine Room (For MR Lifts) Give a tick mark in the appropriate box Above well Below well At side	Frequency * Wire(3 or 4) * MCCB rating * ELCB rating * Are the above entries acceptable Yes No
Roping ratio: _____	

15.5 Visual and Functional Checks

A typical checklist of visual and functional checks involved in the installation of lifts is given in Annex A.

16 MAINTENANCE OF LIFTS

16.1 Following sections specify the elements necessary for the preparation of the instructions for the maintenance operations of lifts. The requirements are applicable for all new installed passenger lifts, goods — passenger lifts, special goods lifts such as vehicle lifts, service lifts.

NOTES

1 Existing installed lifts are not covered.

2 Instructions for installation and dismantling of lifts are not covered.

16.2 Maintenance of the lift essentially covers all necessary operations to ensure safe and intended functioning of the installation and its components after completion of the installation and throughout its life cycle. Maintenance includes:

a) lubrication, cleaning, etc;

NOTE — The following cleaning operations cannot be considered as maintenance:

1) Cleaning of the external parts of the well, and

2) Cleaning of the inside of the car.

b) checks;

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c) passenger rescue operations;
d) the operations of setting and adjustment; and
e) repair or changing of components which may occur due to wear and tear and do not affect the characteristics of the installation.

The following are not considered as maintenance operations:

1) Changing of major component such as the machine, even if the characteristics of the new component are the same as the original;
2) Replacement of installation;
3) Modernization of the installation including changing of any characteristics of the installation (such as load, speed, etc); and
4) Rescue operation carried out by fire brigade.

16.3 Elaboration of Maintenance Instructions

16.3.1 *General*

The installation shall be maintained in good working order in accordance with the manufacturer's instructions. To this effect, regular maintenance of the installation shall be carried out to ensure, in particular, the safety of the installation. The safety of an installation shall take into account the ability to be maintained without causing injury or damage to health.

Regular maintenance of the installation shall be carried out to ensure the reliability of the installation. The access and the associated environment shall be maintained in good working order in accordance with the installer's instructions.

The instructions for maintenance of an installation shall be provided by the installer after completion of the installation as a result of a risk assessment. The instructions for maintenance of the safety components of lifts shall be provided by the manufacturer to the installer. The instructions for maintenance which shall be based on a detailed risk assessment of an installation shall be provided by the manufacturer.

In order that the aim of the maintenance instructions can be achieved, they shall be formulated so that they can be clearly and easily understood by competent maintenance person.

The competent maintenance person within the maintenance organization shall be continuously updated.

NOTE — The owner of the installation should be informed that the qualification of the maintenance organization is in conformity with the regulation applicable in the state in which the installation operates.

The manufacturer shall provide maintenance instructions intended for the owner of the installation including the information intended for the maintenance organization.

16.3.2 *Elements to be Taken into Account for Maintenance Instructions*

When preparing the content of the maintenance instructions the following elements shall be taken into account:

a) The specifications and the intended use of the installation (type of installation, performance, type of goods to be transported, type of users, etc).
b) The environment in which the installation and its components are installed (weather conditions, vandalism, etc).
c) Any restriction of use.
d) The result of risk assessment for every working area and for every task undertaken.
e) The specific maintenance instructions provided by the manufacturer of safety components.
f) In case of components other than safety components, where maintenance is necessary, the maintenance instructions provided by the manufacturer of these components.

16.3.3 *Information to be Included in the Maintenance Instructions*

16.3.3.1 *General*

The maintenance instructions shall contain information relating to the tasks of the owner and respectively the maintenance organization.

16.3.3.2 *Information to the owner of the installation*

The information relating to the tasks of the owner of the installation shall include that given in **16.3.3.2.1** to **16.3.3.2.16**.

16.3.3.2.1 The need for the owner to keep the installation in a safe operating condition. To fulfil this owner shall use a maintenance organization complying with the requirements of this Section.

NOTE — It is recommended to inform the owner of the installation about the need to use a maintenance organization with adequate and proper insurance cover provided by an insurance company.

16.3.3.2.2 The need for the owner to take care of any state/local regulations and other requirements, where relevant, and their implications on maintenance.

16.3.3.2.3 The need for planned maintenance to be carried out by a maintenance organization, at the latest when the installation is put into service or if the installation is to remain unused for a long period of time, before being put into service first time thereafter.

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16.3.3.2.4 The importance for the owner of the installation to have the same maintenance organization in the case of several installations having common well/ spaces and/or machine room.

16.3.3.2.5 The need for the owner of a passenger/goods-passenger lift to keep the two-way means of communication efficient and linked to a 24 h rescue service for the whole of the time that the installation can be used.

16.3.3.2.6 The need for the owner to remove the passenger/goods-passenger lift from service when the two-way means of communication is out of order.

16.3.3.2.7 The need for the owner to put the installation out of service in case of dangerous situations.

16.3.3.2.8 The need for the owner of the installation to inform the maintenance organization,

a) immediately about any perceived abnormal operation of the installation or abnormal change in its direct environment;
b) immediately after putting the installation out of service in the case of a dangerous situation;
c) after any rescue intervention by their authorized and instructed person(s);
d) before any modification related to the installation and/or its environment or use;
e) before any authorized third party inspection or works other than maintenance works are carried out on the installation;
f) before taking the installation out of service for a prolonged period of time; and
g) before putting the installation back into service after a prolonged period of non-operating time.

NOTE — The owner of the installation should obtain from the company carrying out the relevant modification the maintenance instructions for the maintenance organization.

16.3.3.2.9 The need for the owner of the installation to take into consideration the consequences of the risk assessment carried out by the maintenance organization.

16.3.3.2.10 The need for the owner of the installation to make sure that the risk assessment for maintenance is carried out,

a) if the maintenance organization is replaced;
b) if the use of the building and/or the installation changes;
c) after a major modification of the installation or of the building; and
d) if it is the case, after an accident involving the installation.

16.3.3.2.11 The need for the building owner to ensure, through a risk assessment, that,

a) their premises are safe and free from risk to health as far as is practicable. This includes access to the premises and installation equipment, and articles or substances used according to the regulation for the use of work equipment at the workplace;
b) the persons using the premises are informed about any remaining risks; and
c) any action to be done as a consequence of his risk assessment is carried out.

Regarding the access ways to areas reserved to maintenance persons, the need for the owner of the installation to inform the maintenance organization, in particular about,

1) the access ways to be used and fire evacuating procedures from the building;
2) the place where the keys of the reserved areas can be found;
3) if necessary, the persons who shall accompany the maintenance persons to the installation; and
4) if necessary, personal protective equipment to be used in the access ways, and, possibly, where this equipment can be found.

The information shall be made available also on site to the maintenance organization.

16.3.3.2.12 The need for the owner of the installation to ensure that the name and the telephone number of the maintenance organization are always available to the user of the installation, permanently affixed and clearly visible.

16.3.3.2.13 The need for the owner of the installation to ensure that the keys of machine and pulley room doors (trap doors) and of inspection and emergency doors (trap doors) are permanently available in the building and are used only by persons authorized to gain access.

16.3.3.2.14 The need for the owner of the installation to provide, in all circumstances, safe access to the building and to the installation for the maintenance organization involved in the rescue of persons.

16.3.3.2.15 The need for the owner of the installation to keep the access to working areas and working rooms safe and free for the maintenance persons and to inform the maintenance organization about any hazard or change in the workplace and/or the access ways (lighting, obstructions, ground conditions, etc).

16.3.3.2.16 In addition to those examinations and tests which the owner of the installation entrusts to the

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maintenance organization, the need for the owner to carry out periodically, in their own interests, the following:

A full ascent and descent travel to assess any changes in the quality of the ride or damage to the equipment. Typical items to be checked to ensure that they are in place, undamaged and functioning correctly are,

a) landing doors and bottom door tracks;
b) stopping accuracy;
c) indicators that are not located in a reserved area;
d) landing push controls;
e) car push controls;
f) door open controls;
g) two-way means of communication in the car which provides permanent contact with a rescue service;
h) normal car lighting;
j) door reversal device; and
k) safety signs/pictograms.

For goods only and service lifts the checks to be carried out are the same, when relevant.

16.3.3.3 *Information for the maintenance organization*

The information relating to the tasks of the maintenance organization shall include the following:

a) The need to carry out the work of maintenance in conformity with the maintenance instructions and based on systematic maintenance checks. After these checks, the maintenance organization shall decide in conformity with the maintenance instructions what is required to be done.

   A list of typical examples of maintenance checks to maintain the installation is shown in Annex B.

   NOTE — Due to the fact that the components can be different in design and operation, it is therefore not possible to give specific guidelines.

b) The need to update the original maintenance instructions if the installation changes its intended use and/or the environmental conditions existing on the completion of the installation.

   NOTE — The maintenance organization should be provided by the owner of the installation with the relevant maintenance instructions where modifications are carried out on the installation.

c) The need for the maintenance organization to ensure that a risk assessment for any working area and for any maintenance operation has been carried out taking into account the installer's/manufacturer's maintenance instructions and all information supplied by the owner of the installation.

d) The need for the maintenance organization to inform the owner of the installation about any work to be carried out as a consequence of a risk assessment especially for the access and/or the environment related to the building/installation.

e) The need to carry out a maintenance plan so that preventive maintenance is suitable for the installation and maintenance time is as short as reasonably practicable, without reducing the safety of persons, in order to minimize the non-operational time of the installation.

f) The need to adapt the plan for maintenance so as to take account of any predictable failures, for example, those due to misuse, mishandling, deterioration, etc.

g) The need to carry out maintenance operations by competent maintenance persons and provided with the necessary tools and equipment.

h) The need to maintain the competency of maintenance persons.

j) In determining the frequency of maintenance interventions, the following non-exhaustive list should be considered:

   1) Number of trips per year, operating time and any non-operating periods of time;
   2) Age and condition of the installation;
   3) Location and type of building in which the installation is installed, as well as the needs of the users and/or the kind of goods transported;
   4) Local environment where the installation is situated, as well as external environmental elements, for example, weather conditions (rain, heat, cold, etc) or vandalism.

k) The need to provide a 24 h, all year round call-out service for rescue of persons.

m) The need to keep records of the result of each intervention due to a failure of the installation. These records shall include the type of failures in order to detect any repetition. They shall be available to the owner of the installation on request.

n) The need to put out of service the installation, if the maintenance organization is aware of a dangerous situation, detected during the maintenance, which cannot be eliminated immediately, and to inform the owner of the installation of the need to keep it out of service until repaired.

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p) The need to be organized to provide the necessary spare parts for any repair.

q) The possible need for attendance of a competent maintenance person(s), given reasonable notice, for any inspection carried out by an authorized third party or for building maintenance works to be carried out in the areas reserved for the maintenance organization .

r) The need to inform in due time the owner of the installation about necessary progressive upgrading of the installation.

s) The need to organize rescue operations, even with sub-contractor(s), and to make provision for circumstances such as fire, panic, etc.

16.4 Risk Assessment

16.4.1 *General*

Before an installation is placed on the market, it is necessary that the installer/manufacturer carry out a risk assessment. Every risk shall be limited as much as reasonably possible by means of safety measures and suitable instructions. The instructions can never replace a safety measure which can be provided to reduce the risk.

It is necessary to determine the different intervention procedures of the maintenance operations and to determine the appropriate safety measures for each of these procedures.

The use of diagnostic systems (for example, remote monitoring system) may support fault finding, improve the maintainability of the installation and reduce the exposure of maintenance persons to hazards.

Safety in maintenance operations of the installation is ensured by adopting safety measures and providing instructions. Safety measures on the installation and in the building shall be provided by the installer and by the owner of the installation, respectively.

For any working area, it is necessary to identify the list of the specific hazards related to health and safety and to carry out a risk assessment for any maintenance operation, including access to the working area.

For this purpose, the following should be taken into account:

a) Presence of one or more maintenance persons in a working area;

b) Foreseeable actions of persons other than maintenance persons (for example, person switching on or off power circuits and dependent circuits or lighting circuits or trying to use the installation during maintenance operations, etc); and

c) Possible states of the installation (normal or abnormal due to a foreseeable failure of its component parts, external disturbances, disturbance of its power supply, etc).

Annex C gives a list of examples of elements to be taken into account in any risk assessment for maintenance operations. However, several methods are available for the systematic assessment of risk.

16.4.2 *Information for the Maintenance Organization*

For safe maintenance and to provide relevant instructions, it is necessary, first of all, to identify the maintenance operations. In particular, maintenance operations are,

a) those operations considered necessary for a correct and safe functioning of the installation and its components after the completion of the installation;

b) those operations considered necessary during the 'life' of some components, determining, as far as possible, the time or condition after which the functioning or the integrity of the component is no longer ensured even if correctly maintained.

In carrying out specific maintenance operations, if it is necessary to neutralize some safety functions (for example, an electric safety device), the hazard identification shall be taken into account for such a situation.

It is necessary to inform and warn the maintenance persons about,

1) residual risks, that is, those for which risk reduction by design and safeguarding techniques are not - or not totally - effective; and

2) risks that arise from the necessary removal of certain guards to carry out specific maintenance operations.

The maintenance instructions and warnings shall prescribe the procedures and operating modes intended to overcome these risks and, if it is necessary, to specify personal protective equipment, instruments, tools and provisions to be used.

16.5 Information to the Owner for Lift Rescue Operations

The information to the owner shall be inclusive of that given in **16.5.1** to **16.5.5**.

16.5.1 The need for person(s) authorized by the owner of the installation to rescue trapped passengers to be trained by the maintenance organization.

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16.5.2 The need to ensure that the training is appropriate to the specific installation and updated.

16.5.3 The need to ensure his authorized person(s) rescue people only through landing doors.

16.5.4 The need to ensure that the maintenance organization is called when the owner's authorized person(s) are not able to move the car through the use of the manual and/or electric emergency devices.

16.5.5 The need to inform their authorized person(s) about any conditions for which only the maintenance organization shall carry out a rescue operation.

16.6 Markings, Signs, Pictograms and Written Warnings

If the risk assessment of the maintenance organization indicates that additional specific warnings are required for the purpose of maintenance, these shall be affixed directly on the installation/component or, when this is not possible, in the close vicinity.

Markings, signs, pictograms and written warnings shall be readily understandable and unambiguous. Readily understandable signs and pictograms shall be used in preference to written warnings.

Signs or written warnings carrying only 'DANGER' shall not be used.

Information affixed directly on the installation/ component shall be permanent and legible.

Any markings, signs, pictograms and written warnings affixed on the installation shall be renewed if they become illegible.

16.7 Format of the Maintenance Instruction Handbook

The maintenance instruction handbook for any installation shall contain at the front at least the following:

a) Type of installation, with its serial number, to which the instructions apply;
b) Title of the handbook;
c) Date of issue;
d) Name and address of the installer/ manufacturer; and
e) Name of the publisher, when different from the installer/manufacturer.

In the handbook,

1) all units used shall be SI units;
2) all pages shall be numbered; and
3) all references to other documents shall be in full.

Warnings shall state the hazard, the related risks and the appropriate safety measure.

Type and size of print shall ensure the best possible legibility. Safety warnings and/or precautions shall be emphasized through the use of colours or symbols and/ or large print. Signs shall comply with the accepted standard [8-5A(14)].

Documents giving instructions for maintenance shall be produced in durable form (that is, they shall be able to survive frequent handling) or triplicate copies shall be provided.

16.8 Documents to be Kept at the Site of Installation of Lifts

The following documents shall be maintained at the job site near the controller such that they are easily available:

a) Wiring diagram,
b) Lift license copy,
c) Log card, and
d) General arrangement drawing.

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ANNEX A

(*Clause* 15.5)

TYPICAL CHECKLIST OF VISUAL AND FUNCTIONAL CHECKS INVOLVED IN THE INSTALLATION OF LIFTS

A-1 MACHINE ROOM

Sl No.	Requirement	Result	Remarks
i)	There shall be easy access from the top landing to the machine room	Accessible / Not accessible	
ii)	Steps along with handrail for the access to machine room to be provided	Provided / Not provided	
iii)	Locking arrangement shall be provided and machine room shall be kept locked	Provided / Not provided	
iv)	The machine room shall be used for the purpose of lift machinery only	Yes / No	
v)	Machine room should be free from water entry	Yes / No	
vi)	Rope hitches on the machine room are fixed as required and locked with nuts and split pins	Yes / No	
vii)	The hoisting beams or hooks provided as per the required load and marked	Provided / Not provided	
viii)	Trap door at the top of the lift well to lift the machine up or down from the machine room and to be located vertically below the hook provided in the machine room ceiling	Provided / Not provided	
ix)	Rescue chart to be pasted in the machine room with proper identification	Yes / No	
x)	The correct capacity main switch and protective device to be provided as per the requirement	Provided / Not provided	
xi)	Grounding conductor is provided and of correct size	Provided / Not provided	
xii)	Provision of log card pocket	Provided / Not provided	
xiii)	Guards to be provided for moving parts such as over speed governor (OSG), machine sheave, etc	Provided / Not provided	
xiv)	Three pin socket with switch and lighting arrangements	Provided / Not provided	
xv)	The machine room is painted and windows to be provided	Provided / Not provided	
xvi)	There shall be adequate ventilation	Provided / Not provided	
xvii)	Machine room shall be kept in clean condition	Clean / Unclean	
xviii)	Provision of caution notice indicating ‘DANGER’ on machine room door	Displayed / Not displayed	

A-2 POWER SUPPLY

Sl No.	Requirement	Result	Remarks
i)	Incoming power supply to be 415 V ± 10 percent or as specified in the contract agreement	R-Y : _____ Y-B : _____ R-B : _____	

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Sl No.	Requirement		Result	Remarks
			Ok / Not Ok	
ii)	Neutral – Earth voltage	Ideal condition within (0- 3) V	Value: _____ Ok / Not OK	
iii)	Neutral – Earth voltage	Running condition within (0- 3) V	Value: _____ Ok / Not OK	
iv)	Separate supply with MCB	Three phase supply	Provided / Not provided	
		Single phase supply (For car lighting and shaft lighting)	Provided / Not provided	
v)	Check whether the power cables are connected with lugs for termination		Connected / Not connected	
vi)	Shaft lighting to be provided		Provided / Not provided	

A-3 MACHINE AND BRAKE ASSEMBLY

Sl No.	Requirement	Result	Remarks
	Make: *Sl No.:* *Rating:*_____		
i)	Is the machine fixation as per the installation manual	Yes / No	
ii)	Are the electrical connections of the machine routed and well tightened	Yes / No	
iii)	Machine earthing is done, routed and properly tightened	Yes / No	
iv)	Are the machine isolation pads installed correctly (if applicable)	Yes / No	
v)	Are the rope openings below the machine closed adequately as required	Yes / No	
vi)	If applicable, is the machine lubricated as required	Yes / No	
vii)	The height of the machine room shall not be less than 2 100 mm at working areas	Yes / No	
viii)	The clear height for the movement shall not be less than 1 800 mm	Yes / No	
ix)	The width of the clear space around the machine from any two sides shall not be less than 500 mm	Yes / No	
x)	Clear vertical distance of at least 300 mm is available above rotating equipment	Yes / No	
xi)	Are all the components of the brake installed, nuts tightened and locked	Yes / No	
xii)	Is the routing of the machine brake cables free from any moving parts	Yes / No	
xiii)	Is the machine brake and switches properly adjusted with correct clearance	Yes / No	
xiv)	Is the brake assembly clean, no debris and oil on disk or drum	Yes / No	
xv)	Is the manual brake release device is available and easily accessible	Yes / No	

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A-4 CONTROLLER

Sl No.	Requirement	Result	Remarks
	Type: *Sl No.:*	*Wiring drawing No:*	
i)	Is the controller fixed as per the GAD (General Arrangement Drawing)	Yes / No	
ii)	Is the controller identified with the correct contract number	Yes / No	
iii)	The controller should have an easy access to open and close with lock	Yes / No	
iv)	The required warning stickers to be pasted	Provided/Not provided	
v)	All extra cables to be neatly arranged	Yes / No	
vi)	Are the battery terminals covered	Yes / No	
vii)	The field and controller wiring to be properly routed	Yes / No	

A-5 OVER SPEED GOVERNOR

Sl No.	Requirement	Result	Remarks
Make:	*Model:* *Sl No:* *Tripping speed:*		
i)	Is the correct over speed governor provided and installed as per layout	Yes / No	
ii)	The sticker/painted indication represents the down direction of rotation which will facilitate the safety gear actuation	Yes / No	
iii)	Check whether the OSG is calibrated and sealed	Yes / No	
iv)	The governor is aligned and the rope passes through the holes without any obstruction	Yes / No	
v)	The governor rope runs free does not contact any with any object in the hoist-way	Yes / No	
vi)	The governor tripping mechanism is free and clean	Yes / No	
vii)	The electrical switch is provided and operates in both the directions	Yes / No	
viii)	All fixation bolts are provided and adequately tightened	Yes / No	

A-6 GENERAL INSPECTION ON CAR ROOF

Sl No.	Requirement	Result	Remarks
Instructions before entering to the car top: a) Allow the lift to move in down direction from the top terminal landing with no load. b) Stop the lift from the controller by changing to maintenance mode, such that easy access to enter the car top from the top terminal landing. c) Switch on the shaft lighting. d) Use the door open key to open the top terminal landing door. e) Switch on the car top stop switch from the landing to enable the 'STOP' mode. f) And then enter into the car top and switch on the light point there. g) Switch to maintenance mode from the car top and release the stop switch to move the lift in maintenance mode.			

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Sl No.	Requirement	Result	Remarks
i)	Barricade on car roof to be provided	Provided /Not provided	
ii)	Adequate lighting with proper protection is provided on the car roof	Provided /Not provided	
iii)	Wires and trunking are properly routed and does not hinder with any maintenance related equipment	Yes / No	
iv)	The car fan is properly fixed with isolation	Yes / No	
v)	Three pin plug socket with switch is available and is in working condition	Yes / No	
vi)	The emergency stop switch that should be easily accessible from outside the lift is provided of manually opened and closed type	Yes / No	
vii)	Check whether the top car clearance meets the requirement. Value required:_____	Value measured:_____ Ok / Not Ok	
viii)	Overhead dimension in W×H×D Value required:_____	Value measured:_____ Ok / Not Ok	
ix)	If overhead height is less, then the indication to be provided with ZEBRA PAINTING in the overhead	Provided / Not provided	
x)	Floor levelling switches are fixed as per requirement	Yes / No	
xi)	Rope hitches on car roof are fixed as required and locked with nuts and split pins	Yes / No	
xii)	Car sheave if available is adequately guarded from accidental contact	Yes / No	
xiii)	The junction box is fixed securely and all wires are adequately protected	Yes / No	
xiv)	The car shoe liners / rollers are fixed as per requirement and adjusted properly	Yes / No	
xv)	Oil tank are provided and fixed with proper oil levels	Yes / No	
xvi)	Engagement of the car door coupler with the landing door at every landing	Ok / Not Ok	
xvii)	Engagement of shaft limit switches	Ok / Not Ok	
xviii)	The governor rope and linkage is correctly connected to the car	Yes / No	
xix)	The guide rail clips are fixed as per requirements and in the correct directions	Yes / No	
xx)	The safety gear assembly and connecting rod should be free from external disturbances	Yes / No	
xxi)	The safety switches have been verified for correct operation during travel	Yes / No	
xxii)	The safety gear linkages is checked for operation and actuation and actuation of switches	Yes / No	
xxiii)	Clearance between the car door coupler and the landing sill to be as per the manufacturer design at every landing	Ok / Not Ok	
xxiv)	Clearance between the landing rollers with the car sill to be as per the manufacturer design at every landing	Ok / Not Ok	

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A-7 PIT INSPECTION

Sl No.	Requirement	Result	Remarks
Instructions before entering to the pit: a) Allow a person in the car top and ask him to move the lift to the top most landing. b) Open the bottom terminal landing door with door open key. c) Switch on the pit stop switch from outside the pit. d) Enter in to the pit.			
i)	It should be clean and dry	Yes / No	
ii)	Pit ladder to be provided if the pit depth exceeds 1 500 mm as measured below the bottom most landing sill	Provided /Not provided	
iii)	Oil trays are available at the bottom of each guide rail	Provided /Not provided	
iv)	Two pit stop switches to be provided and one should be easily accessible from the bottom terminal landing	Provided /Not provided	
v)	Pit stop switches to be verified with the electrical circuit such that lift should not move further after the activation of pit stop switches	Ok /Not Ok	
vi)	Counterweight screen should be provided and fixed	Provided / Not provided	
vii)	Buffers provided for car and counterweight are correctly fixed and aligned and the electrical switch to be verified, if provided	Ok / Not Ok	
viii)	The governor tension pulley is fixed at the correct height from the pit floor as per the manufacturer recommendation	Ok / Not Ok	
ix)	The electrical switch for the tension pulley is verified, if provided	Ok / Not Ok	
x)	Check whether the bottom car clearance meets the requirement Value required:_____	Value measured:_____ Ok / Not Ok	
xi)	Check for the provision of car bottom light and its function	Ok / Not ok	
xii)	Is the travelling cable below car secured and correctly fixed and the excess cable is not secured below car	Ok / Not Ok	
xiii)	The travelling cable is adjusted and clear of the pit floor with the car at the lowest position	Ok / Not Ok	
xiv)	The bottom guide shoes or rollers are fixed as per requirement and adjusted for smooth travel	Ok / Not Ok	
xv)	The car safety gear is properly adjusted as per the installation manual	Ok / Not Ok	
xvi)	The compensation chain fixing arrangement is fixed as per requirement	Ok / Not Ok	

A-8 EARTHING

Sl No.	Requirement	Result	Remarks
i)	Separate earth bar to be provided in the machine room	Provided /Not provided	
ii)	Earthing to be done for all controllers and the machine	Yes / No	

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Sl No.	Requirement	Result	Remarks
iii)	Earthing to be done for the shaft equipment and car top components	Yes / No	
iv)	Earthing from controller to car top components to be linked through the travelling cable	Yes / No	
v)	Routing of the earth from the controller to the main earth bar	Ok / Not Ok	
vi)	Connection of the lift earth bar to main earth bar	Ok / Not Ok	

A-9 INSPECTION FROM THE LIFT CAR

Sl No.	Requirement	Result	Remarks
Instructions: a) No one should be present in the pit as well as in the car top. b) Make sure the lift to run in normal mode. c) Enter the lift car from any of the landing.			
i)	Car inside width Value required:_____	Value at site:_____ Ok / Not Ok	
ii)	Car inside depth Value required:_____	Value at site:_____ Ok / Not Ok	
iii)	Height below false ceiling. Value required:_____	Value at site:_____ Ok / Not Ok	
iv)	Door opening width Value required:_____	Value at site:_____ Ok / Not Ok	
v)	Door opening height Value required:_____	Value at site:_____ Ok / Not Ok	
vi)	Car capacity to be displayed inside the lift car	Yes / No	
vii)	Safety warning plate to be displayed (*see* Note)	Yes / No	
viii)	Functioning of car display	Functioning / Not functioning	
ix)	Functioning of floor announcement, ARD announcement, etc (if applicable)	Functioning / Not functioning	
x)	DO button and DC button functional check: *For power operated door:* 1) Press the DO button at level — Door should open 2) Press the DO button during running — Door should not open 3) While closing press the DO button at level — Door should open 4) DC button at level when the door is in open condition — Door should close	Functioning / Not functioning	

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Sl No.	Requirement	Result	Remarks
xi)	*For manual operated door:* 1) Lift should not move if any of the door car/landing in open condition 2) If door is opened during run, lift should stop and should not move further	Functioning / Not functioning	
xii)	Car alarm should function even though there is no power supply to the lift	Functioning / Not functioning	
xiii)	Functioning of intercom (*see* Note)	Functioning / Not functioning	
xiv)	Functioning of car call buttons and landing call buttons (*see* Note)	Ok / Not ok	
xv)	Provision of fan and its operations	Provided / Not provided	
xvi)	Provision and working of cabin lights and shaft lights	Provided / Not provided	
xvii)	Provision of emergency light and its functions	Provided / Not provided	
xviii)	Doors are verified for smooth opening and closing at each level	Ok / Not ok	
xix)	Riding comfort — No rail knocks and vibrations are heard while travelling several times in either directions	Ok / Not ok	
xx)	Lift should not move for any safety failure	Ok / Not ok	
xxi)	Provision of grab bars inside the lift car (*see* Note)	Provided / Not provided	
xxii)	Provision of buffer rail (applicable only for service lifts) at the rear panel of the lift car	Provided / Not provided	

NOTE — Lifts open to public use shall also be inspected for requirements as per **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code, including those relating to lift closing time, finishes of interior surfaces, etc.

A-10 INSPECTION FROM THE FLOOR LANDINGS

Sl No.	Requirement	Result	Remarks
i)	Provision and functioning of landing door de-locking at every landing	Functioning / Not functioning	
ii)	Condition of landing door at every floor	Ok / Not ok	
iii)	Functioning of landing display at every floor	Functioning / Not functioning	
iv)	Functioning of landing call button	Functioning / Not functioning	
v)	Functioning of duplex/group operation at every landing (if applicable)	Functioning / Not functioning	

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A-11 RESCUE OPERATIONS

Sl No.	Requirement	Result	Remarks
i)	Is the automatic rescue device (ARD) installed and operating as per the instructions	Yes / No	
ii)	Does visual indicator and audible alarm function during operation	Yes / No	
iii)	Is the floor level acceptable during the automatic rescue operation	Yes / No	
iv)	Whether the lift moves when the brake is opened depending upon the inertia	Yes / No	
v)	Provision of emergency electrical rescue device and its functioning (if applicable)	Functioning / Not functioning	

A-12 FIRE OPERATION

Sl No.	Requirement	Result	Remarks
i)	*Phase I* a) When the fireman switch is activated, all the landing calls to be inoperative and the car shall report to the evacuation floor and the lift doors to be in opened condition b) If the lift is moving away from the evacuation floor, then it shall reverse its direction at the nearest floor landing without opening its door, and return back to the evacuation floor and remains there itself with the doors open	Functioning / Not functioning	
ii)	*Phase II* (if applicable) a) It will be started after the completion of Phase I along with the fireman switch in ON position b) In Phase II, lift should not respond to landing call and when the car call button is pressed, the door should start closing. If the button is released before the full closure of doors, then the doors should open automatically c) After the full close of door, the lift should move on to the floor of registered car call d) The doors should only open if the open button is pressed after reaching the level. If the open button is released before the full opening of doors, then the doors should reclose automatically	Functioning / Not functioning	

A-13 SAFETY DEVICES

Sl No.	Requirement	Result	Remarks
Instructions: a) The lift is in ideal condition and the following safety devices get activated, then it should not move further. b) If the lift is in running condition and the following safety devices get activated, then the lift shall stop and should not move further.			
i)	OSG – Over speed governor	Functioning / Not functioning	
ii)	Car door contact	Functioning / Not functioning	
iii)	Landing door contact	Functioning / Not functioning	

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Sl No.	Requirement	Result	Remarks
iv)	Car top stop switches	Functioning / Not functioning	
v)	Pit stop switches	Functioning / Not functioning	
vi)	Functioning of screen sensors and door safety edge: 1) Door should reopen, if we cut the screen. 2) Door should reopen, if it hit any object.	Functioning / Not functioning	
vii)	Check whether the car and counter buffers are installed as per the requirement	Yes / No	
viii)	Functioning of limit switches so that lift should not travel beyond the limit	Functioning / Not functioning	
ix)	Brake on its own shall be capable of stopping the machine when the car is travelling downward at rated speed and with the rated load plus 25 percent	Ok / Not Ok	
x)	*Safety gear test:* 1) Lift car safety gear to be tested in down direction with 100 percent rated load in the lift car (during maintenance it shall be tested only in inspection speed) 2) If provided, counterweight safety gear to be tested in up direction of lift car with no load Lift stopping distance depends upon the tripping speed of the governor and is to be within the range as per the Indian Standard.	Stopping distance:_____ Ok / Not Ok	

A-14 LEVELLING ACCURACY AND RUNNING CLEARANCE TEST

Instructions:
a) The levelling accuracy shall be within ±5 mm of the finished floor level.
b) The running clearance between the lift car threshold and landing door sill should be 30 mm.

No. of floors: _____

Floors (Landing)	Levelling Accuracy		Running Clearance		
	UP	DN	LH	Centre	RH
1st					
2nd					
3rd					
4th					
5th					
6th					
…					
…					
RESULT Ok / Not Ok					

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A-15 LOAD TEST

Sl No.	Load in Percent	Direction of Travel	Voltage	Current
			V	A
Instructions: a) With balanced load, the current value in both the up and down directions to be same. b) Check the current only after the lift reaches its rated speed.				
i)	No load	UP		
		DN		
ii)	Half load	UP		
		DN		
iii)	Full load	UP		
		DN		

ANNEX B

[*Clause* 16.3.3.3 (a)]

TYPICAL EXAMPLES OF CHECKS TO BE TAKEN INTO ACCOUNT IN MAINTENANCE INSTRUCTIONS

B-1 ELECTRIC LIFTS

Item	Checks
General	Check all components are clean and kept free from dust and corrosion
Pit area	Check for excess oil/grease at bottom of guides. Check the pit area is clean, dry and free from debris
Anti-rebound device and switch (where fitted)	Check for free movement and operation Check for equal tension of ropes Check switch where fitted Check lubrication
Buffers	Check oil level Check lubrication Check switch where fitted Check fixings
Drive motor/generator	Check bearings for wear Check lubrication Check condition of commutator
Gear box	Check gear for wear Check lubrication
Traction sheave	Check condition and grooves for wear
Brake	Check braking system Check parts for wear Check stopping accuracy

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Item	Checks
Controller	Check cabinet is clean, dry and free from dust
Overspeed governor and tension pulley	Check moving parts for free movement and wear Check operation Check switch
Main rope diverter pulley(s)	Check condition and grooves for wear Check bearings for abnormal noise and/or vibrations Check guarding Check lubrication
Car/counterweight guides	Check for film of oil where required on all guide surfaces Check fixings
Car/counterweight guide shoes	Check guide shoes/rollers for wear Check fixings Check lubrication, where necessary
Electric wiring	Check insulation
Lift car	Check emergency lighting, car buttons, key switches Check fixings of panels and ceiling
Safety gear(s)/ascending car over speed protection means	Check moving parts for free movement and wear Check lubrication Check fixings Check operation Check switch
Suspension ropes/chains	Check for wear, elongation and tension Check lubrication only where intended
Rope/chains terminations	Check for deterioration and wear Check fixings
Landing entrances	Check operation of landing locks Check doors for free running Check door guiding Check door gaps Check wire rope, chain or belt when used for integrity Check emergency unlocking device Check lubrication
Car door	Check door closed contact or lock Check doors for free running Check door guiding Check door gaps Check wire rope or chain when used for integrity Check passenger door protective device Check lubrication
Floor level	Check stopping accuracy at landing
Final limit switches	Check operation
Motor run time limiter	Check operation
Electric safety devices	Check operation Check electric safety chain

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Item	Checks
	Check correct fuses are fitted
Emergency alarm device	Check operation
Landing controls and indicators	Check operation
Well lighting	Check operation

B-2 HYDRAULIC LIFTS

Item	Checks
General	Check all components are clean and kept free from dust and corrosion
Pit area	Check for excess oil/grease at bottom of guides Check the pit area is clean, dry and free from debris
Buffers	Check oil level Check lubrication Check switch where fitted Check fixings
Tank unit	Check hydraulic fluid level Check tank and valve unit for leakage
Jack	Check for oil leakage
Telescopic jack	Check for synchronization
Controller	Check cabinet is clean, dry and free from dust
Overspeed governor and tension pulley	Check moving parts for free movement and wear Check operation Check switch
Main rope pulley(s)	Check condition and grooves for wear Check bearings for abnormal noise and/or vibrations Check guarding Check lubrication
Car/balancing weight/jack guides	Check for film of oil where required on all guide surfaces Check fixings
Car/balancing weight/jack guide shoes	Check guide shoes/rollers for wear Check fixings Check lubrication where necessary
Electric wiring	Check insulation
Lift car	Check emergency lighting, car buttons, key switches Check fixings of panels and ceiling
Safety gear/pawl clamping devices	Check moving parts for free movement and wear Check lubrication Check fixings Check operation Check switch
Suspension ropes/chains	Check for wear, elongation and tension Check lubrication only where intended
Ropes/chains terminations	Check for deterioration and wear Check fixings

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Landing entrances	Check operation of landing locks Check doors for free running Check door guiding Check door gaps Check wire rope, chain or belt when used, for integrity Check emergency unlocking device Check lubrication
Car door	Check door closed contact or lock Check doors for free running Check door guiding Check door gaps Check wire rope or chain when used for integrity Check passenger door protective device Check lubrication
Floor level	Check stopping accuracy at landing
Final limit switch	Check operation
Motor run time limiter	Check operation
Electric safety devices	Check operation Check electric safety chain Check correct fuses are fitted
Emergency alarm device	Check operation
Landing controls and indicators	Check operation
Well lighting	Check operation
Anti-creep device	Check operation
Rupture valve/one way restrictor	Check operation
Pressure relief valve	Check operation
Manual lowering valve	Check operation
Hand pump	Check operation
Hose/pipe work	Check for damage and leakage

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ANNEX C

(*Clause* 16.4.1)

EXAMPLES OF ELEMENTS TO BE TAKEN IN TO ACCOUNT IN ANY RISK ASSESSMENT FOR MAINTENANCE OPERATIONS

Elements	Car	Machinery Spaces	Pulley Spaces	Area Outside the Lift	Pit	Car Roof
Unsuitable access (ladders not secure, no hand rails, unsuitable trap door, obstacle on car roof, etc)	NR	R	R	R	R	R
Unauthorized entry	NR	R	R	R	R	R
Inadequate lighting (including access)	R	R	R	R	R	R
Uneven floor surface (holes, projections)	R	R	R	R	R	R
Slippery floor surface	R	R	R	R	R	R
Strength of floor	R	R	R	R	R	R
Unsuitable dimensions (passages, maintenance spaces)	R	R	R	R	R	R
Identification of car position	R	R	NR	NR	NR	NR
Indirect contact with electricity	R	R	R	R	R	R
Switches	NR	R	R	R	R	R
Contact with moving parts (ropes, pulleys)	NR	R	R	R	R	R
Unexpected movements	R	R	R	R	R	R
Crushing by moving parts (car, counterweight)	NR	R	R	R	R	R
Voids between car and well	NR	R	R	NR	NR	R
More than one lift in same area	NR	R	R	R	R	R
Overhead beams and sheaves	NR	R	R	R	R	R
Refuge volume(s)	NR	R	R	NR	R	R
Manual handling	NR	R	R	R	R	R
More than one maintenance person working	NR	R	R	R	R	R
Absence of means of communication	R	R	R	R	R	R
Ventilation and temperature for persons	R	R	R	R	R	R
Dangerous substances	R	R	R	R	R	R
Falling objects	R	R	R	R	R	R
Entrapment	R	R	R	R	R	R
Means/controls for rescue operations	R	R	R	R	R	R
Fire	R	R	R	R	R	R

'R' = Relevant and 'NR' = Not relevant.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Subsection.

	IS No.	*Title*
(1)	14671 : 1999	Code of practice for installation and maintenance of hydraulic lifts
(2)	14665 (Part 1) : 2000	Electric traction lifts Guidelines for outline dimensions of passenger, goods, service and hospital lifts
	(Part 3/ Sec 1 and 2) : 2000	Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
	(Part 4/ Sec 1 to 9) : 2001	Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift Carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(3)	12615 : 2011	Energy efficient induction motors — Three phase squirrel cage
(4)	1950 : 1962	Code of practice for sound insulation of non-industrial buildings
(5)	14665 (Part 4/ Sec 1 to 9) : 2001	Electric traction lifts: Part 4 Components, Section 1 Lift buffers, Section 2 Lift guide rails and guide shoes, Section 3 Lift carframe, car, counterweight and suspension, Section 4 Lift safety gears and governors, Section 5 Lift retiring cam, Section 6 Lift doors and locking devices and contacts, Section 7 Lift machines and brakes, Section 8 Lift wire ropes, Section 9 Controller and operating devices
(6)	14665 (Part 3/ Sec 1 and 2) : 2000	Electric traction lifts: Part 3 Safety rules, Section 1 Passenger and goods lifts, Section 2 Service lifts
(7)	14665 (Part 2/ Sec 1 and 2) : 2000	Electric traction lifts : Part 2 Code of practice for installation, operation and maintenance, Section 1 Passenger and goods lifts, Section 2 Service lifts
(8)	3043 : 1987	Code of practice for earthing
(9)	IS/IEC 60529 : 2001	Degrees of protection provided by enclosures (IP CODE)
(10)	15785 : 2009	Code of practice for installation and maintenance of lifts without conventional machine room
(11)	15259 : 2002	Code of practice for installation and maintenance of home lifts
(12)	15330 : 2003	Code of practice for Installation and maintenance of lifts for handicapped persons
(13)	14665 (Part 5) : 1999	Electric traction lifts: Part 5 Inspection manual
(14)	9457 : 2005	Code of practice for safety colours and safety signs (*first revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts, Escalators and Moving Walks:

5B Escalators and Moving Walks

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 8/Subsection 5B) covers the essential requirements for planning, installation, operation, maintenance and inspection of escalators and moving walks so as to ensure safe movement of people with satisfactory performance, while using these.

This Section was first published in 1970 and was subsequently revised in 1983 and 2005. This Section covers the requirements for installation of lifts and escalators in buildings. This Section shall be read with Part 4 'Fire and Life Safety' of the Code from fire safety requirements point of view. The major changes in the first revision of 1983 were addition of outline dimensions of different types of lifts and detailed requirements of escalators in buildings. Emphasis was laid on coordination between the engineer/architect and the lift manufacturer to arrive at the number and position of lifts for attaining optimum efficiency in serving the building with safety.

The significant changes with respect to lifts incorporated in the last revision in 2005, included addition of new clauses/recommendations on building management system; addition of new clauses on fireman's lift, infrared light curtain, safety and Braille button for blind people and updation of provisions as per the revised standards on lifts on which this Section was based.

As a result of experience gained since implementation of 2005 version of the Code and feedback received as well as revision of Indian Standards on which this Section was based, a need was felt to revise this Section. In this revision, the erstwhile Section 5 on Lifts and Escalators has been divided into two subsections namely:

5A Installation of Lifts

5B Installation of Escalators and Moving Walks

This revision has, therefore, been formulated to take care of these. This Subsection (5B) addresses exclusively the provisions related to installation of escalators and moving walks, which are being increasingly provided in buildings. Compared to the previous version where brief details were covered in Section 5 with respect to escalators, this Subsection now covers comprehensive provisions on all aspects, including requirements for planning, installation, operation, maintenance and inspection of escalators, so as to ensure safe movement of people with satisfactory performance. This also now covers provisions on moving walks.

Assistance has been derived from the following publications in the formulation of this Subsection:

EN 115-1: 2008 Safety of escalators and moving walks — Part 1: Construction and installation

IBC 2015 International Building Code, International Code Council, Washington, USA

JIS A 4302 : 2006 Inspection standard of elevator, escalator and dumbwaiter

CIBSE Guide D: Transportation Systems in Buildings, 2015, The Chartered Institution of Building Services Engineers, London, U.K.

All standards, whether given herein above or cross-referred to in the main text of this Subsection, are subject to revision. The parties to agreement based on this Subsection are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Subsection is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Subsection.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 5 Installation of Lifts, Escalators and Moving Walks: 5B Escalators and Moving Walks

1 SCOPE

1.1 This Code (Part 8/Subsection 5B) covers the essential requirements for planning, installation, operation, maintenance and inspection of escalators and moving walks so as to ensure safe movement of people with satisfactory performance, while using these.

1.2 This Subsection gives information that should be exchanged among the architect/engineer, the consulting engineer and escalator/moving walk manufacturer from the stage of planning to installation including maintenance.

2 TERMINOLOGY

For the purpose of this Subsection, the following terms and definitions apply.

2.1 General Terms Relating to Escalators and Moving Walks

2.1.1 *Angle of Inclination* — Maximum angle to the horizontal in which the steps, the pallets or the belt move.

2.1.2 *Auxiliary Brake* — Fail safe brake, which is used to stop an escalators/moving walk under all normal conditions or under certain fault conditions only, typically situated on one side of the main drive shaft.

2.1.3 *Balustrade* — Part of the escalator/moving walk which ensures the user's safety by providing stability, protecting from moving parts and supporting the handrail.

2.1.4 *Balustrade Decking* — Transverse member of the balustrade which meets the handrail guidance profile and which forms the top cover of the balustrade.

2.1.5 *Brake Load* — Load on the step/pallet/belt for which the brake system is designed to stop the escalator/moving walk.

2.1.6 *Comb* — Pronged section at each landing that meshes with the grooves of the steps

2.1.7 *Comb Lighting* — Small flush light panels located in the skirt panels on both sides of the escalators/moving walk unit at both upper and lower landing and immediately adjacent to the comb teeth to illuminate the comb and step tread and assist passengers boarding and alighting the escalators/moving walk.

2.1.8 *Comb Plate* — Platform at each landing to which the combs are attached.

2.1.9 *Comb Plate Switch* — Switch in safety circuit that opens when excessive force is detected in vertical and/or horizontal direction on the comb or comb plate of escalators/moving walk.

2.1.10 *Comb Teeth* — Series of teeth which ride the grooves of the escalators/moving walk step tread as the step passes underneath and are designed so as to allow them to break off, if a wedging action should occur at their point of contact with step tread.

2.1.11 *Emergency Brake* — Auxiliary mechanically automatically operated brake, which will stop a fully loaded escalator, if the drive chain breaks.

2.1.12 *Emergency Stop Switch* — Separate stop button usually located in adjacent walls, columns or within the balustrade providing the facility to stop the escalator/moving walk, in the event of emergency.

2.1.13 *Inspection Door* — Means of access to equipment areas and other spaces pertaining to an escalators/moving walk installation such as machinery spaces, etc, and with access usually restricted to authorized persons.

2.1.14 *Safety Devices* — Part of a safety circuit consisting of safety switches and/or fail safe circuits.

2.1.15 *Escalator* — Power-driven, inclined, continuous moving stairway used for raising or lowering persons in which the user carrying surface (for example, steps) remains horizontal.

NOTE — Escalators are machines, and even when out of operation, shall not be considered as fixed staircases as there could be a safety concern.

2.1.16 *Exterior Panel* — Part of the exterior side of the enclosure of an escalator or moving walk.

2.1.17 *Handrail* — Power-driven moving rail for persons to grip while using the escalator or moving walk.

2.1.18 *Interior Panel* — Panel located between the skirting or lower inner decking and the handrail guidance profile or balustrade decking.

2.1.19 *Lower Inner Decking* — Profile that connects

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the skirting with the interior panel when they do not meet at a common point.

2.1.20 *Lower Outer Decking* — Profile that connects the exterior panels with the interior panel.

2.1.21 *Machinery* — Escalator or moving walk machine(s) mechanisms and associated equipment.

2.1.22 *Machinery Spaces* — Space(s) inside or outside of the truss where the machinery as a whole or in parts is placed.

2.1.23 *Maximum Capacity* — Maximum flow of persons that can be achieved under operational conditions.

2.1.24 *Moving Walk* — Power-driven installation for the conveyance of persons in which the surface carrying the users remains parallel to its direction of motion and is uninterrupted (for example, pallets, belt).

NOTE — Moving walks are machines, and even when out of operation, shall not be considered as fixed access as there could be a safety concern.

2.1.25 *Newel* — End of the balustrade.

2.1.26 *Nominal/Rated Speed* — Speed in the direction of the moving steps, pallets or the belt stated by the manufacturer for which the escalator or moving walk has been designed, without load on the steps/pallets/ belt at nominal frequency and nominal voltage.

2.1.27 *Pit* — Recess in the floor to receive that portion of the lower landing and the lower end of the incline section which occurs below the floor line when there is no floor under the escalator such as in a basement.

2.1.28 *Rated Load* — Load which the equipment is designed to move.

2.1.29 *Rise (Travel)* — Vertical distance between the upper and lower finished floor levels.

2.1.30 *Safety Circuit* — Part of the electric safety system consisting of electrical safety devices.

2.1.31 *Skirting* — Vertical part of the balustrade interfacing with the steps, pallets or belt.

2.1.32 *Skirt Deflector* — Device to minimize the risk of trapping between the step and the skirting.

2.2 Terms Related to Performance Requirements of Escalators and Moving Walks

2.2.1 *Acceleration* — Rate of change of velocity. It is expressed in m/s^2.

2.2.2 *Background Noise Correction* (K_{1A}) — Correction term to account for the influence of background noise on the emission sound pressure level at the specified positions of the machine under test.

NOTE — The correction in the case of A-weighting is to be determined from A-weighted measured values.

2.2.3 *Emission Sound Pressure Level* (L_{pA}) — A-weighted sound pressure level at the specified positions, excluding the effects of background noise and contribution due to the room characteristics (reverberation) of the *in-situ* environment. It is expressed in decibel.

2.2.4 *Environmental Indicator* (K_{2A}) — Correction term to account for the influence of reflected sound on the emission sound pressure level due the characteristic of the test room.

2.2.5 *Equivalent Sound Pressure Level* (L_{pAeq}) — Average A-weighted sound pressure level.

2.2.6 *Load Carrying Unit* — Part of an escalator or moving walk designed to carry persons for the purpose of transportation. For example, step, pallet or belt.

2.2.7 *Measured Speed* — Speed of the escalator or moving walk with no load measured at the time of testing after the starting sequence has been completed.

2.2.8 *Ride Quality* — Sound levels and vibration of the steps/pallet, relevant to passenger perception, associated with escalator or moving walk operation.

2.2.9 *Sound Pressure Level* (L_p) — Ten times the logarithm to the base 10 of the ratio of the square of the sound pressure to the square of the reference sound pressure.

NOTE — The reference sound pressure level is 20 μPa (2×10^{-5} Pa).

2.2.10 *Velocity* — Rate of change of displacement. Velocity is reported as speed and direction of travel. It is given in metre per second (m/s).

2.2.11 *Vibration* — Variation with time of the magnitude of acceleration. It is expressed in metre per second square (m/s^2).

3 GENERAL

3.1 Conformity with Act and Rules

3.1.1 The installation of escalators and moving walks has been governed in states by different Acts and Rules, as applicable, which are intended to ensure safe installation and operation of the same.

3.1.2 The installation shall be generally carried out in conformity with relevant Act and Rules wherever they are in force.

3.1.3 It is the responsibility of the owner of the premises where the escalators and moving walks will be installed, to obtain necessary permission from the Authority before and after the erection of escalators and moving walks and for their subsequent operation.

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3.1.4 A licence for public use is a safety provision issued by state authorities under applicable Act and Rules, wherever they are in force.

3.2 Conformity with *Indian Electricity Act* and Rules

All electrical work in connection with installation of escalators and moving walks shall be carried out in accordance with the provisions of *The Indian Electricity Act*, 2003 as amended up-to-date along with the rules and regulations framed thereunder and shall also comply with the other provisions of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

3.3 Conformity with Indian Standards

All materials, fittings, appliances, etc, used in electrical installation shall conform to Indian Standard specifications, wherever these exist. In case of materials for which Indian Standard specifications do not exist, the materials shall be approved by the competent authority.

3.4 Conformity with Fire Regulations

The installation shall be carried out in conformity with Part 4 'Fire and Life Safety' of the Code and the state fire acts/local fire regulations, wherever they are in force.

3.5 Safety Design Considerations and Selection of Escalator and Moving Walks

The design consideration for type and selection of escalator and moving walk shall be based on following criteria:

a) *Location* — To ensure reliability, it is important to have design specifications to suit environmental conditions.

b) *Physical requirements* — Physical factors like the vertical and horizontal distance to be spanned shall be considered. The ability of the building infrastructure to support the heavy components is also a critical physical concern.

c) *Type of segment and traffic patterns* — The design consideration depends on segment type. Some typical segments are transit systems like metro, airport, shopping malls, hotels, etc. Traffic patterns shall also be anticipated in escalator and moving walk design. The carrying capacity of an escalator system shall match the expected peak traffic demand.

d) *Safety considerations* — Escalators and moving walks shall not be subjected to abuse, misuse and negligence. There are a number of potential hazards, both from escalators and moving walks themselves and also those hazards that users may bring with them, which include loose clothing, type of footwear, carried goods and trolleys. The severity of these hazards may increase when used by vulnerable groups of people, such as the old, very young and those with impaired mobility. The proper design risk assessment and control, are all critical to ensure reliability and, above all safety.

e) *Aesthetic preferences* — To be suitably decided between the parties concerned.

3.6 Maintenance

The considerations relating to maintenance shall be as follows:

a) The escalator or moving walk installation should receive regular cleaning, lubrication, adjustment and adequate servicing by authorized competent persons at such intervals as the type of equipment and frequency of service demand. It is desirable and normal for the escalator or moving walk supplier to be entrusted with the servicing during the guarantee period of new equipment.

b) In order that the escalator or moving walk installation is maintained at all times in a safe condition, a proper maintenance schedule shall be drawn up in consultation with the manufacturer and rigidly followed. The provision of a log book to record all items relating to general servicing and inspection is recommended. Any accident arising out of operation or maintenance shall be duly reported to the Authority in accordance with the rules laid down.

c) Escalators and moving walks are required by statutory regulations to be examined at regular intervals as specified by Acts and Rules, by a competent person. The company entrusted with maintenance contract shall have valid license to maintain the escalators and moving walks. The persons assigned for maintenance work shall be appropriately qualified and experienced as required by statutory Acts and Rules.

d) Companies and organizations responsible for the safe use of escalator and moving walks should ensure that their employees are adequately instructed and informed about the safe use of the escalator or moving walk and the hazards arising from their unsafe use and are familiar with emergency procedures.

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e) Proper barricading shall be done to ensure that the open pits of escalator shall be reached/ accessed by only the maintenance team. The maintenance service provider shall be responsible for placing of the barricades and signages before start of the maintenance work.

3.7 Energy Efficiency and Sustainability

The following technologies shall be encouraged for reducing power consumption by using energy efficient equipment and behavioural changes:

a) As an option, escalators/moving walk should not run when there are no passengers to move. In this stop mode, only the control system and the passenger detection system are kept running. Another option is to reduce the speed to match the passenger demand, thus reducing energy consumption by the use of variable voltage variable frequency (VVVF) drives, which provide very smooth, almost imperceptible speed transitions.

b) Energy saving LED lamps for lighting in place of conventional lamps.

c) Improvement in total power factor of the motor drive of an escalator or moving walk at the isolator connecting equipment to the building's electrical supply circuit.

d) Adoption of materials and practices that are environmental friendly and sustainable shall be promoted.

4 DESIGN GUIDELINES FOR ESCALATORS AND MOVING WALKS

4.1 Escalators are desirable where the movement of people, in large numbers at a controlled rate in the minimum of space, is involved, for example, railway stations, shopping centres/malls, airports, etc. These encourage people to circulate freely and conveniently. Inclined moving walks are preferable where trolley movement is expected between levels, like department stores, airport, etc.

Typically, horizontal moving walks are used where medium to long distance travel is involved such as airports/metro stations/exhibition halls.

4.2 As the escalators and moving walks operate at a constant speed, serve only two levels and have a known maximum capacity, the traffic study is rather easy, provided the population to be handled in a given time is known. It is easy to predict the rate at which the population can be handled.

Figure 1 shows the brief idea about the steps to be followed for arriving at appropriate escalator and moving walk solution for particular application.

Based on Fig. 1, type and location of building, expected population, and the serving floor details are required to work on the preliminary traffic analysis for escalators and moving walks.

For normal peak periods, the recommended handling capacities for design purposes should be taken as indicated in Table 1. The handling capacity of escalator also depends on the angle of inclination, speed, step widths and the areas at the boarding and alighting levels.

Table 1 Expected Pedestrian Flow Rates
(*Clause* 4.2)

Sl No.	Duty Category	Typical Usage (Passengers/Day)	Typical Locations
(1)	(2)	(3)	(4)
i)	Light	Up to 4 000	Shops, leisure facilities, multiplexes
ii)	Medium	Up to 10 000	Department stores, shopping centres, domestic airports and railway stations
iii)	Heavy	Up to 20 000	Railway (junctions), metro stations, airports
iv)	Intensive	Over 20 000	Major railway (junctions), metro stations, international airports

4.3 The number of persons that may be theoretically carried by the escalators and moving walks in 1 h is given in Table 2 and Table 3, respectively.

Table 2 Theoretical Capacity for Escalators
(*Clause* 4.3)

Sl No.	Step Width m	Theoretical Capacity, in Persons/h		
		For 0.5 m/s Speed	For 0.65 m/s Speed	For 0.75 m/s Speed
(1)	(2)	(3)	(4)	(5)
i)	0.6	4 500	5 850	6 750
ii)	0.8	6 750	8 775	10 125
iii)	1.0	9 000	11 700	13 500

4.4 Though **4.3** indicates the theoretical values for escalators (*see* Table 2) and moving walks (*see* Table 3), Tables 4 and 5 indicate the practical values to be considered while calculating the required number of escalators and moving walks (based on traffic flow pattern).

5 ARRANGEMENT AND PLANNING DIMENSIONS

5.1 Escalators are typically used for short range of movement between adjacent floors. They are usually situated in an obvious circulation path making it easy for pedestrians to board them. Escalators and moving walks should only be accessed from adjacent

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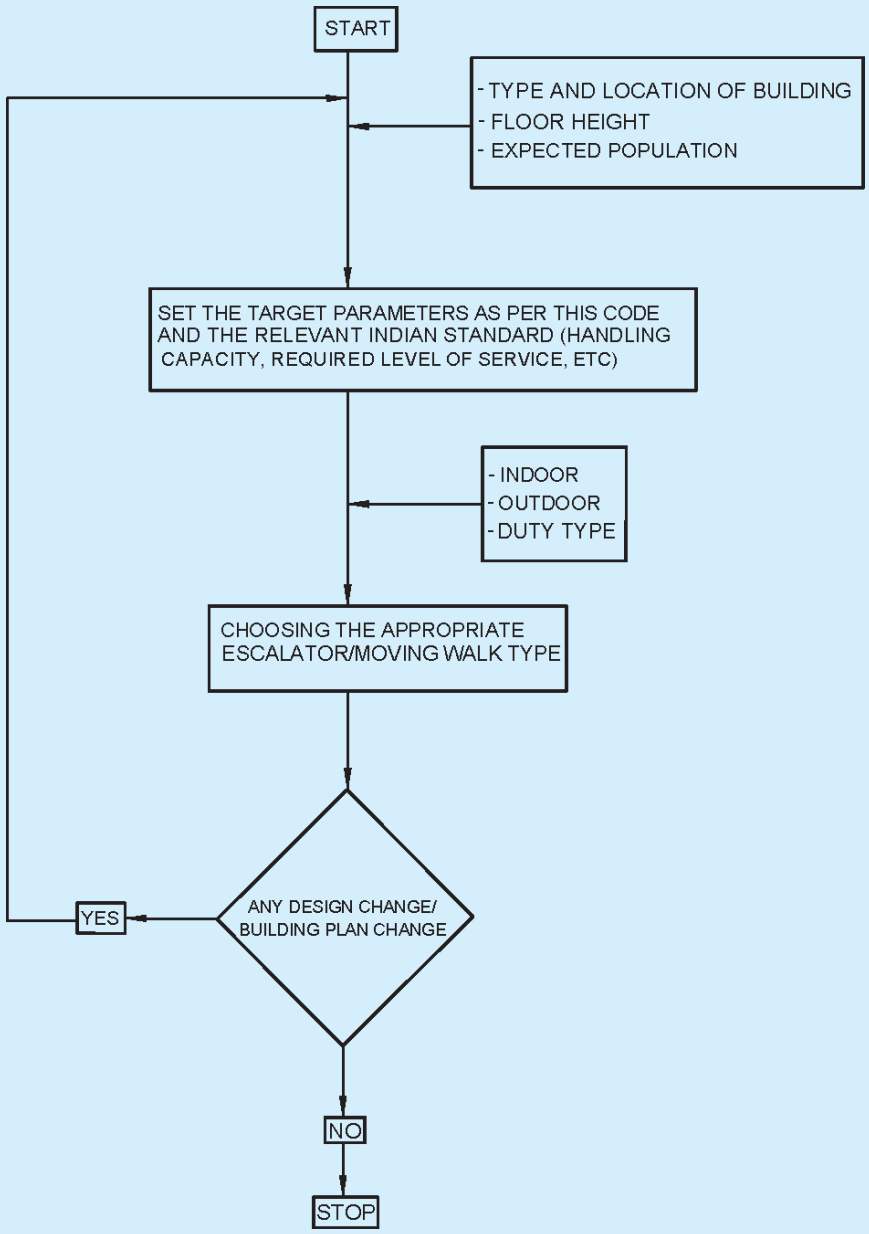


FIG. 1 TYPICAL FLOWCHART ON PRELIMINARY DESIGN OF ESCALATORS/MOVING WALKS

Table 3 Theoretical Capacity for Moving Walks
(*Clause* 4.3)

Sl No.	Step Width	Theoretical Capacity, in Persons/h					
		Horizontal Moving Walk (0° Inclination)			Inclined Moving Walk (For 0.5 m/s Speed)		
	m	For 0.5 m/s Speed	For 0.65 m/s Speed	For 0.75 m/s Speed	For 6° Inclination	For 10° Inclination	For 12° Inclination
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	0.8	3 000	3 700	4 400	3 000	3 700	3 000
ii)	1.0	3 800	4 600	5 400	3 700	3 700	—
iii)	1.4	5 100	6 400	7 700	5 100	—	—

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Table 4 Practical Capacity for Escalators
(*Clause* 4.4)

Sl No.	Step Width	Practical Capacity, in Persons/h		
	m	For 0.5 m/s Speed	For 0.65 m/s Speed	For 0.75 m/s Speed
(1)	(2)	(3)	(4)	(5)
i)	0.6	2 250	2 925	3 375
ii)	0.8	3 375	4 388	5 063
iii)	1.0	4 500	5 850	6 750

corridors/walkways, landing and lobby areas, where people do not obstruct other pedestrian circulation routes. Space should be available to accommodate queuing at the boarding point.

It is especially important that the boarding and alighting areas adjacent to an escalator or moving walk are not part of another circulation route, in order to provide a safe area for passengers to board and alight at landings. The area of this space is defined as a distance between the handrails plus 160 mm, multiplied by a depth of 2.0 m to 2.5 m, depending on the configuration of escalator or moving walk.

Figure 2 illustrates the above clause with option 1 being a 2.5 m landing depth and option 2 being 2.0 m landing depth. Where successive units are installed, each successive escalator or moving walk should have its own individual unrestricted area.

Escalators occupy more space than stairs in order to accommodate their inclination. There are few standard escalator arrangements as shown in Fig. 3. Type (a) and Type (b) provide efficient circulation by providing the shortest transition path and time from one escalator and the next. Type (b) requires larger structural opening than Type (a) and Type (c) and present users with a higher risk of falling into the void. Type (c) is typical of a store as it allows the store to lengthen the circulation route past goods for sale. This configuration also takes up free space.

Some moving walks are adopted to receive and lock on shopping/baggage trolleys. In these cases the unrestricted area at the landing should be increased to at least 5 m and number of flat/horizontal steps at the boarding and alighting points increased. The most significant effect is the increased footprint required for the equipment. Shopping/baggage trolleys are not permitted on escalator.

In order to encourage pedestrian confidence and to assist efficient and safe boarding/ alighting of escalators, the start and end of escalator should present a number of horizontal/flat steps. At least two flat steps are provided for escalators speeds up to 0.5 m/s; at least three flat steps for speeds above 0.5 m/s and up to 0.65 m/s for escalator having rise more than 6 m; and at least four flat steps for speeds above 0.65 m/s. In locations where it is anticipated that escalators may be used by persons with impaired mobility or heavy passenger traffic, additional flat steps should be considered.

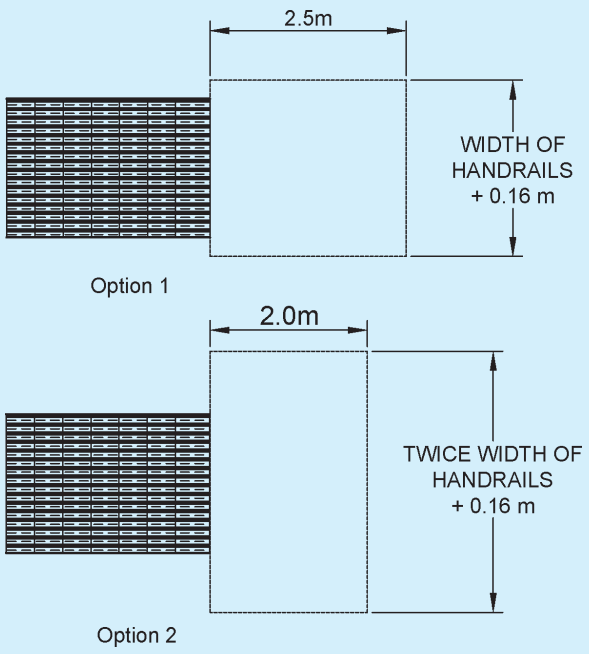


FIG. 2 UNRESTRICTED FREE SPACE

Table 5 Practical Capacities for Moving Walks
(*Clause* 4.4)

Sl No.	Step Width	Practical Capacity, in Persons/h					
		Horizontal Moving Walk (0° Inclination)			Inclined Moving Walk (For 0.5 m/s Speed)		
	m	For 0.5 m/s Speed	For 0.65 m/s Speed	For 0.75 m/s Speed	For 6° Inclination	For 10° Inclination	For 12° Inclination
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	0.8	2 880	3 648	4 320	2 880	2 800	2 800
ii)	1.0	3 600	4 560	5 350	3 600	3 600	—
iii)	1.4	5 040	6 350	7 560	5 040	—	—

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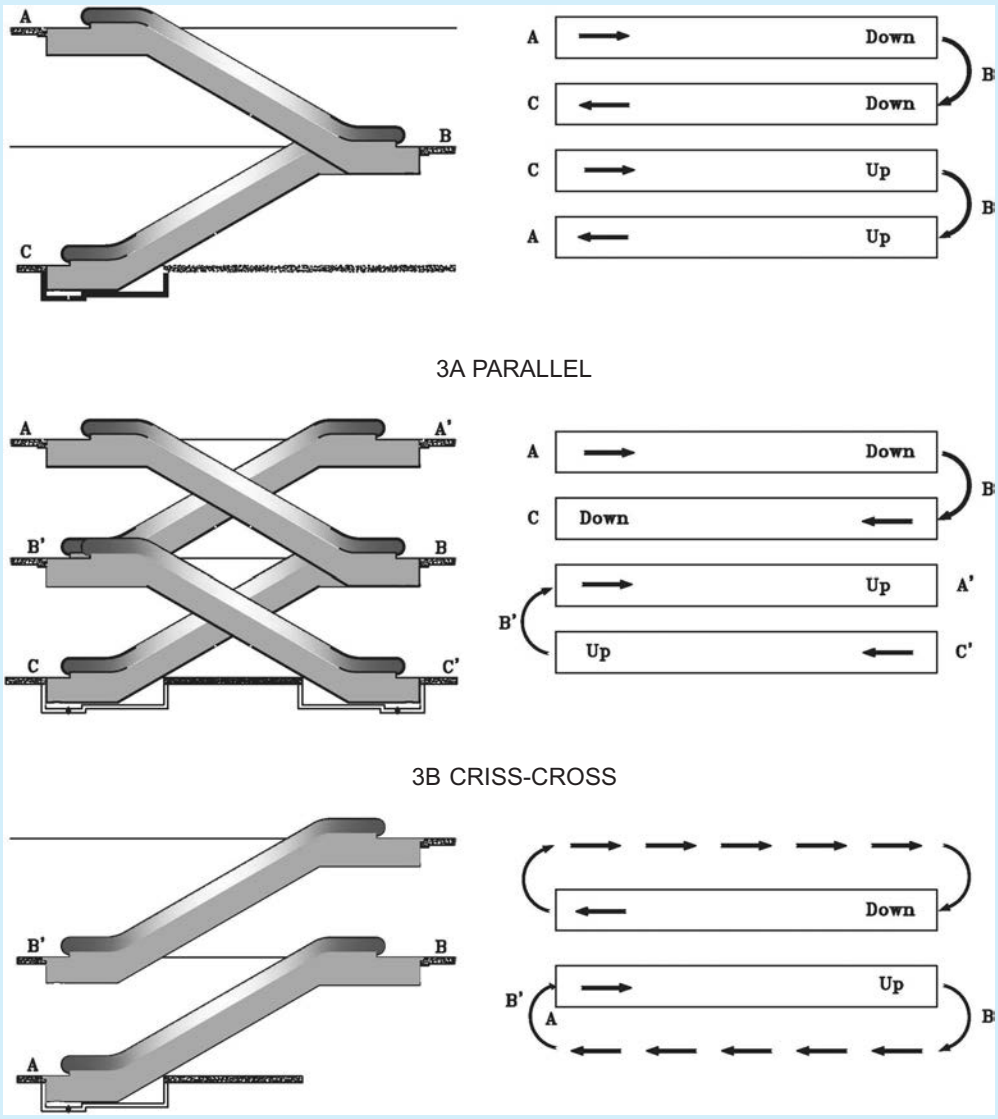


FIG. 3 ESCALATOR CONFIGURATION

5.2 Ensuring Accessibility for All Users

5.2.1 The accessibility requirements given in Part 3 'Development Control Rules and General Building Requirements' of the Code shall be complied with.

5.2.2 The location of escalators and moving walks should be considered in relation to the position of adjacent fire protected lift shafts and lobbies, staircases and their associated areas of rescue assistance, as at the time of an emergency these become non-functional. A surface of the escalator and moving walks should contrast visually with the approach and there should be audible signals or pre-recorded messages that indicate the start and finish of the escalator to help visually impaired people.

For important reasons of safety, special warning notices and tactile warning indicators shall be provided at the top and bottom of escalators. Escalators shall not be considered as the accessible route. Persons with locomotor disability cannot use them. Hence a lift should also be installed as an alternative accessible route.

For moving walks, the maximum inclination should be up to 6° for use by people with disabilities. People with disability may find it difficult to use moving walks. Hence, alternative like an accessible battery cart, may be provided to them in appropriate cases. Moving walks shall be free of projecting objects and obstacles up to a height of 2 100 mm. A minimum level of illumination of 100 lux shall be provided on moving walks.

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6 SPACE REQUIREMENT

6.1 Free Space for Users

6.1.1 The clear height above the steps of the escalator or pallets or belt of the moving walk at all points shall be not less than 2.30 m (*see* X4 in Fig. 4 and Fig. 6). The clear height shall extend to the end of the newel.

NOTE — The clear height of 2.30 m should also be applied to the unrestricted area.

6.1.2 To prevent collision, a minimum free area around the escalator or moving walk is defined as per Fig. 4. The height X12, measured from the steps of the escalator or the pallets or the belt of the moving walk shall be at least 2.10 m (*see* X12 in Fig. 4). The distance between the outer edge of the handrail and walls or other obstacles (*see* Y10 in Fig. 4) shall under no circumstances be less than 80 mm horizontally and 25 mm vertically below the lower edge of the handrail (*see* Y12 in Fig. 7). The area is permitted to be smaller, if by appropriate measures, the risk of injury is minimized.

6.1.3 For escalators arranged adjacent to one another either parallel or criss-cross, the distance between the handrails shall be not less than 160 mm (*see* Y11 in Fig. 4).

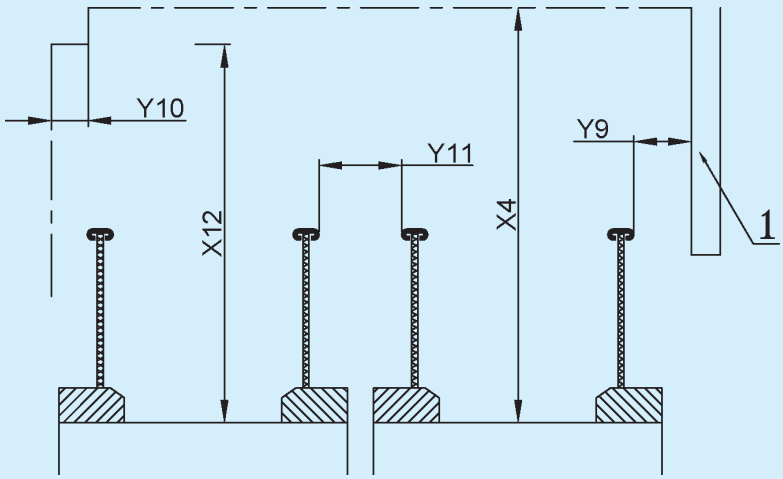
6.1.4 Where building obstacles can cause injuries, appropriate preventive measures shall be taken.

In particular, at floor intersections and on criss-cross escalators or moving walks, a vertical deflector of not less than 0.30 m in height, not presenting any sharp cutting edges, shall be placed above the handrail level and extend at least 25 mm below the lower edge of the handrail, for example, as an imperforate triangle (*see* X5 in Fig. 6 and Fig. 8).

It is not necessary to comply with these requirements when the distance Y9 between the outer edge of the handrail and any obstacle is equal to or greater than 400 mm (*see* Fig. 4).

6.1.5 At the exit(s) of each individual escalator or moving walk a sufficient unrestricted area shall be available to accommodate persons. The width of the unrestricted area shall at least correspond to the distance between the outer edges of the handrails plus 80 mm on each side. The depth shall be at least 2.50 m measured from the end of the balustrade (*see* Option 1 in Fig. 2). It shall be permissible to reduce it to 2.00 m if the width of the unrestricted area is increased to at least double the distance between the outer edges of the handrails plus 80 mm on each side (*see* Option 2 in Fig. 2).

For succeeding escalators and moving walks the depth of an unrestricted area shall be determined in each individual case depending on, for example, type of use (persons only or persons with transport devices, number of intermediate exits, relative orientation and theoretical capacity).



Key

1 Obstacle (for example, Column)

Principal Dimensions	*Ref to Clause*	*Principal Dimensions*	*Ref to Clause*
Y9 ≥ 400 mm	**6.1.4**	X4 ≥ 2 300 mm	**6.1.1**
Y10 ≥ 80 mm	**6.1.2**	X12 ≥ 2 100 mm	**6.1.2**
Y11 ≥ 160 mm	**6.1.3**		

FIG. 4 CLEARANCE BETWEEN BUILDING STRUCTURE AND ESCALATOR/MOVING WALK

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Where the exit of the escalator or moving walk is blocked by structural measures (for example, shutters, fire protection gates) an additional stop switch for emergency situations at handrail level (taking into account **6.1.2**) shall be provided with a distance between 2.0 m and 3.0 m before the step/pallet/belt reaches the comb intersection line. This stop switch shall be reachable from inside the escalator/moving walk.

6.1.6 In the case of successive escalators and moving walks without intermediate exits, they shall have the same capacity.

6.1.7 Where it is possible for people to come into contact with the outer edge of a handrail at a landing and can be drawn into a hazardous situation, such as toppling over a balustrade, appropriate preventative measures shall be taken (for example, *see* Fig. 5).

Some examples are:

a) Prevention of entry into the space by the placement of permanent barriers.

b) Increasing the height of the building structure of the fixed balustrade in the hazard area by at least 100 mm above the handrail level and positioned between 80 mm and 120 mm from the outer edge of the handrail

6.1.8 The surrounding space of the escalator or moving walk shall be illuminated, especially in the vicinity of the combs.

NOTE — Information should be exchanged between the manufacturer and the customer.

6.1.9 It is permissible to arrange the lighting in the surrounding space and/or at the installation itself. The intensity of illumination at the landings including the combs shall be related to the intensity of illumination of the general lighting in the area. The intensity of illumination shall be not less than 50 lux at the comb intersection line measured at floor level.

6.2 Machinery Spaces Outside the Truss

The following shall be ensured:

a) A safe access for persons to machinery spaces shall be provided.

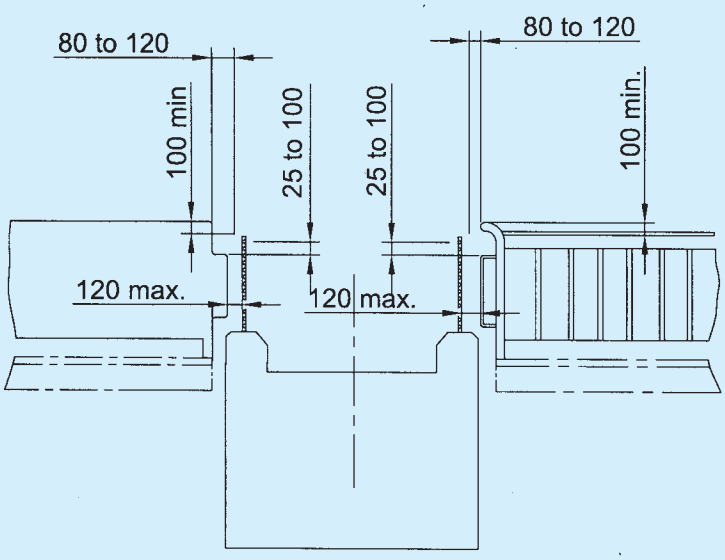
b) Machinery spaces shall be lockable and only accessible to authorized persons.

c) Machinery spaces shall be provided with permanently installed electric lighting on the following basis:
   1) Minimum of 200 lux at floor level in working areas; and
   2) Minimum of 50 lux at floor level in access routes leading to these working areas.

d) Emergency lighting shall be installed to allow the safe evacuation of all personnel working in any machinery space.

   NOTE — Emergency lighting is not intended for continuation of maintenance or other activities.

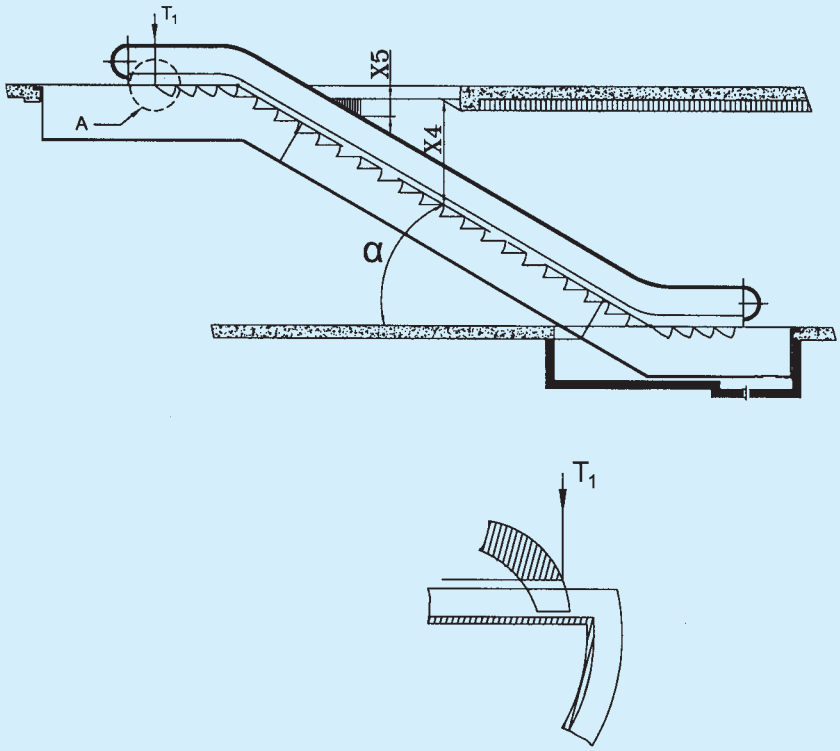
e) The dimensions of machinery spaces shall be sufficient to permit easy and safe working on equipment, especially the electrical equipment. In particular these shall be provided at least a clear height of 2.00 m at



All dimensions in millimetres.

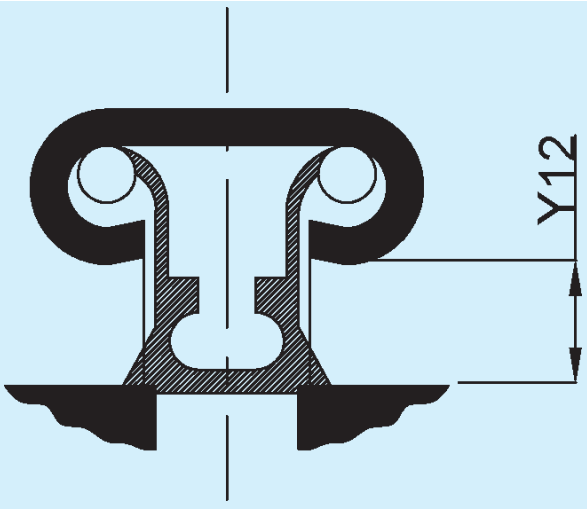
FIG. 5 EXAMPLE OF BARRIERS AT LANDINGS

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Principal Dimensions	*Ref to Clause*
X4 ≥ 2.30 m	**6.1.1**
X5 ≥ 0.30 m	**6.1.4**
α = Angle of inclination	

FIG. 6 ESCALATOR (ELEVATION), PRINCIPAL DIMENSIONS



Principal Dimensions	*Ref to Clause*
Y12 ≥ 25 mm	**6.1.2**

FIG. 7 HANDRAIL — SECTIONAL VIEW

working areas, and a clear horizontal area in front of the control panels and the cabinets. This area is defined as follows:

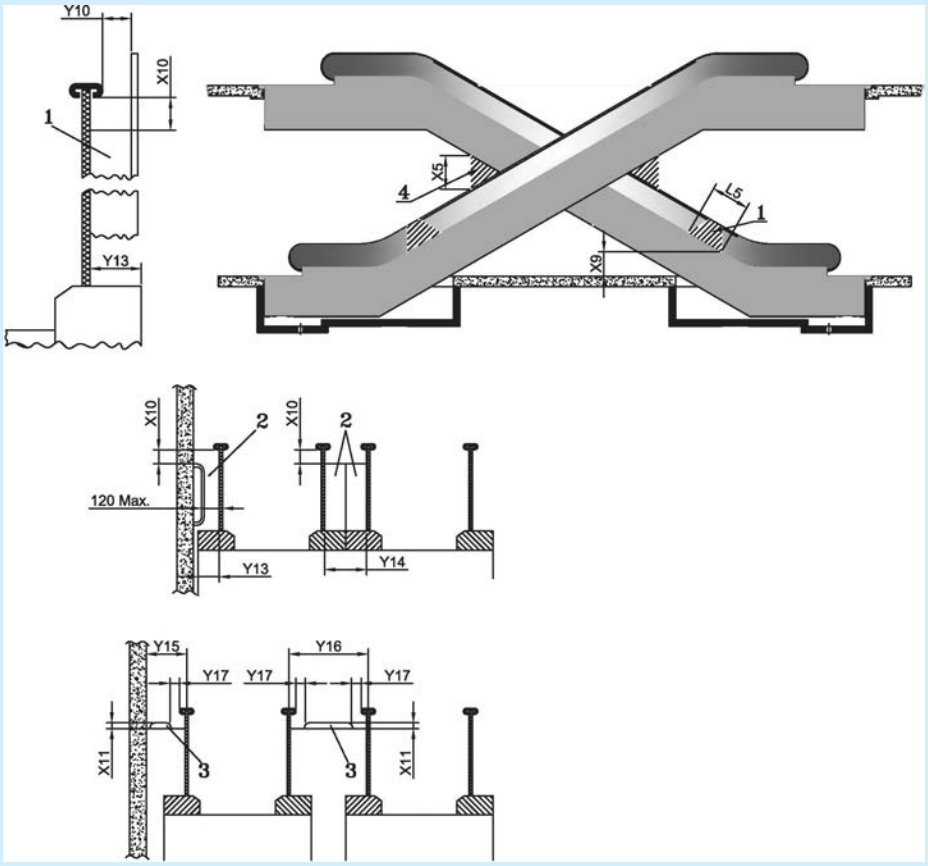
1) Depth, measured from the external surface of the enclosures : At least 0.70 m;

2) Width, the greater of the following values : 0.50 m or the full width of the cabinet or panel.

A clear horizontal area of at least 0.50 m x 0.60 m for maintenance and inspection of moving parts at points where this is necessary.

f) The clear height for movement shall not be less than 1.80 m. The access ways to the clear spaces shall have a width of at least 0.50 m. This value may be reduced to 0.40 m where there are no moving parts. This full height for movement is taken to the underside of the structural roof beams and measured from both,

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Key

1 Anti-climbing device (*see* **6.3**)
2 Access restriction device (*see* **6.3**)
3 Anti-slide device (*see* **6.3**)
4 Vertical deflector (*see* **6.1.4**)

Principal Dimensions	*Ref to Clause*
Y13, Y14, Y15, Y16	**6.3**
Y17 ≥ 100 mm	**6.3**
X5 ≥ 0.30 m	**6.1.4**
X9 = (1 000 ± 50) mm	**6.3**
X10 = 25 mm to150 mm	**6.3**
X11 ≥ 20 mm	**6.3**
L5 ≥ 1 000 mm	**6.3**

FIG. 8 ANTI-MISUSE DEVICES

1) the floor of the access area; and
2) the floor of the working area.

g) In machinery spaces the clear height shall under no circumstances be less than 2.0 m.

h) 3 pin plug with socket for the maintenance propose.

j) Machinery spaces shall not accommodate equipment not related to the escalator or moving walk.

6.3 Balustrade

Balustrades shall be installed on each side of the escalator or moving walk. The dimensions of balustrade shall be as follows.

In the inclined section the vertical height X1 from step nose or pallet surface or belt surface to top of the handrail shall be not less than 0.90 m and not exceed 1.10 m (*see* Fig. 9).

The balustrades shall have no parts on which a person will normally stand.

Appropriate measures shall be taken to discourage people from climbing on the outsides of the balustrade if there is a danger of people falling from them.

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To ensure this, on escalators and moving walks, devices (*see* 1 in Fig. 8) shall be provided on the lower outer decking at a point 1 000 ± 50 mm above the floor level (*see* X9 in Fig. 8) where the bottom of the device intersects with the balustrade decking and shall extend to a length L5 of at least 1 000 mm parallel with the balustrade decking where no stepping is possible. The device shall extend to at least a height in line with the top of the handrail not conflicting with the requirements of Y10 and Y12 (*see* Fig. 4 and Fig. 7).

Where escalators or moving walks are located adjacent to walls, devices (*see* 2 in Fig. 8) to restrict access to the balustrade decking shall be provided at the top and bottom ends of these walls when the lower outer decking width Y13 exceeds 125 mm. On adjacent parallel arrangements, this protection shall be provided when the combined balustrade decking width Y14 exceeds 125 mm. The device shall extend to the height X10 (*see* Fig. 8).

All exposed fastener heads for the devices should be of the vandal resistant type.

Where handrail level balustrade decking are provided between escalators/inclined moving walks and adjacent walls, anti-slide devices (*see* 3 in Fig. 8) shall be provided on the balustrade decking when the distance Y15 between the structure of the building (wall) and the centreline of the handrail is greater than 300 mm. These devices shall consist of objects fastened to the balustrade decking, no closer than 100 mm to the handrail (*see* Y17) and spaced no greater than 1 800 mm apart. The height X11 shall be not less than 20 mm. The devices shall have no sharp corners or edges (*see* Fig. 8).

The above mentioned also applies to adjacent escalators/inclined moving walks when the distance Y16 between the centrelines of the handrails is greater than 400 mm.

6.4 Installation

The following needs to be planned and carried out on site to ensure easy installation of escalators and moving walks.

6.4.1 *Installation Timing*

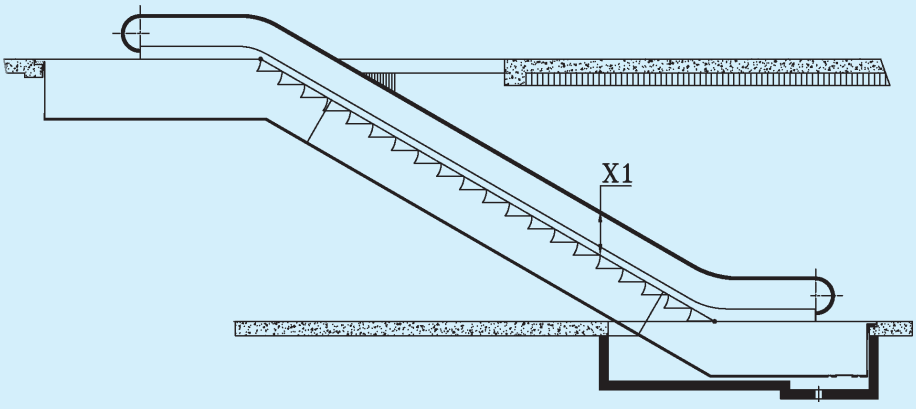
To prevent damage to the escalator during the construction phase, the timing of installation and assembly should be as close as possible to the opening date. It should, however, proceed completion of the floor so as to dispense with the need to take further measures to protect floor coverings. Ensure that the provisional floors along the transport route in the building can comfortably cope with the load weight.

6.4.2 *Transport to the Assembly Site*

A suitable unloading area shall be available in front of the building. The access routes to the building shall be level and negotiable by heavy duty rollers. Along the entire transport route to the assembly site, the free height shall not be less than the minimum specified in the manufacturer plan (also goes for pipes and other attachments fitted by others to the ceiling structure).

6.4.3 *Access Openings, Transport Route and Load Capacity*

Normally, escalators are moved in through openings at the side of the building at ground level. Optionally, suitable roof openings should be provided, in order to



Principal Dimensions	*Ref to Clause*
0.9 m ≤ X1 ≤ 1.10 m	**6.3**

FIG. 9 ESCALATOR (ELEVATION), PRINCIPAL DIMENSIONS

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bring the escalators by crane. It is important that the route to the assembly location within the building is free of obstacles and level, and the ceiling can support a load. Otherwise the appropriate weight distribution shall be catered to.

6.4.4 *Special Delivery*

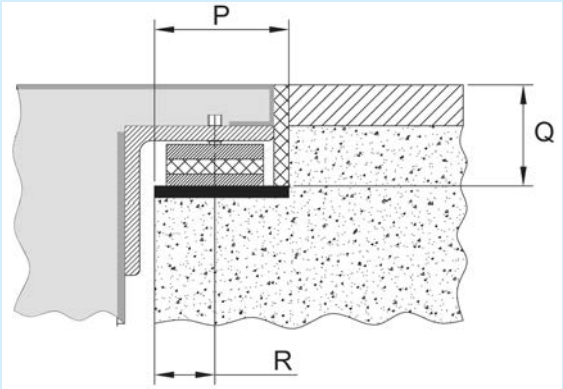
Some escalators are so long that they have to be installed in sections. In this case, the escalator may have to be manufactured in split form and assembled on site.

6.4.5 *Ceiling Openings*

Manufacturer should notify the location and size of the required ceiling openings on the installation drawing. Builder shall supervise the precise implementation of these.

6.4.6 *Top and Bottom Supports*

While designing the support recess, the support loads shall be taken into account. They are shown on the installation drawing given by the manufacturer. At those locations where the supports of escalator (or moving walk) will be placed, the support shall be able to bear the weight of the escalator including traffic load. When preparing the supporting structures the measurements indicated on manufacturer's installation plans shall be precisely adhered to (*see* Fig. 10).



NOTE — P, Q, R = Based on Manufacturing Drawing

FIG. 10 TOP AND BOTTOM SUPPORTS

6.4.7 *Intermediate Supports*

Intermediate supports are needed on escalators with a considerable travel height and on long moving walks. The manufacturer shall inform the builder about the installation plan of the location of the intermediate supports and load to include the additional required space in construction plan (*see* Fig. 11).

6.4.8 *Hoisting Arrangement*

It has to be ensured that pick-up points for hoisting and supporting the escalator shall be fitted securely during assembly. These should be located exactly above the centre of the supporting points. For systems with several supporting structures, plan for additional pick-up points above the intermediate supports. All pick-up points shall be capable of taking a load strain (*see* Fig. 12).

6.4.8.1 *Installation with a frame*

If no assembly holes can be provided, the escalators and moving walks should be lifted to their final location by means of especially sturdy girder construction. In this case, ceiling load strain shall bear the capacity as per the manufacturer's instruction.

6.4.8.2 *Installation with lifting gear*

Holes with a 100 mm diameter are to be made through the ceiling, according to manufacturer instructions. These are used by installation team for fixing the lifting gear. In this way escalator or moving walk is simply lifted upwards from floor to floor. The load strain of every pick-up point shall be maintained as per the manufacturer instruction.

6.4.8.3 *Installation with crane assembly*

Where a suitable roof opening is available or the site is located outdoor lift the escalator or moving walk by

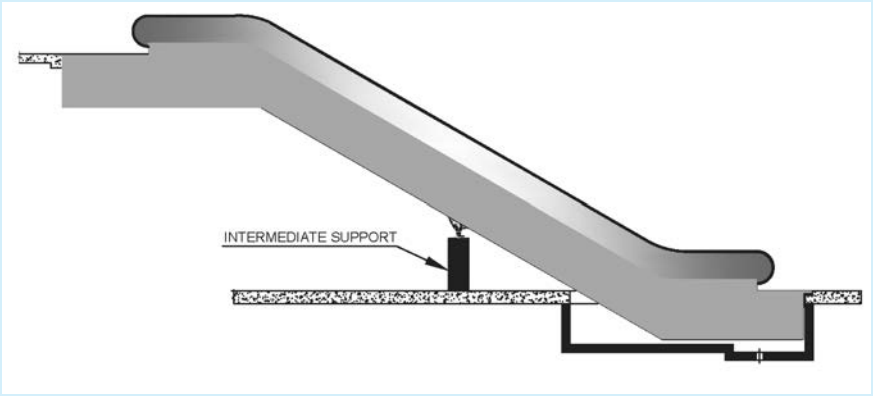


FIG. 11 INTERMEDIATE SUPPORTS

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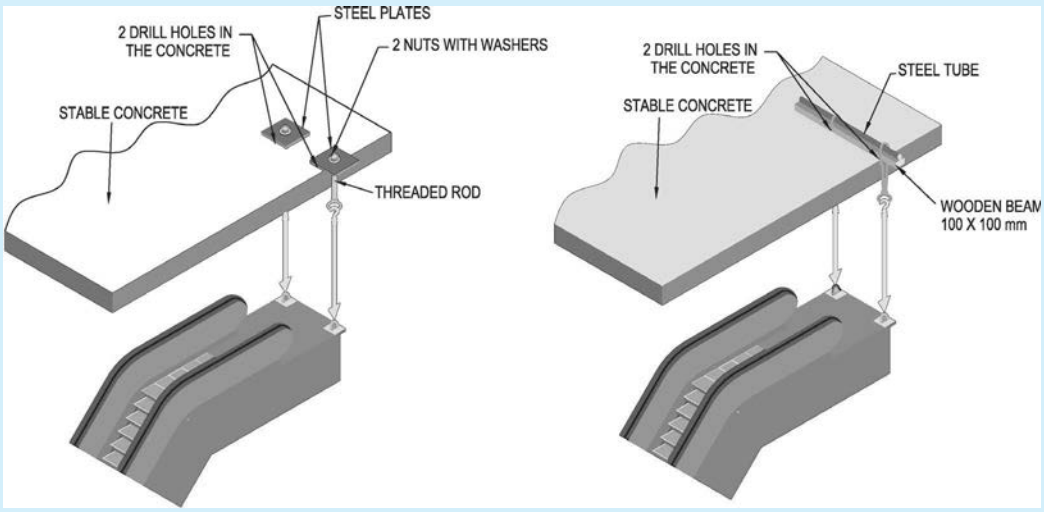


FIG. 12 PICK-UP POINTS

crane and place it on the supports provided. The builder is responsible for ensuring for all local authority approvals.

6.4.8.4 Permanent hoisting hooks shall be provided by the builder in the top slab for hoisting the escalator as per the load requirement.

6.4.9 *Sprinkler Piping*

An optional safety feature is the installation of a sprinkler piping within the escalator or moving walk (*see* Fig. 13).

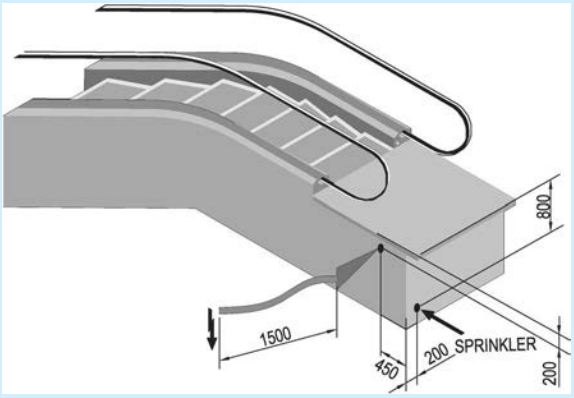


FIG. 13 SPRINKLER PIPING

6.4.10 *Oil Separator*

A type-proofed oil separator is essential for escalators and moving walks which are exposed to the weather. At the construction site, a recess shall be provided for the oil separator in the escalator pit.

6.4.11 *Railings*

In the threshold areas of the escalators, railings have to be installed by the builder. The distance to the escalator handrail from railing has to be at least 80 mm. For adjacent escalators, the distance between the edges of the handrails shall be at least 160 mm (*see* Y11 in Fig. 4).

6.5 Electrical Requirement

6.5.1 The electrical installations shall be in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code and good practices [8-5B(1)].

6.5.2 *Power Supply*

Power supply cable with 3 phase 415 $^{+6\ \text{percent}}_{-10\ \text{percent}}$ V and earthing to be laid up to escalator control panel and a single phase 230 V supply for lighting may be necessary, and shall be provided by the concerned party.

6.5.3 *Protection*

Suitable over load and short circuit protection and earth leakage protection needs to be provided in ensuring protection to the power system.

7 FIRE PROTECTION

Fire protection and building requirement differ with the application/use of building. For specific requirements for fire protection, Part 4 'Fire and Life Safety' of the Code shall be referred. It is recommended that escalators and moving walks are made of non-combustible material that do not create additional hazard in case of fire.

To limit the danger caused by overheating, ventilation for the spaces that contain the motors and gears shall be provided. Extinguishing systems can be installed in these areas. In case sprinklers are used, their integration and fixation into the escalator and moving walk shall

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be done by taking into consideration the special needs of the machine.

Accumulation of materials (such as grease, oil, dust, paper) represent a fire risk. Therefore it should be possible to clean the underside enclosure. If such cleaning is not possible, other precautions (such as installation of sprinkler system) shall be provided to avoid the fire hazard. It is recommended that as far as possible, escalators and moving walks are not used in case of emergency situations.

8 MINIMUM TECHNICAL AND SAFETY REQUIREMENTS

8.1 General

The safety requirements of escalators and moving walks shall comply with good practice in accordance with this Subsection. Certain escalators and moving walks are subject to special operational and environmental conditions.

8.2 Supporting Structures (Truss) and Enclosure

The truss shall be designed to safely sustain steps and running gear in its guides. All mechanically moving parts of the escalator or moving walk shall be completely enclosed within imperforate panels or walls. Exceptions are the accessible steps, the accessible pallets, the accessible belt and that part of the handrail available for the user. Apertures for ventilation are permitted. However, it shall not be possible to pass a straight rigid rod 10 mm in diameter through the enclosure and to touch any moving part through a ventilation aperture.

The supporting structure shall be designed in a way that it can support the dead weight of the escalator or moving walk plus a rated load of 5 000 N/m^2. Based on the rated load, the maximum calculated or measured deflection shall not exceed 1/750 of the distance between the supports. Angle of inclination of an escalator from the horizontal shall not exceed 30°, but for rises not exceeding 6 m and nominal speed not exceeding 0.5 m/s the angle of inclination is permitted to be increased to 35°.

Rise m	*Speed* m/s	*Angle of Inclination*	
		Standard	Option
≤ 6	≤ 0.5	30°	35°
≤ 6	> 0.5	30°	—
> 6	≤ 0.5	30°	—
> 6	> 0.5	30°	—

The angle of inclination of moving walks shall not exceed 12°.

8.3 Step, Pallet or Belt

For escalators and moving walks, the nominal width shall be not less than 0.58 m and not exceed 1.10 m. For moving walks with an angle of inclination up to 6°, widths up to 1.65 m are permitted.

8.3.1 *Step Treads and Pallets*

The step depth in the direction of travel shall not be less than 0.38 m. The step height shall not exceed 0.24 m. The surface of the step treads shall have grooves in the direction of the movement, with which the teeth of the combs mesh. They shall be sensibly horizontal in the usable area of the escalator. The step risers shall be cleated and the surface of the cleat shall be smooth. The ends of the step tread shall mesh with the cleating of the next step riser.

The width of the grooves shall be at least 5 mm and shall not exceed 7 mm. The depth of the grooves shall not be less than 10 mm. The web width shall be at least 2.5 mm but not exceed 5 mm.

8.3.2 *Belts*

The belts shall have grooves in the direction of travel with which the teeth of the comb mesh. The width of the grooves shall be at least 4.5 mm and shall not exceed 7 mm. The depth of grooves shall not be less than 5 mm. The web width shall be at least 4.5 mm but not exceed 8 mm. Splicing of tread way belt shall be such as to provide continuous unbroken tread way surface.

8.4 Driving Machine and Brake

8.4.1 A driving machine shall not drive more than one escalator or moving walk.

8.4.2 The speed of an unloaded escalator shall not deviate by more than ± 5 percent from nominal speed at nominal frequency and nominal voltage. The nominal speed of the escalator shall not exceed 0.75 m/s for an angle of inclination up to 30° and 0.5 m/s for an escalator with an angle of inclination of more than 30° but within 35°. The nominal speed of moving walk shall not exceed 0.75 m/s.

Deviating from the above nominal speed up to 0.90 m/s is permitted provided the width of the pallets or the belt does not exceed 1.10 m and at the landings, the pallets or the belt move horizontally for a length of at least 1.60 m before entering the combs.

8.4.3 The driving machine shall be connected to main drive shaft, preferably by non-friction driving elements such as by gear wheels, shaft, coupling, multiplex chain, two or more single chains. Where friction elements are used such as trapezoidal belts (flat belts are not permitted) an auxiliary brake shall be used.

Safety factors of all driving elements shall be at least

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5 for static calculations. In the case of trapezoidal belts, at least 3 belts shall be applied.

8.4.4 *Braking System*

Escalators and moving walks shall have an operational braking system by means of which they can be brought to rest with a uniform deceleration and maintained stationary; there shall be no intentional delay in the application of the braking system. If the control system starts a braking sequence immediately to bring the escalators/moving walk to a stop, this is not considered as an intentional delay. A device shall be provided to monitor the lifting of the braking system after starting the escalator/moving walk.

Operational braking shall be effected by an electro-mechanical brake or by other means. Where no electro-mechanical operational brake is used, an auxiliary brake shall be provided.

8.4.4.1 *Auxiliary brake*

Escalators and inclined moving walks shall be equipped with auxiliary brake(s) if:

a) the connection between the operational brake and the driving sprockets of the steps/pallets or the drum of the belt is not accomplished by shafts, gear wheels, multiplex chains, or more than one single chain;
b) the operational brake is not an electro-mechanical brake;
c) the rise exceeds 6 m; or
d) escalators or moving walks are part of a public transport/service system.

The connection between the auxiliary brake and the driving sprockets of the steps/pallets or the drum of the belt shall be accomplished by shafts, gear wheels, multiplex chains or more than one single chain. It is not permissible for the connection to comprise friction drives, that is, clutches.

8.5 Steps and Pallets Drive

The steps of escalators shall be driven by at least two chains of which at least one shall be located on each side of the step. The pallets of moving walks may be permitted to be driven by only one chain, if the parallel movement of the pallets in the usable area is ensured by other mechanical measures.

The step chain design shall be of nominally infinite fatigue life.

The safety factor against breaking of each chain shall be at least 5. When more than one chain is used it is assumed that the load is equally distributed over the chains.

8.6 Belt Drive

The belt shall be driven by drums and be tensioned continuously and automatically. Springs working in tension are not permitted for the tensioning device. When weights are used for tensioning they shall be safely retained should their suspension break. The factor of safety of the belt including splicing shall be at least 5 for the dynamic forces.

8.7 Balustrade

8.7.1 Balustrades shall be installed to comply with the requirements of **6.3**.

8.7.2 The horizontal distance (measured at right angles to the direction of travel) between the interior panel at lower points shall be equal to or less than the horizontal distance measured at points higher up.

8.7.3 The parts of the balustrade facing the steps shall be smooth. Covers or strips not in the direction of travel shall not project more than 3 mm. They shall be sufficiently rigid and have rounded or bevelled edges. Cover or strips of such nature are not permitted at the skirting. Cover joints in the direction of travel (in particular between the skirting and balustrade interior panelling) shall be arranged and formed in such a manner to eliminate the risk of injury caused by trapping.

Gap between interior panels of the balustrade shall not be wider than 4 mm. The edges shall be rounded off or bevelled. The balustrade interior panelling shall have adequate mechanical strength and rigidity. When a force of 500 N is applied at any point of the panelling at right angles on an area of 2 500 mm^2, there shall be no gap greater than 4 mm and no permanent deformation (setting tolerance however, are permitted).

If glass is used for the interior panel it shall be toughened glass. In case of splinter free one layer safety (tempered) glass, the minimum thickness shall be 6 mm. When multi-layer glass balustrades are used, they shall be laminated toughened glass, the thickness of at least one layer shall also be not less than 6 mm.

8.8 Skirting

The skirting shall be vertical, plain and sufficiently rigid. Where the skirting of escalators or moving walks is placed beside the steps and pallets or the belt the horizontal clearance shall not exceed 4 mm at either side, or 7 mm for the sum of clearances measured at both sides at two directly opposite points.

Where the skirting of moving walks finishes above the pallets or the belt, the clearance shall not exceed 4 mm measured vertically from the tread surface. Motion of the pallets or the belt in lateral direction shall not cause

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a gap between the sides of the pallets or the belt and the vertical projection of the skirting

8.8.1 *Requirements for Skirt Deflectors*

The deflectors shall be designed with rounded edges. Fastening heads and joint connections shall not extend into the path of travel. They shall consist of a rigid and a flexible part (for example, brushes and rubber profiles). They shall have a minimum projection of 33 mm and a maximum of 50 mm from the vertical face of the skirt panels. The terminal end piece shall be tapered to give a flush interface with the skirting. The terminal end piece of any deflector device shall end not less than 50 mm and maximum 150 mm prior to the comb intersection line.

8.9 Handrails

Each balustrade shall be provided with a handrail moving, on the top of each balustrade, in the same direction and at the same speed, within tolerance of $^{+2}_{0}$ percent, as the steps, pallets or belt. Each moving handrail shall extend at normal handrail height not less than 300 mm beyond the line of point of comb plate teeth at the upper and lower landings. Hand or finger guards shall be provided at the points where handrails enter the balustrade.

The width of handrail shall be between 70 mm and 100 mm. The distance between the handrail and the edge of the balustrade shall not exceed 50 mm. The handrail shall be a minimum of 80 mm horizontally and 25 mm vertically away from adjacent surfaces (*see* Fig. 5). The distance between centreline of handrails shall not exceed the distance between the skirting by more than 0.45 m. The handrail shall be guided and tensioned in such a way that it does not leave its guides during normal use.

8.10 Landing

The landing area (that is, comb plate and floor plate) of escalator shall have a surface that provides a secure foot hold (combs are exempted from this) for a minimum distance of 0.85 m measured from the root of the comb teeth.

8.10.1 *Configuration of Steps, Pallets and Belts*

8.10.1.1 At the upper and lower landing, the steps of the escalator shall be guided in such a way that the front edges of the steps leaving the comb and the rear edges of the steps entering the comb are moving horizontally for a length of at least 0.80 m measured from point T1 (*see* Fig. 6 and detail A).

At nominal speeds above 0.50 m/s and not more than 0.65 m/s or rises above 6 m, this length shall be at least 1.20 m, measured from point T1 (*see* Fig. 6 and detail A).

At nominal speeds above 0.65 m/s this length shall be at least 1.60 m measured from point T1 (*see* Fig. 6 and detail A).

A vertical difference in level between two consecutive steps of 4 mm is permitted.

8.10.1.2 For escalators, the radius of curvature in the upper transition from incline to horizontal shall be,

a) at least 1.00 m for nominal speeds $v \leq 0.5$ m/s (inclination of maximum 35°);
b) at least 1.50 m for nominal speeds 0.5 m/s $< v \leq$ 0.65 m/s (inclination of maximum 30°); and
c) at least 2.60 m for nominal speeds $v > 0.65$ m/s (inclination of maximum 30°).

The radius of curvature in the lower transition from incline to horizontal of the escalator shall be:

1) at least 1.00 m for nominal speeds $v \leq 0.65$ m/s; and
2) at least 2.00 m for nominal speeds $v > 0.65$ m/s.

8.10.1.3 For belt moving walks, the radius of curvature in the transition from incline to horizontal shall be at least 0.40 m.

For pallet moving walks, it is not necessary to determine the radius of curvature because, on account of the maximum permissible distance between two consecutive pallets, it will always be sufficiently large.

8.10.1.4 At the upper landings of moving walks with an inclination of more than 6°, the pallets or belt shall move for a length of at least 0.40 m at a maximum angle of 6° before entering or after leaving the comb.

8.11 Comb Plates

There shall be a comb plate at the entrance and at the exit of every escalator. The comb plate teeth shall be meshed with and set into the tread surface so that the points of the teeth are always below the upper surface of the treads. The comb plates shall be adjustable. Combs shall be easily replaceable.

8.12 Speed Governor

8.12.1 Where speed control devices are used for this purpose, they shall have switched off the escalator before the speed exceeds 1.2 times the nominal speed. This requirement may not be applied if the design prevents the excessive speed.

8.12.2 Escalators and inclined ($\alpha \geq 6°$) moving walks shall be equipped in such a way that they stop automatically by the time the steps and pallets or the belt change from the pre-set direction of travel.

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8.12.3 For operation and safety devices, electrical work, precautions and tests, reference may be made to good practice [8-5B(2)].

8.13 Inspection Control

Escalators or moving walks shall be equipped with inspection controls to permit operation during maintenance or repair or inspection by means of portable and manually operated control devices. At least one portable control device shall be provided for each escalator or moving walk.

For this purpose, one inspection outlet for the connection of flexible cable of the portable manually operated control device shall be provided at least at each landing, for example, in the driving station and the return station in the truss. The length of the cable shall be at least 3.00 m. Inspection outlets shall be located in such a way that any point of the escalator or moving walk can be reached with the cable.

8.14 Information for Use

8.14.1 *General*

All escalators and moving walks are required to be provided with documentation that shall include an instruction handbook relating to use, maintenance, inspection, periodic checks and rescue operations. Information for use shall cover, separately or in combination, transport, assembly and installation, commissioning, use (setting, teaching/programming, operation, cleaning, fault finding and maintenance) of the escalator and moving walk, and, if necessary, de-commissioning, dismantling and disposal.

8.14.2 *Signals and Warning Devices*

8.14.2.1 *Plates, inscriptions and notices for use*

a) *General* — All signs, inscriptions and notices for use shall be of durable material, placed in a conspicuous position and written in clearly legible characters in English as well as in local language.

b) *Safety signs near the entrances of escalators or moving walks* — The following mandatory action signs and prohibition signs for the user shall be fixed in the vicinity of the entrances:

1) Small children shall be held firmly (*see* Fig. 14);
2) Pets shall be carried (*see* Fig. 15);
3) Use the handrail (*see* Fig. 16); and
4) Push chairs not permitted (*see* Fig. 17).

When required by local conditions, prohibition signs, for example, 'Transportation of bulky and heavy loads not permitted' and mandatory action signs like 'Use permitted only with footwear', shall be necessitated.

The minimum diameter of the signs shall be 80 mm.



FIG. 14 MANDATORY ACTION SIGN 'SMALL CHILDREN SHALL BE HELD FIRMLY'



FIG. 15 MANDATORY ACTION SIGN 'PETS SHALL BE CARRIED'



FIG. 16 MANDATORY ACTION SIGN 'USE THE HANDRAIL'



FIG. 17 PROHIBITION SIGN 'PUSH CHAIRS NOT PERMITTED'

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Stop devices shall be coloured red either on the device itself or in its immediate vicinity and be marked with the inscription 'STOP'.

During maintenance, repair, inspection or similar work, the access to the escalator or moving walk shall be barred to unauthorized persons by devices which shall bear the notice 'No Access' or the 'No Entry' indicator, and be available in immediate area.

NOTE — The safety sign (*see* Fig. 18) shall be affixed prominently near the entrances of escalators or moving walks which are inclined above 6°:



FIG. 18 WHEEL CHAIR USERS NOT PERMITTED

c) *Instructions for hand winding devices* — If a hand winding device is provided, operating instructions for use shall be available in the vicinity. The direction of travel of the escalator or moving walk shall be indicated clearly.

d) *Notices on the access doors to machinery spaces outside the truss, driving and return stations* — On access doors to machinery spaces outside the truss, and driving and return stations, a notice shall be fixed with the inscription reading, 'MACHINERY SPACE — DANGER' and 'ACCESS PROHIBITED TO UNAUTHORIZED PERSONS'.

9 SPECIAL TECHNICAL REQUIREMENTS

If escalators or moving walks are intended to be operated under special conditions, such as directly exposed to the weather or explosive atmosphere, or in exceptional cases serve as emergency exits, appropriate design criteria, components, materials and instructions for use should be used that satisfy the particular conditions.

9.1 Escalators or Moving Walks for Public Transport

For escalators and moving walks for public transport which,

a) are part of a public transport system including entrance and exit points; or

b) are suitable for intensive use, regularly operating for approximately 140 h/week with a load reaching 100 percent of the brake load for a total duration of at least 0.5 h during any time interval of 3 h.

It is recommended to install auxiliary brakes also for rises less than 6 m. Auxiliary brakes shall be mandatory for public transport. The load conditions and additional safety features should be agreed to between the manufacturer and the owner reflecting the traffic levels which exist.

9.2 Measures to Prevent Access of Shopping Trolleys and Baggage Carts

9.2.1 *General*

If there is a reasonable foreseeable risk that shopping trolleys and/or baggage carts can be taken onto escalators or moving walks, adequate measures shall be taken to eliminate risks and access shall be prevented, if the following conditions are given:

a) *For escalators* — Where shopping trolleys or baggage carts are available in the area around; and where shopping trolleys or baggage carts are in an area not close to the escalator but it is reasonably foreseeable that they are taken onto the escalator.

b) *For moving walks* — Where shopping trolleys or baggage carts are not intended to be used on a moving walk.

9.2.2 *Barriers*

If barriers are used, the following requirements shall be fulfilled:

a) Barrier shall be installed at the entrance only. An installation at the exit is not permitted in the unrestricted area.

b) Design of the barrier shall not create another risk.

c) Free entrance width between ends of the newels and barriers and between barriers itself, shall be at least 500 mm and less than the width of the type of shopping trolley or baggage cart to be used.

d) Height of the barrier shall be between 900 mm and 1 100 mm.

e) Barrier and its fixation have to withstand the following load: At a height of 200 mm a horizontal force of 3 000 N applies. This force results from an impact of a chassis of a shopping trolley/baggage cart loaded with 160 kg moving with a speed of 1.00 m/s.

f) Barrier shall be fixed preferably at the building

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structures. It is also permitted to fix it at the floor plate. In that case, when the defined forces apply, there shall be no permanent deformation and increased/additional gaps.

g) If the escalator/moving walk is dedicated to operate in both directions, the presence of the removable barrier shall be electrically monitored preventing wrong positioning of the barrier resulting in operation towards the barrier, except when under maintenance condition.

9.2.3 *Fixed Devices*

Where fixed devices such as guiding barriers and/or traffic columns are necessary in the unrestricted area, their design shall not create another risk. The following requirements shall be complied with:

a) Guiding barriers or traffic columns shall have a minimum horizontal distance (radius) of 500 mm to any point of the handrail and shall be positioned outside of the centre line of the handrail.

b) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 300 mm, provided that the guiding barriers or traffic columns are positioned outside of the centre lines of the handrails and an additional barrier is installed between the guiding barriers or traffic columns and the vertical centre line of the balustrade newel.

The additional barrier shall have a lateral distance between 80 mm and 120 mm of the handrail outer edge and shall close at least the area between the actual lowest point of the handrail entry into the newel and the balustrade decking profile and shall have filled inlets with gaps less than 25 mm.

c) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 180 mm, provided that the guiding barrier or traffic column is positioned outside of the outer edge of the handrail and an additional barrier is installed between the guiding barrier or traffic column and the vertical centre line of the balustrade newel.

The additional barrier shall have a lateral distance between 80 mm and 120 mm of the handrail outer edge and shall close at least the area between the actual lowest point of the handrail entry into the newel and the balustrade decking profile and shall have filled inlets with gaps less than 25 mm.

d) Minimum horizontal distance (radius) to any point of the handrail may be reduced to 100 mm, provided that the guiding barrier or traffic column is of a round shape and is positioned outside of the outer edge of the handrail and an additional barrier is installed between the guiding barrier or traffic column and the vertical centre line of the balustrade newel

The additional barrier shall have a lateral distance between 80 mm and 120 mm of the handrail outer edge and shall close at least the area between the actual lowest point of the handrail entry into the newel and the balustrade decking profile and shall have filled inlets with gaps less than 25 mm

In addition, the following specific requirements shall apply:

1) Devices and its fixation shall withstand a horizontal force of 1 kN/m applied to the top of the device.
2) Barrier shall be fixed preferably at the building structures. It is also permitted to fix it at the floor plate. In that case, when the defined forces apply, there shall be no permanent deformation and increased/additional gaps.
3) Height of traffic columns shall be at least the height of the handrail level.
4) Height of guiding barriers shall be at least the height of the balustrade decking.
5) If fixed devices are placed inside the unrestricted area, the size of the unrestricted area shall remain the same and in this case be extended in the length.
6) Guiding barriers and traffic columns are not considered as structural measures that block the exit.

NOTE — For fixed devices in the immediate environment of the unrestricted area these requirements also apply.

9.3 Escalators and Moving Walks Subject to Seismic Conditions

9.3.1 *Structural Requirements*

a) *General* — Escalators and moving walks, if specified to meet specified seismic conditions, shall comply with the relevant safety requirements and/or protective measures as listed below.

b) *Pit/support* — Pit and support conditions are to be secured in that way that the escalator and moving walk under seismic condition is not subjected to constraint. One support has to be executed as fixed support the other supports are to be executed as movable support in horizontal direction. The supporting conditions need to be simply statically

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determinate.

Escalator and moving walk shall be retained on the supports in vertical direction by adequate measures so that the unit cannot jump off the supports under seismic conditions.

c) *Arrangement* — The length and the movability of the escalator and moving walk have to be chosen in accordance with the building movement between two storeys of the building. The minimum allowable compensation length of the movable support of the escalator and moving walk has to be chosen same as the maximum allowed storey drift of the building.

d) *Mechanical safety devices for escalators and moving walks* — If the design of the escalator and moving walk does not allow the safe situation in the pit or support an additional safety device need to be applied so that the escalator and moving walk cannot fall off the support.

9.3.2 *Design Requirements*

It is assumed that negotiations have been made for each contract between the customer and the supplier/installer about the peak ground acceleration to be considered. The building designer or owner shall provide the design acceleration which shall be documented in the information. Client and supplier/contractor have to agree on one common acceleration value. The acceleration value need to be communicated between all participants of the contract. Also,

a) the design of the truss for the escalators and moving walks shall be sufficiently executed for the ambient seismic condition. The structural design shall provide a dissipation capacity to withstand a design-relevant earthquake of the region where it is located.

b) *Drive and control unit* — Machinery [including control cabinet(s) and drive system, machine, main switch(es), and means for emergency operations], free-wheeling switch shall be designed and anchored to prevent overturning and displacement as a result of the forces imposed on them including forces generated by the design acceleration.

c) *Electrical installation and other equipment* — In case the building where the escalator and moving walk will be installed is equipped with a seismic detector/sensor, the electrical system of the unit shall provide an interface for the connection and shall stop the escalator and moving walk in case of seismic activity.

9.4 Escalator/Moving Walk Interface with Building Management System (BMS)

Where required, a means to interface, monitor and control be provided by the escalator/moving walk manufacturer, which should become the part of building management system. Following information and controls, but not limited to these, may be provided either through potential free contacts or building automation interface device suitable for providing necessary escalator/moving walk information over accepted communication protocols:

a) *Monitoring signals:*

1) Power status,
2) Running up/down (Escalator),
3) Running forward/backward (Moving walk),
4) Under maintenance,
5) Under fault, and
6) Emergency 'STOP' pressed.

b) *Remote operation* — Escalator or moving walk shall not be started or stopped from remote monitoring station using remote signal, unless the particular escalator/moving walk operation is visible/monitored from the remote station.

10 PERFORMANCE REQUIREMENTS FOR ESCALATORS AND MOVING WALKS

10.1 It is necessary to have uniformity in the definition, measurement, processing and expression of vibration and noise signals that comprise escalator and moving walk ride quality. The aim of such uniformity is to benefit escalator and moving walk users by reducing variability in the results of ride quality measurements caused by differences in the methods of acquiring and quantifying the signals. Experience indicates that passenger perception and sound pressure levels measured while travelling on an escalator or moving walk can be influenced by the presence of extraneous noise and vibration sources and by acoustic characteristics of the environment in which the unit is installed and operated. Additionally, the proximity of the escalator or moving walk to strong reflecting surfaces such as walls, ceilings or diagonally opposite units can also influence the sound pressure level measured. These influences can cause a sound pressure level measurement to significantly overestimate the sound level emitted exclusively by the unit. In order to address this issue, this Subsection defines the methodology for measuring vibration and sound pressure level that corresponds to passenger perception and additionally defines the methods that should be used, if further understanding of the result is required in order to quantify vibration and noise emitted by the

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unit as compared to the background or environmental contributions.

10.2 Measurement of Escalator and Moving Walk Ride Quality

Escalator and moving walk should be measured in both running directions except where the unit is designed to operate in one direction only. The measurements should be carried out under following conditions where, escalator and moving walk shall,

a) be assembled completely, adjusted and operating in accordance to the requirement;
b) have reached normal operating temperature;
c) be measured in unloaded condition;
d) be measured after starting sequence has been completed. If the unit operates at different speeds, all the speeds shall be measured;
e) have finished star/delta changeover, if used, before starting the measurement;
f) have vibration measurements made by aligning the axis of transducer to the axis of entire escalator or moving walk; and
g) have the noise measured at measuring distance to the floor/surface of steps and pallets of 1.55 ± 0.075 m.

11 ESCALATOR AND MOVING WALK ENQUIRY OR INVITATION TO TENDER

11.1 A period of two to four weeks is normally sufficient for return of tenders. This should be extended, if large numbers of escalators/moving walks or special requirements are involved. The enquiry documents should be kept to the essential minimum, and should be strictly confined to material relevant to the escalators/moving walk works and to the particular project concerned.

When enquiring for and ordering the escalators/moving walks, the particulars given below should be furnished:

a) Type(s) of escalator/moving walk;
b) Number of escalators/moving walks;
c) Location of escalators/moving walks (indoor or outdoor);
d) Capacity/usage type (persons per day/heavy duty, medium duty, light duty);
e) Angle of inclination, in degree;
f) Rise (travel), in m;
g) Nominal speed, in m/s;
h) Step width, in m;
j) Number of flat steps (2 or 3);
k) Balustrade details;
m) Construction, design, finishes details;
n) Escalator/moving walk lighting details;
p) Electric supply: power volts a.c./d.c.; phase; cycles; wire system;
q) Proposed date for commencement on site;
r) Additional items, if required;
s) Details of maintenance, schedule and circuit diagram where so specified; and
t) Details of voice announcements, visual contrast, tactile indicators and warning signage.

11.2 Additional Items

The enquiry should state any additional items required beyond those specified in good practice [8-5B(2)], such as interface requirements, seismic design, etc.

11.3 Finishes

Finishes should be specified at the enquiry stage or provisional sums should be included for them. Finishes to be considered may include step lighting, handrail colour, handrail lighting, balustrade material, step colour, truss cladding details (weight to be considered).

11.4 Inclusions and Exclusions

A number of peripheral items are associated with escalators/moving walk installation, of which some should always be provided by the builder and some are best included by the manufacturer. The requirements vary to some extent with the type of installation.

It is important that the limits of responsibility are clearly understood, and the enquiry documents should be specific in this respect.

The escalators/moving walk manufacturer should include items, such as,

a) tracks,
b) drive unit,
c) controller,
d) broken chain,
e) stop switches at both ends,
f) balustrade,
g) handrail,
h) steps/step drive assembly,
j) saree/skirt guard,
k) step demarcation lights,
m) missing steps,
n) comb plate,
p) flat steps,
q) comb plate switches/skirt switches,
r) landing steps (anti-slip material),
s) truss,

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t) guarantee of equipment, and
u) scaffolding for installation.

The escalators/moving walk manufacturer should exclude the supply and fixing of the items or as per the contract conditions as follows:

1) Hoisting hook/beam fixing,
2) Truss cladding,
3) Temporary guarding,
4) Cutting and making goods,
5) Working lights/permanent electricity supplies, and
6) Site painting of steel work.

For more detailed discussion of the requirements for site preparation and work by other trades, reference should be made to relevant provisions of the Code and other good practices.

Facilities for the use of the main contractor's crane should be provided to assist in installing heavy equipment in addition to other unloading facilities on site in the course of erection. The main contractor should be instructed to include these facilities in his own bill of quantities.

11.5 Site Programme

The enquiry should indicate as accurately as possible the contract programme as it affects the manufacturer, in particular the target date for completion, construction schedule, site preparedness, the availability of crane for hoisting, coordination details (with other contractors like BMS interfacing, CCTV interfacing, etc).

12 ACCEPTANCE OF TENDER AND SUBSEQUENT PROCEDURE

12.1 Order

The owner places an order with the selected contractor for supply and installation of escalator/moving walk.

12.2 The general arrangement drawings supplied by owner with the tender documents,

a) are provided for the supplier's guidance and information when tendering;
b) should the arrangement and dimensions shown be inadequate to properly install the equipment as specified then necessary amendments shall be issued by client; and
c) any amendments issued after the commencement of contract shall be subject to the agreement and approval.

12.3 Layout Drawings

The contractor shall furnish proposed layout giving particulars such as dimensions, steel work requirements and loading imposed on structure. Such drawings shall include the following details:

a) Position and sizes of all holes and cuttings,
b) Loads on beams and structure,
c) Escalator/moving walk pits and associated equipment,
d) End supports requirement including layout,
e) Hoisting facilities and access requirement for delivery of equipment,
f) Builder's work, and
g) Power and ventilation requirement.

12.4 Approval of Layout Drawings

The contractor shall commence actual production of equipment after approval of drawings submitted by contractor. Where the contract provides for the purchaser's choice of decorative finishes, colours, etc, the decisions should be communicated as early as possible, and preferably not later than the time of approval of drawings.

12.5 Programme of Works

The contractor shall submit a detailed programme showing intended method and stages together with period of time estimated for each stage. The programme shall include the following:

a) Date of commencement and completion of every stage of the works in line with the building construction programme;
b) Date of expected completion of builder's work requirements;
c) Date of delivery of equipment and materials to site;
d) Date of requirement of temporary and permanent electricity supply; and
e) Date of completion, commissioning and testing.

The contractor shall ensure the work in accordance with the criticality of adherence of installation dimensions and supports as indicated in layout.

12.6 Electricity Supply to Escalators/Moving Walk

Operation of the machine under power is required from a comparatively early stage of installation for most efficient working, and power supply shall be furnished accordingly. Whilst temporary power supply may be sufficient for erection purposes, final testing and setting up can only be carried out with the permanent power supply connected. For this reason, the timely provision of the permanent power supply is important.

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13 COORDINATION OF SITE WORK

13.1 Preparatory Work on Site

13.1.1 It is expected for the escalator/moving walk supplier to make periodic visits to the site to check progress on the construction and discuss relevant matters with the owner. The contractor should assure himself that all building work has been completed in accordance with his requirements. Immediately before the time for erection to commence, the contractor should check that site conditions are fit to permit erection to proceed.

13.1.2 Building works to be completed before the erection work, includes the following:

a) Providing adequate access to the well-way to allow for setting the equipment in place.
b) If the project is not ready for placement at the time of delivery, providing dry storage area located close to well-way.
c) Providing protection of all floor openings adjacent to and in the general area of escalator/ moving walk.
d) Providing safety compliant stairwell access to floors.
e) Providing clear unobstructed workspace adjacent to well-way.
f) Providing safety compliant overhead and floor opening protection.
g) Providing barricades to prevent the entrance of unauthorized personnel to construction area.
h) Drying and cleaning of pit and floor openings with proper dimensions.
j) Providing properly located supports of adequate strength for the truss at the landings including intermediate supports, if required.
k) Providing suitable floor fill and patching of flooring including floor covering, adjacent to the landing plates of the escalator/moving walk; all floor finishing to be completed after installation of the landing plates.
m) Providing flooring with little slope in direction outwards of the escalator to prevent ingress of water, etc, into the escalator.

13.2 Delivery of Material

The contractor should advise the owner when equipment is ready for dispatch, so that the owner can make arrangements on site to receive and unload as near as possible to the well-way.

13.3 Storage

Adequate provision should be made by the owner for storing, protecting and preserving against loss, deterioration of or damage to all material on the site. Attention is drawn to the adverse effect of damp conditions on electrical equipment.

13.4 Site Meetings

The contractor shall coordinate his proposed programme of work with that of the building contractor and all other contractors and sub-contractors in order to adhere to the latest overall construction programme and in order to achieve efficient and safe working on site. In large sites, regular meetings of all parties are beneficial for successful progress of work. *See also* Part 0 'Integrated Approach — Prerequisite for Applying Provisions of the Code' of the Code.

13.5 Service of Other Trades

The contractor may require the services of other trades as the work proceeds, and it is essential that the contractor should give due notice to the building contractor of the demands to be made on other trades, so that he can plan accordingly.

13.6 Connecting to Power Supply

The contractor should give prior notice to the owner of the date the power supply is required, so that suitable arrangements for connection can be made. During erection, necessary electrical power shall be provided for illumination, operation of required tools and hoist and for starting, testing and adjustment

14 INSPECTION AND ACCEPTANCE PROCEDURES

14.1 General

Escalators and moving walks shall be inspected, before their first use; after major modifications; and at regular intervals. Such inspections and tests should be made by a competent person.

14.2 Constructional Inspection and Acceptance Inspection and Test

14.2.1 The constructional inspection and acceptance inspection and test shall be carried out at the job-site on completion of the escalator or moving walk. During inspection and tests, precautions shall be taken so that escalators or moving walks cannot be set in motion without the knowledge and consent of the person(s) performing such work.

For the constructional inspection and acceptance inspection and test, the data specified in **14.4** should form part of a pre-completed test sheet. Furthermore, layout drawings, description of the equipment and wiring diagrams (current flow chart with legend or explanations, and a terminal connection chart) which

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permit a check of compliance with the safety requirements, shall be provided.

The constructional inspection comprises the examination of the completed installation for conformity with the required data and with regard to proper workmanship as specified hereunder.

14.2.2 The acceptance inspection and test comprises,

a) overall visual inspection;
b) functional test;
c) test of electric safety devices with regard to their effective operation; and
d) test of the brake(s) of the escalator or moving walk under no load, for compliance with the prescribed stopping distances.

14.2.3 *Stopping Distances for Escalator*

The stopping distances for unloaded and downward moving loaded escalators shall be as given in Table 6.

For intermediate speeds the stopping distances shall be interpolated.

The stopping distances shall be measured from the time the electric stopping device is actuated.

NOTE — It is recommended to achieve the shortest possible stopping distance within the given deceleration limit and stopping distances for escalator.

Additionally, for escalators, a test of the stopping distances under brake load is required unless the stopping distances can be verified by other methods.

Table 6 Stopping Distances for Escalators
(*Clause* 14.2.3)

Sl No. (1)	Nominal Speed, *v* m/s (2)	Stopping Distance shall be Between (3)
i)	0.50	0.20 m and 1.00 m
ii)	0.65	0.30 m and 1.30 m
iii)	0.75	0.40 m and 1.50 m

14.2.4 *Brake Load for Escalators*

For determining the brake load for escalators, the following relation shall be used:

Nominal Width	*Brake Load per Step* kg
Up to 0.60 m	60
More than 0.60 m up to 0.80 m	90
More than 0.80 m up to 1.10 m	120

The number of steps to be considered is determined by 'Rise divided by maximum visible height of the step riser'. For the purpose of a test, the total brake load is permitted to be distributed over two-thirds of the number of steps thus obtained.

14.2.5 *Stopping Distances for Moving Walks*

The stopping distances for unloaded and horizontally or downward moving loaded moving walks shall be as given in Table 7.

Table 7 Stopping Distances for Moving Walks
(*Clause* 14.2.5)

Sl No. (1)	Nominal Speed, *v* m/s (2)	Stopping Distance shall be Between (3)
i)	0.50	0.20 m and 1.00 m
ii)	0.65	0.30 m and 1.30 m
iii)	0.75	0.40 m and 1.50 m
iv)	0.90	0.55 m and 1.70 m

For intermediate speeds, the stopping distances shall be interpolated.

The stopping distances shall be measured from the time the electric device for stopping is actuated

NOTE — It is recommended to achieve the shortest possible stopping distance within the given deceleration limit. For moving walks, a brake test under no load is sufficient.

14.2.6 *Brake Load for Moving walks*

To determine the brake load for moving walks which in their length overcome several inclinations (differences in level), only the downward running sections shall be considered. For loaded moving walks, the manufacturer shall prove the stopping distances by calculation (*see* table).

Nominal Width	*Brake Load per 0.4 m Length* kg
Up to 0.60 m	50
More than 0.60 m up to 0.80 m	75
More than 0.80 m up to 1.10 m	100
More than 1.10 m up to 1.40 m	125
More than 1.40 m up to 1.65 m	150

An examination of the brake adjustment according to the calculation is required. Calculation of the stopping distances for loaded moving walks (*see* together with adjustment data) is also necessary.

Measurement of the insulation resistance of the different circuits between conductors and earth shall also be done. For this measurement, the electronic components shall be disconnected. This includes a test of the electric continuity of the connection between the earth terminal(s) in the driving station and the different parts of the

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escalator or moving walk, liable to be live accidentally.

14.3 Inspection and Test after Major Modifications

A major modification is a change of the location, a change of the speed, of the electric safety devices, of the braking system, of the drive, of the control, of the step band, of the truss and of the balustrades. Wherever applicable, the principles set forth for the constructional inspection and acceptance inspection and test should apply to the new environmental conditions, modified components and other components which are affected.

The replacement of parts with parts of same design is not considered to be a major modification.

14.4 Specific Data, Test Reports and Certificates

The following documentation should be held by the manufacturer:

a) Stress analysis of the truss or equivalent certificate by a competent person;
b) Proof by calculation of sufficient breakage resistance of the parts directly driving the steps, pallets or the belt, for example, step chains, racks;
c) Calculation of the stopping distances for loaded moving walks together with adjustment data;
d) Test certificate for steps or pallets;
e) Test certificate for the breaking strength of the belt;
f) Test certificate sliding coefficients for skirting;
g) Test certificate for anti-slip properties of tread surfaces (steps, pallets, floor and comb plates without combs);
h) Test certificate for stopping distances and deceleration values; and
j) Test certificate for handrail breaking strength (for public service escalators and public service passenger moving walks).

14.5 Escalator Site Checks and Inspection List

Suitable site checklist/inspection list may be used. A typical list is given at Annex A.

14.6 Escalator Commissioning and Acceptance Tests

14.6.1 *Escalator Details*

Typical details to be provided are given below:

a) Name of station :
b) Location :
c) Escalator No. and job No. :
d) Drawing No. :
e) Rise :
f) Type of balustrade : SS / Glass - Tick (√)
g) Manufacturer's Sl No. :

14.6.2 *General Inspection*

A typical general inspection list is given below:

Sl No.	*Item*	*Method/ Requirement*	*Result*
(1)	(2)	(3)	(4)
i)	All unwanted material have been removed	Visual check	
ii)	Escalator (including steps, handrails, floor plate, cladding, etc) has been cleaned	Visual check	
iii)	Proper barricading of the area has been done prior to testing	Visual check	
iv)	Emergency signage to be fixed at the emergency stop; safety labels placed at top/bottom newel end	Visual check	
v)	Check provision of 'Danger Sign' plate on the escalator control panel	Visual check	

14.6.3 *Electrical Test*

A typical check list of electrical tests is given below:

Sl No.	*Item*	*Test Procedure*	*Recommended Result*	*Instrument/ Sl No.*	*Measured Value*	*Result*
(1)	(2)	(3)	(4)	(5)	(5)	(7)
i)	Insulation resistance test	Shall be tested between lines connected together and earth at 500 V d.c.	> 0.5 MΩ (Mega Ohm)			

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14.6.4 *Functional Tests on Safety Switches and Devices*

A typical check list is given at Annex B.

15 OPERATION AND MAINTENANCE

15.1 General

The installation shall be maintained in good working order in accordance with the installer's instructions. To this effect, regular maintenance of the installation shall be carried out to ensure, in particular, the safety of the installation. The safety of an installation shall take into account the ability to be maintained without causing injury or damage to health.

Regular maintenance of the installation shall be carried out to ensure the reliability of the installation. The access and the associated environment shall be maintained in good working order in accordance with the installer's instructions.

The instructions for maintenance of an installation shall be provided by the installer, after completion of the installation as a result of a risk assessment. The instructions for maintenance of an installation shall be provided by the manufacturer, when placed on the market, and be the result of a risk assessment.

In order that the aim of the maintenance instructions can be achieved, they shall be formulated so that they can be clearly and easily understood by competent maintenance person. The competent maintenance person within the maintenance organization shall be continuously updated.

The installer/manufacturer shall provide maintenance instructions intended for the owner of the installation (*see* **15.3.2**) including the information intended for the maintenance organization (*see* **15.3.3**).

NOTE — The owner of the installation should be informed that the qualification of the maintenance organization is in conformity with the regulation applicable in the location in which the installation operates.

15.2 Elements to be Taken into Account for Maintenance Instructions

When preparing the content of the maintenance instructions (*see* **4.3** and **5**) the following elements shall be taken into account:

a) Specifications and the intended use of the installation (type of installation, performance, etc);
b) Environment in which the installation and its components are installed (weather conditions, vandalism, etc);
c) Any restriction of use;
d) Result of risk assessment (*see* **5**) for every working area and for every task undertaken;
e) Specific maintenance instructions provided by the manufacturer of safety components; and
f) In case of components other than safety components, where maintenance is necessary, the maintenance instructions provided by the manufacturer of these components.

15.3 Information to be Included in the Maintenance Instructions

15.3.1 *General*

The maintenance instructions shall contain information relating to the tasks of both the owner and the maintenance organization, respectively.

15.3.2 *Information to the Owner of the Installation*

The information relating to the tasks of the owner of the installation shall include the following:

a) Need for the owner to keep the installation in a safe operating condition. To fulfil this, the owner shall use a maintenance organization complying with the requirements of this Subsection.

   NOTE — It is recommended to inform the owner of the installation about the need to use a maintenance organization with adequate and proper insurance cover provided by an insurance company.

b) Need for the owner to take care of applicable regulation(s) and other requirements, where relevant, and their implications on maintenance.
c) Need for planned maintenance to be carried out by a maintenance organization, at the latest when the installation is put into service or if the installation is to remain unused for a long period of time before first being put into service.
d) Importance for the owner of the installation to have the same maintenance organization in the case of several installations having common well/spaces and/or machine room.
e) Need for the owner to put the installation out of service in case of dangerous situations.
f) Need for the owner of the installation to inform the maintenance organization,
   1) immediately about any perceived abnormal operation of the installation or abnormal change in its direct environment;
   2) immediately after putting the installation out of service in the case of a dangerous situation;
   3) after any rescue intervention by their authorized and instructed person(s);

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4) before any modification related to the installation and/or its environment or use;

NOTE — The owner of the installation should obtain from the company carrying out the relevant modification the maintenance instructions for the maintenance organization.

5) before any authorized third party inspection or works other than maintenance works are carried out on the installation;

6) before taking the installation out of service for a prolonged period of time; and

7) before putting the installation back into service after a prolonged period of non-operating time.

g) Need for the owner of the installation to take into consideration the consequences of the risk assessment carried out by the maintenance organization.

h) Need for the owner of the installation to make sure that the risk assessment for maintenance is carried out:

1) if the maintenance organization is replaced;

2) if the use of the building and/or the installation changes;

3) after a major modification of the installation or of the building; and

4) if it is the case, after an accident involving the installation.

j) Need for the building owner to ensure, through a risk assessment, that:

1) their premises are safe and free from risk to health as far as is practicable. This includes access to the premises and installation equipment, and articles or substances used according to the regulation for the use of work equipment at the workplace;

2) the persons using the premises are informed about any remaining risks; and

3) any action to be done as a consequence of his risk assessment is carried out.

Regarding the access ways to areas reserved to maintenance persons, the need for the owner of the installation to inform the maintenance organization, in particular about,

i) the access ways to be used and fire evacuating procedures from the building;

ii) the place where the keys of the reserved areas can be found;

iii) if necessary, the persons who shall accompany the maintenance persons to the installation; and

iv) if necessary, personal protective equipment to be used in the access ways, and, possibly, where this equipment can be found.

The information shall be made available also on site to the maintenance organization.

k) Need for the owner of the installation to ensure that the name and the telephone number of the maintenance organization are always available to the user of the installation, permanently affixed and clearly visible.

m) Need for the owner of the installation to ensure that the keys of machine room doors (trap doors) and of inspection and emergency doors (trap doors), if any, are permanently available in the building and are used only by persons authorized to gain access.

n) Need for the owner of the installation to provide, in all circumstances, safe access to the building and to the installation for the maintenance organization involved in the rescue of persons.

p) Need for the owner of the installation to keep the access to working areas and working rooms safe and free for the maintenance persons and to inform the maintenance organization about any hazard or change in the workplace and/or the access ways (lighting, obstructions, ground conditions, etc).

q) In addition to those examinations and tests (for escalators/moving walk) which the owner of the installation entrusts to the maintenance organization, the need for the owner to carry out periodically, in their own interests, include the following:

1) A full travel in both directions, when they exist, to assess any changes in the quality of the ride or damage to the equipment.

2) Typical items to be checked to ensure that they are in place, undamaged and functioning correctly are,

i) all lighting and indicators;

ii) emergency stopping device;

iii) hand rails;

iv) skirting/deflector devices;

v) combs;

vi) safety signs/pictograms;

vii) approximation of speed between handrail and steps/pallets;

viii) steps/pallets;

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ix) balustrade and panels;

x) head guard and decking;

xi) safe and unobstructed access to entry and exit areas.

15.3.3 *Information for the Maintenance Organization*

The information relating to the tasks of the maintenance organization shall include the following:

a) Need to carry out the work of maintenance in conformity with the maintenance instructions and based on systematic maintenance checks. After these checks, the maintenance organization shall decide in conformity with the maintenance instructions what is required to be done. A list of typical examples of maintenance checks to maintain the installation is shown in Annex C.

NOTE — Due to the fact that the components can be different in design and operation, it is therefore not possible to give specific guidelines in this Subsection.

b) Need to update the original maintenance instructions, if the installation changes its intended use and/or the environmental conditions existing on the completion of the installation.

NOTE — The maintenance organization should be provided by the owner of the installation with the relevant maintenance instructions where modifications are carried out on the installation.

c) Need for the maintenance organization to ensure that a risk assessment for any working area and for any maintenance operation has been carried out taking into account the installer's maintenance instructions and all information supplied by the owner of the installation.

d) Need for the maintenance organization to inform the owner of the installation about any work to be carried out as a consequence of a risk assessment especially for the access and/or the environment related to the building/installation.

e) Need to carry out a maintenance plan so that preventive maintenance is suitable for the installation and maintenance time is as short as reasonably practicable, without reducing the safety of persons, in order to minimize the non-operational time of the installation.

f) Need to adapt the plan for maintenance so as to take account of any predictable failures, for example, those due to misuse, mishandling, deterioration, etc.

g) Need to carry out maintenance operations by competent maintenance persons and provided with the necessary tools and equipment.

h) Need to maintain the competency of maintenance persons.

j) Need to carry out the maintenance periodically. In determining the frequency of maintenance interventions, the following non-exhaustive list should be considered:

1) Operating time and any non-operating periods of time;

2) Age and condition of the installation;

3) Location and type of building in which the installation is installed, as well as the needs of the users; and

4) Local environment where the installation is situated, as well as external environmental elements, for example, weather conditions (rain, heat, cold, etc) or vandalism.

k) Need to provide a 24 h, all year round call-out service for rescue of persons.

m) Need to keep records of the result of each intervention due to a failure of the installation. These records shall include the type of failures in order to detect any repetition. They shall be available to the owner of the installation on request.

n) Need to put out of service the installation, if the maintenance organization is aware of a dangerous situation, detected during the maintenance, which cannot be eliminated immediately, and to inform the owner of the installation of the need to keep it out of service until repaired.

p) Need to be organized to provide the necessary spare parts for any repair.

q) Possible need for attendance of a competent maintenance person(s), given reasonable notice, for any inspection carried out by an authorized third party or for building maintenance works to be carried out in the areas reserved for the maintenance organization.

r) Need to inform in due time, the owner of the installation about necessary progressive upgrading of the installation.

s) Need to organize rescue operations, even with sub-contractor(s), and to make provision for circumstances such as fire, panic, etc.

15.4 Maintenance Contract

It is recommended that the maintenance is carried out by original equipment manufacturer (OEM). Any maintenance contract should include the following at a minimum, to ensure that escalators/moving walk is always maintained/operated in the safe working condition:

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a) All batteries used for emergency operations,
b) All safety switches/devices,
c) Handrail system components including handrails,
d) Operational and auxiliary brake, and
e) Combs.

15.5 Risk Assessment

15.5.1 *General*

Before an installation is placed on the market, it is necessary that the installer/manufacturer carries out a risk assessment. Every risk shall be limited as much as reasonably possible by means of safety measures and suitable instructions. The instructions can never replace a safety measure which can be provided to reduce the risk.

It is necessary to determine the different intervention procedures of the maintenance operations and to determine the appropriate safety measures for each of these procedures.

The use of diagnostic systems may support fault finding, improve the maintainability of the installation and reduce the exposure of maintenance persons to hazards.

Safety in maintenance operations of the installation is ensured by adopting safety measures and providing instructions. Safety measures on the installation and in the building shall be provided by the installer and by the owner of the installation, respectively.

For any working area, it is necessary to identify the list of the specific hazards related to health and safety and to carry out a risk assessment for any maintenance operation, including access to the working area.

For this purpose, the following should be taken into account:

a) Presence of one or more maintenance persons in a working area;
b) Foreseeable actions of persons other than maintenance persons (for example, person switching on or off power circuits and dependent circuits or lighting circuits or trying to use the installation during maintenance operations, etc); and
c) Possible states of the installation (normal or abnormal due to a foreseeable failure of its component parts, external disturbances, disturbance of its power supply, etc).

Annex D gives a list of examples of elements to be taken into account in any risk assessment for maintenance operations. However, several methods are available for the systematic assessment of risk.

15.5.2 *Information for the Maintenance Organization*

For safe maintenance and to provide relevant instructions, it is necessary, first of all, to identify the maintenance operations.

In particular, maintenance operations are,

a) those operations considered necessary for a correct and safe functioning of the installation and its components after the completion of the installation; and
b) those operations considered necessary during the 'life' of some components, determining, as far as possible, the time or condition after which the functioning or the integrity of the component is no longer ensured even if correctly maintained.

In carrying out specific maintenance operations, if it is necessary to neutralize some safety functions (for example, an electric safety device), the hazard identification shall be taken into account for such a situation.

It is necessary to inform and warn the maintenance persons about: (a) residual risks, that is, those for which risk reduction by design and safeguarding techniques are not there or not completely effective; and (b) risks that arise from the necessary removal of certain guards to carry out specific maintenance operations. The maintenance instructions and warnings shall prescribe the procedures and operating modes intended to overcome these risks and, if it is necessary, to specify personal protective equipment, instruments, tools and provisions to be used.

15.6 Markings, Signs, Pictograms and Written Warnings

If the risk assessment of the maintenance organization indicates that additional specific warnings are required for the purpose of maintenance, these shall be affixed directly on the installation/component or, in the close vicinity, when this is not possible . Markings, signs, pictograms and written warnings shall be readily understandable and unambiguous. Readily understandable signs and pictograms shall be used in preference to written warnings.

Signs or written warnings carrying only the words 'DANGER' shall not be used. Information affixed directly on the installation/component shall be permanent and legible.

Any markings, signs, pictograms and written warnings affixed on the installation shall be renewed if they become illegible.

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15.7 Format of the Maintenance Instruction Handbook

The maintenance instruction handbook for any installation shall contain at the front at least the following:

a) Type of installation, with its serial number, to which the instructions apply;
b) Title of the handbook;
c) Date of issue;
d) Name and address of the installer/ manufacturer; and
e) Name of the publisher, when different from the installer/manufacturer.

In the handbook,

1) all units used shall be SI units;
2) all pages shall be numbered; and
3) all references to other documents shall be in full.

Warnings shall state the hazard, the related risks and the appropriate safety measure.

Type and size of print shall ensure the best possible legibility. Safety warnings and/or precautions shall be emphasised through the use of colours or symbols and/ or large print.

Documents giving instructions for maintenance shall be produced in durable form (that is, they shall be able to survive frequent handling) or triplicate copies shall be provided.

15.8 Maintenance Record and Annual Inspection

Maintenance organization is required to maintain a log book at the equipment to record of maintenance and repair work carried out on the equipment. In addition, the layout diagram and latest wiring diagram is required to be maintained at the equipment by maintenance organization. Maintenance organization is required to carry out annual inspection of the installation and certify that escalator is in safe for operation. Owner of the installation is responsible for ensuring that any deficiencies found during the annual inspection are rectified before the equipment is put back in service.

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ANNEX A

(*Clause* 14.5)

TYPICAL ESCALATOR SITE CHECKLIST/INSPECTION LIST

Sl No.	Items	Frequency and Method	Requirement	Value Required	Value Measured	Result
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Definition of datum and installation of bearing plate	100 percent (Visual check)	Check whether metal plate and isolation rubber pad provided at both top and bottom escalator support notches	YES/NO		
ii)	Intermediate support	100 percent (Visual check)	Check whether both support points are loaded by ensuring:	YES/NO		
			a) Tightness of bolts and locking of check-nut			
			b) Check for any sag by holding a thread from the nose of top-most step to the nose of bottom-most step (excluding flat steps)	YES/NO		
iii)	Alignment of truss and end supports	100 percent (Visual check)	Check horizontal level using spirit-level on step:			
			a) Top support	OK/NOT OK		
			b) Bottom support	OK/NOT OK		
			c) Middle level	OK/NOT OK		
iv)	Alignment of drive top/reverse/bottom/ tension carriage	Random (Visual check)	Alignment : Factory setting	OK/NOT OK		
			Check tightness of nuts and bolts	OK/NOT OK		
v)	Alignment of track brackets	Random (Visual check)	Alignment : Factory setting	OK/NOT OK		
			Check tightness of nuts and bolts	OK/NOT OK		
vi)	Alignment of inclined tracks	Random (Visual check)	Alignment : Factory setting	OK/NOT OK		

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ANNEX A — (*Continued*)

Sl No.	Items	Frequency and Method	Requirement	Value Required	Value Measured	Result
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			Check tightness of nuts and bolts	OK/NOT OK		
vii)	Installation and alignment of upper and lower newel wheels	Random (Visual check)	Alignment : Factory setting	OK/NOT OK		
			Check tightness of nuts and bolts	OK/NOT OK		
viii)	Alignment of skirting brackets and panels	Randomly at number of locations (Measure using taper gauge/ tape)	a) Clearance between comb plate and skirt	2 mm, *Max*		
			b) Distance between skirt panel	(1 000 + 7) mm		
			c) Clearance between skirt and step	One side 4 mm, both sides total 7 mm		
			d) Levelness of skirt joint	0.5 mm, *Max*		
			e) Clearance of skirt joint	0.5 mm, *Max*		
ix)	Installation of step chain and steps	Randomly at number of locations (Visual check)	a) Visual check chain joint — Step chain joint link plate fixed properly	OK/NOT OK		
			b) Step assembly (random check 10 pieces) — Circlip of step chain is properly secured in its position	OK/NOT OK		
			c) No step transverse movement (random check 10 pieces)	OK/NOT OK		
			d) Colour on Step, As per specifications	YES/NO		
x)	Installation of balustrade steelworks	Randomly at number of locations (Visual check and by using spanner/screw driver)	Check tightness of nuts and bolts	OK/NOT OK		

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ANNEX A — (*Continued*)

Sl No.	Items	Frequency and Method	Requirement	Value Required	Value Measured	Result
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xi)	Glass balustrade	100 percent (Measure using tapper gauge/visual check)	a) Gap between the glass panels	4 mm OK/NOT OK		
			b) Provision of rubber pad between the glass	YES/NO		
xii)	Stainless steel balustrade	100 percent (Measure using feeler) gauge)	a) Gap between the panel (inner)	OK/NOT OK		
			b) Visual check the outer cladding	OK/NOT OK		
xiii)	Alignment of handrail tracks	Randomly at number of locations (By feeling the edges at joints)	Handrail guide joints fitted without sharp edges	OK/NOT OK		
xiv)	Installation of top decking panels, inner panels, skirting returns and kick plates	100 percent (Visual check)	Check whether all decking and skirt panels are provided properly	OK/NOT OK		
xv)	Installation of upper and lower comb plates and access floor covers	100 percent (Visual check)	Check whether comb plates and floor plates are provided properly	OK/NOT OK		
xvi)	Floor plate	100 percent (Visual check/tape/ stainless steel ruler)	a) No tripping hazard on floor plate	YES/NO		
			b) Clearance between floor plate and frame	2 mm, *Max*. YES/NO		
			c) Clearance between comb plate and floor plate	6-8 mm YES/NO		
xvii)	Alignment of main drive chain, handrail drive chains	100 percent (Tape/stainless steel ruler)	Sagging of handrail drive chain	10-20 mm YES/NO		
			Sagging of drive chain	10-20 mm YES/NO		
xviii)	Alignment of ‘over speed / under speed’ detection unit drive chain	100 percent (Visual check)	Check whether the ‘over speed’ ‘under speed’ sensor is provided	YES/NO		

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ANNEX A — (*Concluded*)

Sl No.	Items	Frequency and Method	Requirement	Value Required	Value Measured	Result
(1)	(2)	(3)	(4)	(5)	(6)	(7)
xix)	Cables are properly laid in raceway and properly dressed. The power and control wiring is done properly with ferruling and identification tags	100 percent (Visual check)	Check provision of proper arranged cable tray (or) flexible hose	YES/NO		
			Check provision of labels/ ferruling	YES/NO		
			Check for proper dressing of cables	YES/NO		
xx)	Installation of switches and wiring	100 percent (Visual check)	Safety switches and limits switches and its location fixing arrangement to be checked	YES/NO		
xxi)	Installation of lubrication system	100 percent (Visual check)	Check whether automatic lubrication system is provided	YES/NO/NA		
xxii)	Earthing has been extended to all relevant locations	100 percent (Visual check)	Check tightness of earthing strips/wires	YES/NO		
xxiii)	Installation of controller	100 percent (Visual check)	Check, if controller is fixed properly(for tightness, straightness)	YES/NO		
xxiv)	Installation of escalator cladding and decking	100 percent (Visual check)	Check whether cladding and decking have been provided properly	YES/NO		
xxv)	Others: Over lapped type joints of drip pan	100 percent (Visual check)		YES/NO		
xxvi)	The clear height above the steps	Measuring tape	At all points shall be not less than 2.30 m	YES/NO		

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ANNEX B

(*Clause* 14.6.4)

TYPICAL CHECK LIST FOR FUNCTIONAL TESTS ON SAFETY SWITCHES AND DEVICES

Sl No.	Check Point	Method	Value Required	Measured Value	Result
(1)	(2)	(3)	(4)	(5)	(6)
i)	The over speed protection devices	Tripping the over speed device manually	OK/NOT OK		
ii)	The handrail tension malfunction devices/broken handrail monitor	Test operation of handrail tension/broken handrail switch	OK/NOT OK OK/NOT OK	Left: Right:	
iii)	The broken drive chain protection	Tripping the broken drive chain device manually by hand	OK/NOT OK		
iv)	Broken step chain monitor	Tripping the broken step chain device manually under the step chain spring at 2 locations in the bottom pit	OK/NOT OK OK/NOT OK	Left: Right:	
v)	Emergency stop switch	Push the button	OK/NOT OK OK/NOT OK OK/NOT OK	Top: Intermediate level: Bottom:	
vi)	Direction key switch (Start switch)		OK/NOT OK OK/NOT OK	Top: Bottom:	
vii)	Traffic bollard		OK/NOT OK		
viii)	Traffic light working	Check for correct movement indication (Up/Down) visual check	OK/NOT OK OK/NOT OK	Top: Bottom:	
ix)	Provision of comb light	Visual check	OK/NOT OK		
x)	Phase failure/ Phase reversal protection	Visual check simulate the function device	OK/NOT OK		
xi)	Hand rail inlet monitor	In the handrail inlet at 4 locations; trip manually	OK/NOT OK OK/NOT OK OK/NOT OK OK/NOT OK	Bottom Left: Bottom Right: Top Right: Top Left:	
xii)	Skirt panel deflection safety switch	Trip manually	OK/NOT OK OK/NOT OK OK/NOT OK OK/NOT OK	Bottom Left: Bottom Right: Top Right: Top Left:	
xiii)	Step sag monitor	Trip manually	OK/NOT OK OK/NOT OK	Top: Bottom:	
xiv)	Comb plate safety device	Trip manually	OK/NOT OK OK/NOT OK OK/NOT OK	Top Left: Top Right: Bottom Left:	

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ANNEX B — (*Concluded*)

Sl No.	Check Point	Method	Value Required	Measured Value	Result
(1)	(2)	(3)	(4)	(5)	(6)
			OK/NOT OK	Bottom Right:	
xv)	Floor plate open switch	Open floor plate- manually	OK/NOT OK	Top:	
			OK/NOT OK	Bottom:	
xvi)	Step missing monitor	Simulate function of sensor - manually	OK/NOT OK	Top:	
			OK/NOT OK	Bottom:	
xvii)	Float safety switch	Trip manually	OK/NOT OK		
xviii)	Handrail speed monitor	Simulate change in speed manually	OK/NOT OK	Left:	
			OK/NOT OK	Right:	
xix)	Step up-thrust monitor	Trip manually	OK/NOT OK	Top:	
			OK/NOT OK	Bottom:	
xx)	Brake open detect switch	Trip manually	OK/NOT OK	Left:	
			OK/NOT OK	Right:	
xxi)	Provision to measure the braking distance	Visual check, provision of sensor/encoder	Yes/No		
xxii)	Sprinkler:				
	a) Connected to main system		Yes/No/NA		
	b) Number of sprinkler heads provided		Yes/No/NA		
xxiii)	Hand winding unit (Check for proper operation)	Escalators should move easily in downward direction	Yes/No		
xxiv)	Details of gear box:				
	a) Gear box make				
	b) Sl No.				
	c) Reduction ratio				
	d) Check gear oil level				
xxv)	Details of motor:				
	a) Manufacturer				
	b) Motor Sl No.				
	c) kW Rating				
	d) Current rating				
	e) RPM				
	f) Insulation class				

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ANNEX C

[(*Clause* 15.3.3(a)]

TYPICAL EXAMPLES OF MAINTENANCE CHECKS TO MAINTAIN THE INSTALLATION

C-1 ESCALATORS AND MOVING WALKS

Sl No.	Component	Checks
(1)	(2)	(3)
i)	Controller	Check cabinet is clean, dry and free from dust
ii)	Gear box	Check gear and associated parts
		Check lubrication
iii)	Drive motor	Check bearings for wear
		Check lubrication
iv)	Brake	Check braking system
		Check parts for wear
v)	Auxiliary brake	Check braking system
		Check parts for wear
vi)	Intermediate gear box	Check gear and associated parts Check lubrication
vii)	Main drive chain	Check for tension and wear
		Check lubrication
viii)	Step/pallet chain	Check for tension and wear
		Check lubrication
ix)	Step/pallet	Check step/pallet and step/pallet wheels for integrity
x)	Conveyor belt	Check for condition and tension
xi)	Drive belt	Check for condition and tension
xii)	Clearances	Check step to step and step to skirting clearances
xiii)	Combs	Check condition
		Check meshing with steps, pallets or belt
xiv)	Comb plate	Check clearances and operation
xv)	Handrails	Check for free running and condition
		Check tension
		Check synchronization between step/pallet band and the handrail
xvi)	Track system	Check for condition and wear
		Check fixings
xvii)	Safety devices	Check operation
xviii)	Deflector devices	Check condition
xix)	Lighting	Check operation
xx)	Display	Check operation
xxi)	Signs/pictograms	Check condition
xxii)	Balustrade	Check condition of panels
		Check fixings of interior claddings

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ANNEX D

(*Clause* 15.5.1)

EXAMPLES OF ELEMENTS TO BE TAKEN INTO ACCOUNT IN ANY RISK ASSESSMENT FOR MAINTENANCE OPERATIONS

D-1 ESCALATORS/MOVING WALKS

Elements	Machinery Spaces	On Step/ Pallet Band	Inside Step/ Pallet Band	Upper and Lower Landing	Control Cabinet	Machine Room (External Drives)
Access and entry	R	R	R	R	R	R
Inadequate lighting (including access)	R	R	R	R	R	R
Falls/slips	R	R	R	R	R	R
Falling on machine	NR	R	NR	R	NR	NR
Falling over balustrade	NR	R	NR	R	NR	NR
Contact with moving machinery	R	R	R	R	R	R
Indirect contact with machinery	R	R	R	R	R	R
Crushing and shearing (step to step or comb/step to skirting)	R	R	R	NR	NR	NR
Gaps in balustrade	NR	R	NR	NR	NR	NR
Intersection between floors and/or escalators	NR	R	NR	NR	NR	NR
Persons on the step band	NR	R	NR	R	NR	NR
Safety switches and emergency stopping device(s)	R	R	R	R	R	R
Inspection control	R	R	R	R	R	R
Intersection between fixed and moving parts	NR	R	NR	NR	NR	NR
Unintentional start/stop	R	R	R	R	R	R
Machine moving (other than on power)	R	R	R	R	R	R
More than one maintenance person working	R	R	R	R	R	R
Manual operation	R	NR	R	R	R	R
Falling objects	R	R	R	R	NR	R
Unexpected water/dirt	R	R	R	R	R	R
Contamination by oil and grease	R	R	R	R	NR	R
Dangerous substances	R	R	R	R	R	R
Fire	R	NR	R	NR	R	R
Missing step/pallet	R	R	R	R	NR	NR

'R' = Relevant and 'NR' = Not relevant

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of reference in this Subsection.

	IS No.	*Title*
(1)	732 : 1989	Code of practice for electrical wiring installation
	3043 : 1987	Code of practice for earthing
(2)	4591 : 1968	Code of practice for installation and maintenance of escalators

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 6 Information and Communication Enabled Installations

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 8/Section 6) covers the essential requirements for information and communication enabled installations, technology systems and cabling installations in a building. It also covers the basic design and integration requirements for telecommunication spaces within building/buildings along with their cabling infrastructure, their pathway components and passive connectivity hardware. It also includes general requirements relating to installation of different communication equipment, cable terminations, power connections and general guidelines required for planning and providing information and communication technology (ICT) services in the building at the planning and execution stages. The provisions given herein are basic requirements applicable to all residential and other buildings. These can be used at the time of upgradation of existing buildings for properly accommodating telecom systems/services. Buildings meant for data centres and those for housing telecom exchanges/facilities for offering public services may have various other considerations. For such buildings, provisions of this Section are indicative and may be a subject of actual requirements.

Telecommunication plays a vital role in modern society similar to electricity, water and transport systems. It is difficult to imagine a life without telecommunication technologies. In a building, a broad variety of telecommunication systems are expected to be installed. Buildings have provision for installation of various utilities. However, unlike traditional utilities, telecommunication systems are constantly evolving at a rapid pace.

Telecommunications connectivity can be delivered through cable, wire, optical fibre, fixed wireless and mobile wireless technologies. Each of these technologies when considered for use inside buildings, especially when the buildings are either commercial or multi-dwelling units or complexes, places its own requirement in terms of building space, power supply, internal extensions to various work areas/dwelling units. For example, for wire line services, broadband cable television, etc, the entry to the buildings/complexes will be through underground cables and the distribution of services further into the complexes will be from the bottom of the building to the upper stories. On the contrary, any wireless technologies, where antennas are to be installed at terrace along with a system which can distribute the signals through cables, the flow of cables will be from top storeys of the building to the bottom. It is also to be kept in view that there are multiple service providers for each type of service with similar or different technologies.

The telecom facilities can be chosen by the user from the gamut of technologies and associated features as options are available based on the requirement, cost, service and maintenance convenience, future upgradation requirements, etc. While providing telecom enabling infrastructure in the building, the provisions are to be made for making the infrastructure supportive for multiple technologies/products and the requirements of telecom service providers. Use of Building Management System (BMS) and creation of 'Smart' building will require significant telecom infrastructure to be created within the buildings. This may be supported by machine to machine (M2M) communication technologies. Individual/tenant users of the building may also have their own M2M/IoT systems with wireline or wireless gateways. The telecom support infrastructure in the buildings/campuses needs to be responsive and accommodative of these requirements.

In order to facilitate installation/upgradation of telecom systems, proper planning and understanding of enabling provisions for telecom technologies and physical infrastructure are necessary. Modern telecommunication technologies such as Distributed Antenna System, Wi-Fi and other in-building solutions are also to be considered during the building planning stage itself. The enabling infrastructure may include cable riser systems, conduits, cable trays, etc. Appropriate space need to be earmarked for installation of equipment at the entry point of service and running the cables, etc, through shafts and horizontal conduits inside the walls, centre of the corridors and centre of the work space, etc. Thus, cabling pathways infrastructure should be designed to be of general nature but flexible enough to accommodate a variety of telecom systems and emerging technologies.

Choice of service to be provided inside the complexes/buildings will depend on the users. As already mentioned above, the delivery of service can be spread across technologies and across various service providers. Therefore,

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the arrangement for telecommunication infrastructure needs to be made in such a manner that the requirements and the challenges of at least near future can be met without disturbing the building infrastructure. This Section has been formulated to cover these aspects.

In the formulation of this Section, due weightage has been given to international coordination among the standards and practices prevailing in different countries, in addition to relating it to the practices in this field in this country. This has been done by deriving assistance from the publications of ISO, IEC, ITU, etc.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 8 BUILDING SERVICES

Section 6 Information and Communication Enabled Installations

1 SCOPE

1.1 This Code (Part 8/Section 6) covers the essential requirements for information and communication enabled installations, technology systems and cabling installations in a building. It also covers the basic design and integration requirements for telecommunication spaces within building/buildings along with their cabling infrastructure, their pathway components and passive connectivity hardware.

1.2 It also includes general requirements relating to installation of different communication equipment, cable terminations, power connections and general guidelines required for planning and providing information and communication technology (ICT) services in the building at the planning and execution stages. The provisions given herein are basic requirements applicable to all residential and other buildings. These can be used at the time of upgradation of existing buildings for properly accommodating telecom systems/services. Buildings meant for data centres and those for housing telecom exchanges/ facilities for offering public services may have various other considerations. For such buildings, provisions of this Section are indicative and may be a subject of actual requirements.

NOTE — In this Section, 'Telecom' has been used interchangeably with 'ICT', as most of the time there may be only telecommunication hardware present. Apart from the provision of telecommunication systems, Information Technology (IT) system in the building may be either common for the building or separate for the individual users. In case the entire building is used by the same user, the IT system may be common and thus IT space for Building Management System (BMS), CCTV, etc, can be shared with telecom facilities. In case where individual IT systems owned by several users are provided, separate spaces may be earmarked inside telecom spaces for individual IT infrastructure. Sometimes, individual users may also use the common IT facilities. However, the cabling, wiring, etc, for IT systems should use the same pathways, which are used for telecommunication hardware.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Access Point — A hardware device or a computer's software that acts as a communication hub or as an interconnection port for users of wireless devices to connect them to a wired or wireless local area network (LAN).

2.2 Antenna — An electrical device designed to transmit or receive radio waves or more generally, electromagnetic waves for the purpose of radio frequency communication such as Wi-Fi, radio, television, satellite communication, radar communication and mobile communication. This is also called an aerial.

2.3 Attenuation — A general term that refers to any reduction in the strength of an electrical/electro-magnetic signal.

2.4 Backbone — A high-capacity facility (for example, pathway, cable or conductors) which acts as a major pathway within a network from which further smaller capacity facilities get distributed.

2.5 Backbone Cabling Media Distribution and Building Pathway — A part of a building premises telecom cable distribution system that provides connection between telecommunications spaces. It typically provides building connections between floors in multi-storeyed buildings as well as campus connections in multi-building environments.

2.6 Building Management System — It is a low voltage automation or remote control system installed for managing different building sub-systems like, heating, ventilation, lighting, air conditioning, fire protection, access control, etc.

2.7 Bus Bar — It refers to thick strips of copper or aluminium, in electrical power distribution that conduct electricity within a switchboard, distribution board, substation, or other electrical apparatus.

2.8 Coaxial Cable — A type of wire that consists of a centre wire surrounded by insulation and then a grounded shield of braided wire. The shield minimizes electrical and radio frequency interference.

2.9 Consolidation Point (CP) — A location for interconnection between horizontal cables extending from building pathways and horizontal cables extending into furniture pathways.

2.10 Cross-Connect — A facility enabling the termination of cable elements and their interconnection or cross-connection.

2.11 Direct to Home (DTH) — The direct reception of satellite programs using small dish (personal dish) placed on a roof or window of a house.

2.12 Frequency — The measurement of the number of times that a repeated event occurs per unit of time.

2.13 Horizontal Cabling — It includes, (a) the cabling

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between and including the telecommunications outlet/connector and the horizontal cross-connect, and (b) the cabling between and including the building management system outlet or the first mechanical termination of the horizontal connection point and the horizontal cross-connect.

2.14 Horizontal Cabling Media Distribution and Building Pathway — It consists of the horizontal cabling in the building, the horizontal pathways supporting the horizontal cabling, and the telecommunications spaces that support the horizontal pathways. The use of the term horizontal in the name of the element does not require that the elements be placed or installed parallel to the ground or floor.

2.15 Horizontal Cross-Connect (HC) — A cross-connect of horizontal cabling to other cabling, for example, horizontal, backbone, and equipment.

2.16 Inside Plant (ISP) — Telecommunications infrastructure designed for installation, interior to the buildings.

2.17 Intermediate Cross-Connect (IC) — A cross-connect between first level and second level backbone cabling. First level backbone is a cable between a main cross-connect (MC) and intermediate cross-connect (IC) or horizontal cross-connect (HC). Second level backbone exists between an intermediate cross-connect (IC) and horizontal cross-connect (HC).

2.18 Internet of Things (IoT) — A network of all physical objects connected to internet primarily using M2M communication technologies.

2.19 Local Multipoint Distribution System (LMDS) — A broadband radio service designed to provide two-way transmission of voice, high-speed data and video (wireless cable TV) digitally through microwave.

2.20 Local Area Network (LAN) — A computer network covering a local area, like a home, office or small group of buildings.

2.21 Machine to Machine (M2M) Communication — It is a set of wired/wireless communication technologies which enable machine/device (for example sensor, meter, etc) to capture an event (for example temperature, motion, meter reading, etc) and relay through communication network to an application that translates the data from device to a meaningful information.

2.22 Main Cross-Connect (MC) — A cross-connect for first level backbone cables, entrance cables, and equipment cables.

2.23 Main Distribution Frame (MDF) — A structure where all the copper wires, fibre or coaxial cables for a network terminates for patching/cross-connection on separate or composite frames.

2.24 Metropolitan Area Network (MAN) — A network designed to carry data over an area larger than a campus, such as an entire city and its outlying area.

2.25 Multichannel Multipoint Distribution System (MMDS) — A method of delivering multiple voice/data/television signals digitally by microwave transmission to subscriber households.

2.26 Multi-User Telecommunications Outlet Assembly (MUTOA) — A grouping in one location of several telecommunications outlet/connectors.

2.27 Optical Fibre — It refers to the medium and the technology associated with the transmission of signals/information as light pulses along a glass fibre.

2.28 Optical Distribution Frame (ODF) — Optical fibre distribution frame where ends of optical fibre terminates for further patching/cross-connection.

2.29 Outside Plant (OSP) — Telecommunications infrastructure designed for installation, exterior to the buildings.

2.30 Propagation Delay — In a communications system, it refers to the time lag between the departure of a signal from the source and the arrival of the signal at the destination.

2.31 Public Mobile Network — A network that is established and operated by a telecom service provider for the specific purpose of providing mobile telecommunications services to the public using technologies such as GSM, CDMA and LTE.

2.32 Radio Frequency — A frequency range from 20 kHz and above, used for transmitting/receiving text, data, audio, or video signals.

2.33 Server — Any computer on a network that contains data or applications shared by users of the network on their client terminals.

2.34 Splicing — The process of permanent joining of bare fibre end to another fibre by means of splicing tools.

2.35 Smart City/Building/Home — An innovative city/building/home that uses information and communication technologies, and other means to improve quality of life, efficiency of operation and services and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects.

2.36 Telecommunication Spaces — The rooms and areas where telecommunications cabling systems are terminated, cross-connected and interconnected to installed telecommunications equipment. Various examples of these

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based on the function and areas, are equipment room (ER), telecommunications room (TR), entrance facilities (EF) and telecommunication enclosures (TE).

NOTE — The definitions of telecommunication spaces and workspace (*see* **2.44**) are used for calculation of infrastructure requirements, facilities, etc. This does not inhibit the utilization of space for any other purpose. Depending upon the requirements, number of telecommunication spaces in a given building may vary for the same area.

2.37 Telecom Service Provider (TSP) — A service provider who is authorized to operate telecom services by Government of India. It includes telecom Infrastructure Providers (IPs) also.

2.38 Telecom Tower — A vertical structure for installation of antenna(e) that provide radio frequency air interface for telecommunications services. It can also be in the form of mast or multiple poles of varying height. Poles may be located at different points typically on the roof.

2.39 Telecommunication Media and Connecting Hardware — It consists of cables, equipment cords, patch cords, and connecting hardware components. All balanced twisted-pair, optical fibre, coaxial cabling and wireless systems are made up of such components. These cabling components and resulting cabling systems are used in outside plant (OSP) and premises cabling [also known as inside plant (ISP)] environments of the building telecommunication infrastructure.

2.40 Underground Cable Vault (UCV) — An underground cable vault (part of an underground duct system) used to facilitate placing, connecting, and maintaining telecommunications cables and associated equipment. It collectively refers to manholes, hand holes, and pull holes.

2.41 Very Small Aperture Terminal (VSAT) — It usually refers to satellite terminal used to transmit and receive signal from satellites with an antenna installed in user premises.

2.42 Wide Area Network (WAN) — It is a network that is capable of spanning a geographical area larger than a city.

2.43 Workstation — An electronic device that performs some information processing or display function and connects to the communications network. Typically, this may be a desktop computer with keyboard and display or laptop computer, but might also be a telephone, a printer, an access control terminal, or some data-gathering device.

2.44 Workspace — Any location and the space around where a workstation may be located. Typically there can be several workspaces in a room.

3 GENERAL REQUIREMENTS FOR TELECOMMUICATION SPACES AND CONNECTING HARDWARE

3.1 Telecommunication Spaces

3.1.1 *General Considerations*

The following shall be the considerations for telecommunication spaces:

a) *Accessibility* — Telecom spaces that are intended to serve multiple users should be located in common spaces that should be accessible through a common corridor or outside door. The space for each telecom service providers may be separated to the extent feasible by partitions for security reason and controlled access to their equipment. The telecommunication spaces should be accessible, but the access should be controlled against the unauthorized access (for example, with a lock and key arrangement or by an electronic access system).

b) *Acoustic noise levels* — Acoustic noise levels in telecom spaces should be kept to a minimum by not collocating noise-generating equipment (for example, photocopy equipment, high-speed printers, and mechanical equipment).

c) *Administration* — All pertinent documentation of deployment of telecom equipment and cables should be maintained by owner or agent when the installation is completed. All telecom spaces shall have appropriate signs to identify the space and should be included within the security plan of the building.

d) *Cable separation* — Telecom cables should be separated from possible sources of electromagnetic interference (EMI) and from possible radio frequency interference (RFI). For safety purposes, power cables should be separated from telecom cables.

e) *Ceilings* — The general requirements for ceilings in telecom spaces should include the following:

1) Generally, the minimum ceiling height shall be 2.4 m above finished floor. However, consideration may be given for having a 3 m ceiling height.

2) If suspended ceilings are provided, necessary rodent protection may be provided.

3) The ceiling finish should minimize dust and be light coloured to enhance the room lighting.

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f) *Conduits, trays, slots, sleeves and ducts* — Slot/sleeve systems should be located in places where pulling and termination of cables is easy to achieve. Bend radius requirements and service loop guidelines shall be considered. Sleeves and slots shall not be left open after cable installation. All sleeves and slots shall be fire-stopped in accordance with Part 4 'Fire and Life Safety' of the Code.

The size and number of conduits or sleeves used for backbone pathways depends on the usable floor space served by the backbone distribution system. However, sleeves in multiple of 100 mm are recommended to serve a TR, ER or EF. Multiple telecom spaces on the same floor shall be interconnected with a minimum of one 75 mm conduit or a pathway that provides equivalent capacity.

g) *Dust and static electricity* — Dust and static electricity should be avoided by,

1) placing active printers outside of telecom spaces, and
2) treating floors, walls, and ceiling to minimize dust.

h) *Electrical power* — When active equipment of TSPs or the building equipment (for example, PABX) are installed in TR/ER, etc, the telecom spaces shall be equipped to provide adequate electrical power. The recommendations are as under:

1) A diesel generator (DG) set may be considered if longer power interruptions are expected for which the battery backup is not adequate. Further, as telecom services are required on 24x7 basis, uninterrupted electrical power for telecom services shall be provided from local or central uninterrupted power supply (UPS) with adequate battery backup. One of the option is that individual TSP provide their own UPS. However, this may not be space and energy efficient. Further, UPS arrangement may be extended to equipment in TE/corridors also.
2) Separate socket outlets for equipment, tools, test instruments, etc.
3) Separate electrical distribution panels that serve telecom equipment/spaces from those that serve other purposes are recommended. These should be clearly identified with proper sign writing.

j) *Prevention from flooding* — Telecom spaces should be located above any threat of flooding. When locating telecom spaces where a threat of flooding is unavoidable, rack elevations may be designed so that active equipment and telecom components are placed above the threat level. Sometimes locating the ER/TR on a floor above ground floor may be safer. The locations that are below or adjacent to areas of potential water hazard (for example, restrooms, kitchens) should be avoided. Liquid carrying pipes (for example, water, waste, steam) should not be routed through, above, or in the walls encompassing the ICTs space. If due to unavoidable circumstances, liquid carrying pipes are passing through telecom spaces then these spaces may be preferably monitored for water seepage by deploying suitable water seepage detection system. Otherwise, regular watch may be kept to detect seepage.

When air conditioning ducts are installed in telecom spaces, water dripping/leaking from AC vent should be controlled and, if required, monitored by water leaking system. Instructions for prevention from liquid cleaning agents, air purifying liquids, pest repellants and sprays usage should be indicated by proper sign writing.

k) *Lighting* — Following are the important considerations for lighting of telecom spaces:

1) Locating light switches near the entrance(s) to the telecom space.
2) Coordinating the lighting layout with the planned equipment layout (especially overhead cable trays) to ensure that lighting is not obstructed.
3) Providing electrical power for the lighting and ICT equipment from different circuits.
4) Placing at least one light or set of lights on normal power and one light or set of lights on emergency/UPS power.
5) Using a light coloured finish on walls, floors, and cabinets to enhance room lighting.
6) Providing task lighting illumination at the point of cable termination.
7) Providing adequate lighting of spaces, which may be controlled by automated controllers such as Building Management System (BMS), if required, or ensured otherwise. Use of dimmers and occupancy sensors is not recommended.

m) *Location* — All telecom spaces shall be located in areas that are best suited to serve

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the occupants of a floor or building. The following shall be observed when locating the spaces:

1) Telecom spaces in multi-floor buildings should be aligned vertically.
2) Telecom spaces should be located in areas that are dedicated to telecom use. Equipment that is not related to the support of telecom spaces (for example, piping, duct work, distribution of building power) shall not be located in or pass through a telecom space.

n) *Environmental control* — When active devices which are heat producing equipment are present, original equipment manufacturer (OEM) recommended temperature and humidity range should be maintained by adequate arrangement for heat dissipation. If environmental parameters are exceeded, an alarm should be activated. A positive pressure is required to be maintained with a minimum of one air change per hour in the telecom space. More stringent requirements may apply based on the equipment needs in the telecom space.

p) *Fire protection* — The telecom spaces shall be equipped with adequate fire detection, alarm and suppression systems as per Part 4 'Fire and Life Safety' of the Code.

q) *Bonding and grounding* — All equipment and cable shields shall be properly bonded to the telecom bonding and grounding infrastructure of the space (*see* **4.1** for details).

3.1.2 *Equipment Room (ER)*

3.1.2.1 An equipment room is an environmentally controlled centralized space for telecom equipment that usually house equipment of higher complexity than telecommunication rooms and also usually houses a main or intermediate cross-connect. Any or all of the functions of a telecommunications room may be provided in an equipment room. ERs differ from TRs in the way, that, ERs are generally considered to serve a building, campus, tenant, or SP, whereas TRs serve a floor area of a building. In some cases, an ER may also contain the EF or it may serve as TR. ERs may be connected to backbone pathways that run both within and between buildings. Although an ER usually serves an entire building, many building designs may use more than one ER in order to provide separate facilities for different types of equipment and services or redundant facilities and disaster recovery strategies.

The initial assessment for design and specifications for an ER shall be based on detailed information about the site, including,

a) user requirements;
b) telecom pathway locations;
c) service provider's requirements;
d) environment/facility conditions; and
e) building requirements.

3.1.2.2 *Space allocation and layout*

The space allocation and layout may be determined by following methods:

a) *Determining size based on area served* — When the telecom designer does not know what specific equipment will be used in an ER, the designer can use the amount of floor space that the room will serve, to determine the minimum size of the ER. If the usable floor space is also unknown, the usable floor space may be estimated by deducting 20 percent from the total floor area.

   Generally, an area of 9.3 m^2 may be considered for calculating the work areas. If work areas are smaller leading to possible increase in number of work areas in building, the size of the ER should be increased accordingly. The minimum recommended size for ER is 14 m^2. The general practice is to provide 0.07 m^2 of ER space for every 10 m^2 of usable floor space. For special use buildings, such as, hospitals and hotels, ER size requirements may vary.

b) *Telecom service provider space requirements* — If equipment or cable terminations that are owned or maintained by a TSP are to be located in the ER, then location and amount of space required shall be determined as per the space requirement of TSP.

c) *Telecom equipment locations* — As equipment for communication systems are located in the various equipment rooms throughout the building, these rooms shall be physically secure, aesthetically provisioned and conveniently located. The communication equipment may be located with due consideration of the modular provision of building design and criteria for expansion joints matching to electrical distribution and maximum fire safety distance requirements. The other considerations for telecom equipment location include the following aspects:

   1) Types of cables, their uses, bending radius, turning radius, conduit radius, etc.
   2) *Provision for future expansion* — In view of the evolving nature of the communication technologies, provision for future expansion should be ensured by way of stand-by arrangements. The distribution infrastructure should also be as flexible

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as possible. Small conduits will quickly fill up and may not accommodate some technologies, for example, low loss broadband or high capacity fibre optic cables. The most flexible distribution design involves cable trays for horizontal (floor level) distribution with large conduit sleeves for wall penetration, where necessary. Vertical trunk distribution should also be achieved with conduit sleeves.

3) *Maintainability* — As it is difficult to remove or shift just a few cables from a crowded or convoluted conduit system for operational or maintenance requirements, steps should be taken to ensure easy access and maintainability of cable system right in the initial architectural design stage.

3.1.3 *Telecommunications Room (TR)*

3.1.3.1 A telecommunications room is the area within a building that houses the telecommunications cabling system equipment. This includes the mechanical terminators and/or cross-connects for floor-serving distribution facility for horizontal cabling and backbone cabling system. There should be at least one TR or TE per floor. TR or TE can also house active equipment, like LAN switches, routers, etc, or passive equipment, like optical splitters. Most of these equipment are available in wall mount units. The switches/routers can also be shared between telecom equipment and other low voltage in-building systems. This reduces the demand on floor space requirements for TR/TE. Sometimes, a TSP with the consent of the building owner may require to provide additional equipment, such as for mobile signal booster, at a later stage, in TR/TE. Therefore, it is recommended to have additional space in advance, specially in tall buildings of five storeys or higher, preferably on top floor.

3.1.3.2 Multiple rooms or TEs are required if the cable length between the horizontal cabling (floor distribution) [HC (FD)] and the work area outlet location, including slack, exceeds 90 m. If the usable floor space to be served exceeds 930 m^2, additional TRs should be considered. Following are the guidelines for TR size:

Area Served	*Dimension of TR*
465 m^2 or less	3 m × 2.4 m
More than 465 m^2 and less than equal to 930 m^2	3 m × 3.4 m

NOTE — The size of 3 m × 2.4 m has been specified to allow a centre rack, cabinet, or enclosure configuration.

In smaller buildings, less space is required to serve the telecom distribution needs of the occupants. The size guidelines for smaller buildings should be as below:

Building Smaller Than	*Served as*
465 m^2	Shallow/Walk-in rooms (Walk-in rooms shall be at least 1.3 m × 1.3 m. Shallow rooms shall be at least 0.6 m deep by 2.6 m wide.)
93 m^2	Wall cabinets, self-contained cabinets, enclosed cabinets

NOTE — Installation of active equipment in shallow or walk-in rooms is not recommended because many types of equipment require environmental controls and a depth of at least 1 m.

3.1.4 *Entrance Facilities (EF)*

Building entrance facilities (EF) provide the point at which outdoor cabling of the telecom service provider interfaces with the intra-building/intra-campus backbone cabling. In cases, where the functions of the EF are combined with the functions of the ER in the same space, the room may house equipment that is owned and maintained by service providers. In these cases, requirements specified by the service providers shall be considered when designing the ER.

If a separate space is required for service providers, it should be in or adjacent to the EF and may require a mesh partition or locked cabinet. A space of at least 1.2 m × 1.83 m shall be considered for each service provider. An entrance facility necessarily be an enclosed space. However, having an enclosed area or access protected area is suggested at all occasions, considering safety requirements.

The duct from the cable vault (CV) of the telecom service provider generally consists of 100 mm conduits encased in reinforced concrete. The exact number of conduits will depend upon the size and use of the building. These conduits may be used for all communication systems serving the building including additional capacity and access cables and pathways capacity. To maintain the safety of the TSP cable, it may preferably enter the building above the ground and then feed the equipment room.

A separate 230 V, 16/6 A circuit with double outlets should be provided (for plugging in temporary test equipment or to power the tools) every 2.4 m along the EF and ER combined wall. All wall outlets are to be located approximately 300 mm above the finished floor levels with the breaker and clearly labelled. In addition, two dedicated 230 V, 16/6 A sockets should be provided for each (permanently installed)

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communication service rack. If the sockets of racks are fed from UPS power, appropriate levelling may be provided to distinguish between main power sockets and UPS power sockets.

3.1.5 *Telecommunication Enclosures (TE)*

A TE is simply a case or housing for telecom equipment, cable terminations, and cross-connect cabling for distribution of telecom services on a floor. The TE may also contain access points for wireless services. Although, TEs serve much in the same way as that of a TR, a minimum of one TE should be located on each floor, if no TR is considered on the floor. The TE door(s) may be hinged or removable. If the enclosure consists of metallic components, it shall be earthed.

3.2 Telecom Media and Connecting Hardware

3.2.1 A cabling system consists of cables, equipment cords, patch cords, and connecting hardware components. All balanced twisted-pair, optical fibre, and coaxial cabling systems are made up of such components. There can be different topologies for cabling used in a building like star, tree, bus bar, ring, etc, or a combination of these to suit different technological requirements. Within a building, most of the wiring is between the work spaces and the equipment room. Wireless systems can also be part of the telecom media. However, connectivity to the network, which delivers telecom service, is generally provided using cables at the back end.

The selection of appropriate style of cabling is important and accordingly, some of the user requirements to be considered before selecting the specifications and style of cabling and connectors for a telecom enabled building may include the following:

a) Number of user work areas and telecom spaces used to serve the building occupants;
b) Types of services and technology used for delivery of services;
c) Number of telecom outlets/connectors desired at each user work area;
d) Number and styles of user equipment (for example, telephony, LAN, building automation);
e) Cabling system transmission performance expectations;
f) Backbone distances and horizontal cable lengths involved in the building or campus;
g) Future growth expectations (for example, 15 to 20 percent recommended minimum growth factor);
h) Environmental conditions including electromagnetic interference; and
j) Other types of low voltage systems and their network requirements.

3.2.2 The cables should have ferrule marking at the terminations as well as along the length of the cable at suitable interval. Similarly, copper pair/fibre pair should be identifiable at terminating end for easy identification and convenience during maintenance. For the purpose, a suitable chart should be available at locations, like inside cross-connect box. Further, all the documentation of pathways and cables should be properly maintained.

3.2.3 While designing the cabling system for large multi-tenant building, it should be kept in mind that the tenants may prefer subscribing to the services of multiple service providers. Thus, enough space should be available in ducts, pathways, etc, for laying additional conduits/trays, keeping in view the present and future demands. Capacity for pathways (that is, conduit, raceways, trays, baskets) may be planned so that initial installation achieves a fill of 40 percent and at final installation, fill of 60 percent, taking into account the expected future requirements.

3.2.4 Various cabling systems are described under **3.2.4.1** to **3.2.4.3**. For the purpose of reference, the details about connecting hardware components and classification of cables by fire safety properties are given in Annex A.

3.2.4.1 *Copper twisted-pair*

The transmission performance of balanced twisted-pair cabling and telecom associated components are based on a number of factors within the cabling or component design. These performance levels use the terms category and class. Standards developed internationally utilize both class and category, depending on the specific cabling element, as described in Table 1.

A large number of cable designs are used in the ICT industry, resulting in various names and acronyms for their identification. The ISO/IEC 11801 : 2002 'Information technology — Generic cabling for customer premises', gives balanced twisted-pair cable designations using *x*/*y* designation, where *x* is the overall screen type and *y* is the individual pair screen type, which may be used. Details of various nomenclature based on this, using various categories of cables, are given in Annex A.

3.2.4.2 *Optical fibre*

Optical fibre cables are used in backbone and horizontal cabling applications, when the service is delivered on fibre to the user or inter/intra building communication is to be carried on fibre. Example of former is GPON

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Table 1 Balanced Twisted-Pair Cabling Channel Performance

(*Clause* 3.2.4.1)

Sl No.	ISO Category/Class	TIA Category	Frequency MHz	Maximum Data Transfer Rate
(1)	(2)	(3)	(4)	(5)
i)	Category 3/Class C	Category 3	16	10 Mbps
ii)	Category 5/Class D	Category 5e	100	100 Mbps
iii)	Category 6/Class E	Category 6	250	10 Gbps
iv)	Category 6A/Class EA	Category 6A	500	10 Gbps
v)	Category 7/Class F	NA	600	10 Gbps
vi)	Category 7A/Class FA	NA	1 000	—
vii)	Category 8/Class G	Category 8	1 500 to 2 000	—

(Gigabit Passive Optical Network), which require Fibre to Home (FTTH) and the example of latter is LAN implementation using optical network. Transmission of information through optical fibre cables is not degraded by crosstalk, ambient noise, lightning, and most electromagnetic interference (EMI). It has better loss characteristics compared to copper pair. Thus it permits high data rate communication to be carried out to much larger distances than copper pair.

Optical fibres are classified as either single-mode or multi-mode. Single-mode optical fibres have a relatively small diameter featuring a core of 8 to 11 µm and a cladding diameter of approximately 125 µm. Multi-mode optical fibre has a larger core diameter (for example, 50 µm or 62.5 µm) with the cladding of approximately 125 µm. Multi-mode fibre has higher loss compared to single-mode fibre. However, it is generally recommended for in building/intra campus use as it cost less than the single fibre. The latter has low loss characteristics and can carry higher speed to longer distances due to which it is mainly used in long haul applications. However, depending upon the size of the building/ campus or availability of various types of cables, combination of both types of cables or only single-mode cable may need to be used. Use of single-mode fibre has the advantage that future upgradation requirements are taken care of right in the beginning.

Optical fibre cables are available in various capacities in terms of number of fibres like 6 fibre, 12 fibre, 24 fibre, 48 fibre, 96 fibre, etc. Each fibre has a different colour which helps in easier identification during installation and operations. The colour scheme is repeated for every group of 12 fibres for higher fibre count cables. Selection of optical fibre cable size for different segments of cabling depends upon various factors.

The colour code chart for fibre optic cable is as under:

Fibre/Tube No.	*Colour*
1	Blue
2	Orange
3	Green
4	Brown
5	Gray
6	White
7	Red
8	Black
9	Yellow
10	Purple
11	Rose
12	Aqua

NOTE — The specifications of the certain types of optical fibre cables are available in Department of Telecommunications, Telecom Engineering Centre (TEC), Govt of India, the details of which can be seen from TEC website, www.tec.gov.in.

When it is decided to use optical fibre cable, choice is to be made from among variety of standard cables. There are two broad categories of cables namely OM (multi-mode optical fibre) and OS (single-mode optical fibre). The former is suitable for much shorter distances compared to the later as, data rate supported by cable is a function of cable length used. OM cables are preferred cables for campus applications as they are economical for short distances. OM cables are further sub-categorized into OM1, OM2, OM3 and OM4, which are differentiated based on data speed and distance combinations. Once the data speed and distance to be covered is decided, choice of cable category becomes simpler. When used inside the buildings, attenuation of signals is caused due to cable fibres facing sharp bends. Multi-mode cables show larger attenuation than single-mode cables on bends inside the building.

Considering that backbone cable carries the combined traffic of all work areas and the growth of data use with time, provision for future expansion should be provided. It is recommended that planning should be done for 10 Gbps and above speeds. Therefore, when using multi-mode cable, choice may need to be made typically from among OM3 and OM4 cables.

A chart showing typical length and data rate support characteristics of various cables is given below:

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Subsystem	*Backbone Lengths Up to*	*Data Rates Up to*
Campus backbones (OM1 fibre)	2 000 m	155 Mb/s
Campus backbones (OM2 fibre)	550 m	1 Gb/s
Building backbones (OM2 fibre)	300 m	1 Gb/s
Building backbones (OM3 fibre)	300 m	10 Gb/s
	100 m	100 Gb/s
Campus/building backbones (OM4 fibre)	550 m	10 Gb/s
	150 m	100 Gb/s
Campus/building backbones (OS fibre)	10 000 m	100 Gb/s

Enhanced versions of OM3/OM4 cables can also be examined for use. Once the cable category is selected, care should be taken that active equipment which feeds the fibre is equipped with the corresponding interface, to take care of, for example requirement of different optical power source and optical wavelengths for different types of cables.

3.2.4.3 *Coaxial cable*

The predominant coaxial cables are Series-6, Series-11, and radio grade (RG) 59. These coaxial cables have a characteristic impedance of 75 Ω. While the termination procedures may be similar, special attention shall be paid to the manufacturer's specific instructions for termination and connectors. The cables/ passive components used for DAS/IBS system should cover frequency range from 400 MHz to 2 300 MHz.

Coaxial cable is used for computer networks, CATV and video systems. Historically, coaxial cable was designated as RG cable. Coaxial cables used in broadband applications are available in the market with following constructional variations:

a) Centre conductor diameter;
b) Centre conductor being solid or stranded;
c) Dielectric composition;
d) Outer braid's percent of coverage; and
e) Impedance.

3.2.5 *Wireless Systems*

Wireless connectivity is also provided inside the building for enabling access to public mobile network or for enabling internet/intranet connectivity with flexibility of user terminal movement. Various wireless systems are described below:

a) *Wireless LAN (WLAN) access point (AP)* — A wireless LAN (WLAN) access point (AP) is a network device located in areas of a building or campus and placed in relatively close proximity to where users interact with their wireless enabled network devices. APs allow wireless enabled devices (for example, computer, printer) to connect through Wi-Fi or related standards. Wireless networks here can even include the networks of low voltage automation system in the building as well as M2M/IoT smart buildings/smart homes/smart offices. There are various wireless standards for M2M/IoT device connectivity. AP network devices are typically mounted on walls or ceilings with structured cabling that provides a physical connection to a HC (FD), which provides further connectivity to private/public network through the facility installed in TR/ TE.
b) *Wi-Fi access points (WAP) with centralized controller* — Access point shall support 802.11 a/b/g/n. There may be numbers of WAPs to cover area/building and in such situation user may prefer centralized controller. Centralized controller can be hardware or software based and depending upon number of WAPs may be provided at each ER/TR/TE. These access points can also be used for connecting the low voltage automation systems (building management system and other in-building system). The access points are connected to the network as described in (a).
c) *Distributed antenna systems (DAS)/In-building solutions (IBS)* — DAS/IBS are signal distribution systems for strengthening the public mobile wireless signal inside the buildings or installations. They require cable and passive antenna to be installed in corridors/rooms, normally along the centre line. The active equipment, wherever required can be installed in ER/TR/TE, on which cables to/from DAS/IBS are connected.
d) *Wireless repeater* — It takes an existing signal from a wireless router or wireless access point and rebroadcast it with amplified signal. It is also called wireless range extender. This is used to mitigate low signal issues.

While installing wireless devices, it is required to maintain enough spacing between them to avoid frequency overlap and interference by their own signal. The wireless coverage area radius is impacted by a number of factors including the following, and these factors are to be taken into account by using the site survey approach:

1) Building materials (concrete, sheetrock, wood, steel, etc);
2) Building configuration (closed, semi-closed or open space); and

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3) Building furnishings (cabinets, partitions, furniture, etc).

3.2.6 *Connecting Hardware*

The ends of cable terminating in work areas or on intermediate equipment like LAN switches, splitters, etc, need to be provided with connectors. There can be variety of equipment which may be connected to the cable ends. Hence a careful planning should be done to identify types of connectors with flexibility to connect variety of equipment keeping in view also the fact that the cable ends are permanently wired on to connector panels in the work areas. Details of the typical connecting hardware are given in Annex A.

3.3 Backbone Cabling Media Distribution and Building Pathways

The backbone distribution system provides interconnection between telecom spaces, that is, telecommunication rooms, equipment rooms and entrance facilities. It consists of the backbone cables, intermediate and main cross-connects, mechanical terminations and patch cords or jumpers used for backbone-to-backbone cross-connection. This includes,

a) vertical cable connections between floors (risers);
b) cables between an equipment room and building cable entrance facilities; and
c) cables between buildings (inter building).

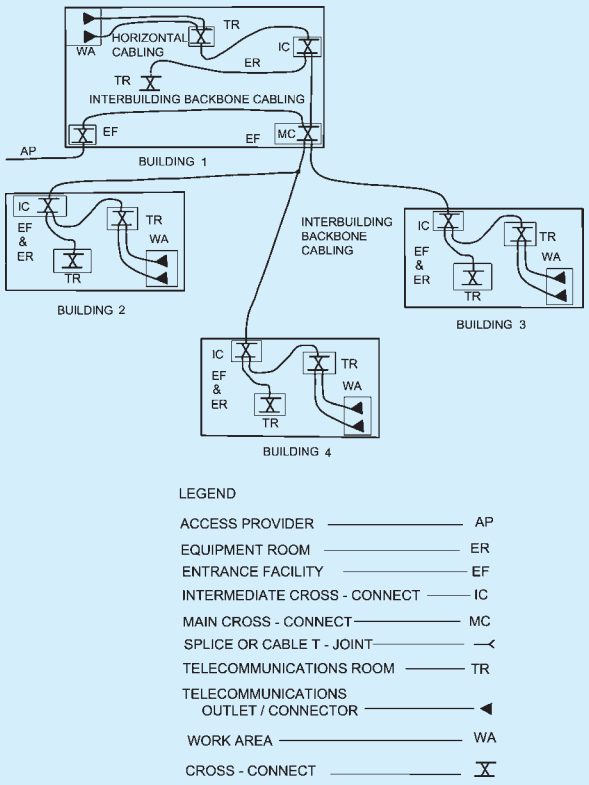
The elements of the telecommunications cabling system structure are:

1) Horizontal cabling,
2) Backbone cabling,
3) Work area,
4) Telecommunications rooms,
5) Equipment rooms, and
6) Entrance facilities.

Figure 1 illustrates a representative model for the various functional elements that comprise a building campus/complex telecommunications cabling system. It depicts the relationship between the elements and how they are configured to create a total system.

3.3.1 *Backbone Cabling and Topologies*

Cabling between the building cross-connect (main or intermediate) and the horizontal cabling (floor distribution) [HC (FD)] is designated as backbone cabling. In a multi-building complex, inter-building cabling, though terminating in the EF, is designated as inter-building backbone cabling. The cable(s) can be of any type, for example, copper pair, optical fibre or coaxial.



NOTES

1 This figure is not meant to be an all-inclusive representation of the telecommunications cabling system and is provided only as a typical example.

2 All cross-connects located in the telecommunications rooms (TRs) in this figure are horizontal cross-connects (HCs).

FIG. 1 TYPICAL TELECOMMUNICATIONS CABLING SYSTEM

3.3.1.1 The two primary options for connectivity are:

a) Star topology, where the HC (FD) is connected directly to the main cross-connect (campus distributor) [MC (CD)] which is further connected to inter building backbone, where applicable.
b) Hierarchical star topology, where some or all of the HCs (FDs) are connected to an intermediate cross-connect (building distributor) [IC (BD)], which in turn, is connected to the MC (CD).

3.3.1.2 The best design is the star design between the building MC and the HCs. However, in some extremely large buildings (for example, high-rises), a hierarchical star may be an option for consideration. The trade-offs between different cable sizes and labour cost is to be considered to determine a suitable cost effective solution. The direct connections between HCs are generally avoided. Although this kind of connectivity might be of value in providing a redundant path, a user should design a link from HC to HC only in specific

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applications. The best design is the star design between the building MC and the HCs.

3.3.1.3 A typical star configuration in a building with MC (CD) or HC (FD) is given Fig. 2.

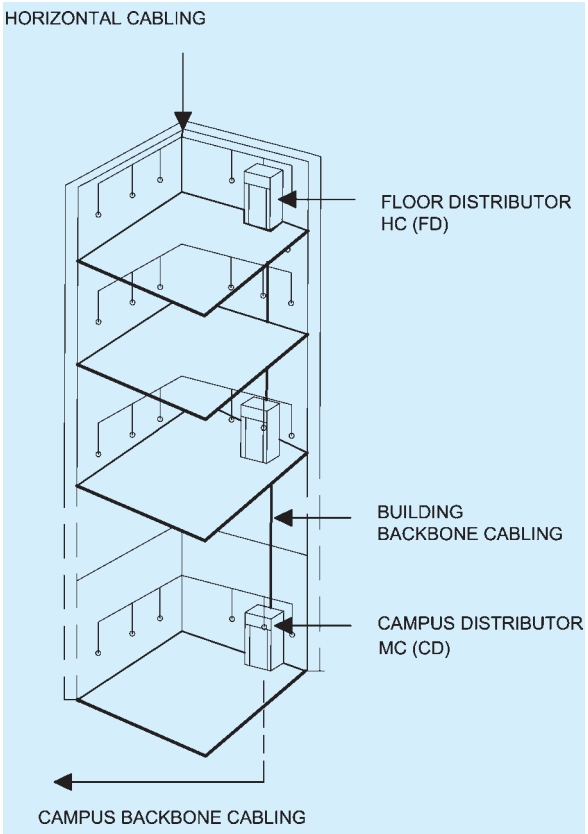
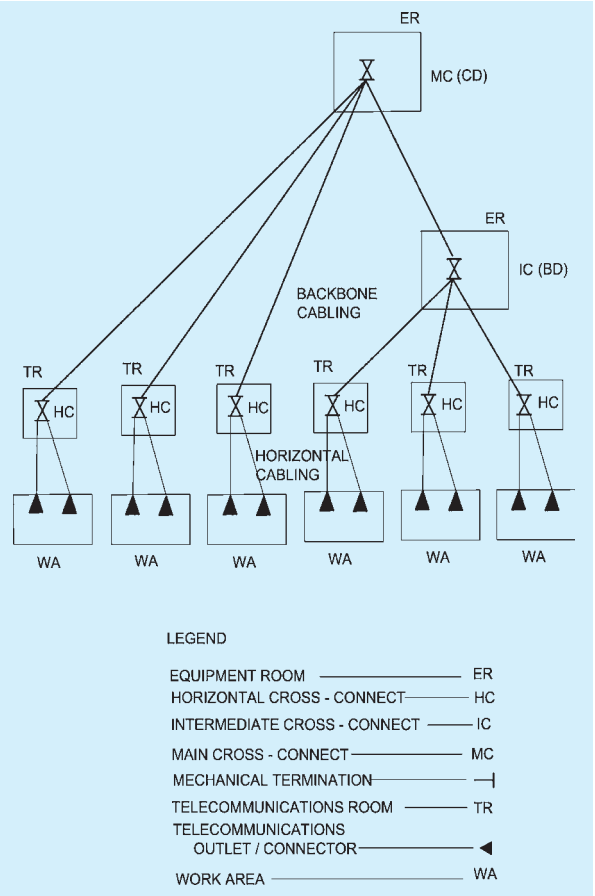


FIG. 2 TYPICAL CABLING STAR CONFIGURATION IN A BUILDING



NOTES

1 Backbone cabling covers intra and inter building cabling.

2 IC is a cross-connect for in building cabling.

FIG. 3 EXAMPLE OF BACKBONE HIERARCHICAL STAR TOPOLOGY

3.3.1.4 An example of backbone hierarchical star topology with addition of IC (BD) is shown in Fig. 3.

3.3.2 *Inter-Building Pathways*

In a campus environment, inter-building pathways are required to connect separate buildings. For this, underground, buried, aerial and tunnel are the main pathway types used. As the complexes have varying conditions of land features and locations, size and use of building, choice if any or combination of the pathways need to be made based on local requirements. The cable running over the pathways generally terminates at the entrance facility of the building at both ends.

3.3.2.1 *Underground inter-building backbone pathways*

The pathway shall be fully covered and the cabling shall be installed within protective conduit or ducting for the entire external section of the cable route in all inter-building pathways. Provision should be made for existing as well as future demand. Underground pathways consist of conduit, ducts and troughs; possibly including manholes. The manhole can be planned normally, if

a) the cable requires joint;
b) the distribution of copper/fibre pair is required midway; or
c) numbers of bends in the path are more than two.

Each manhole should be dimensioned to accommodate spare cable of 2 m to 4 m length in each direction, which is generally kept in spare loop to take care of maintenance needs. All conduit and duct shall have a diameter of at least 100 mm. Bends are not recommended; however, if required, there should be not more than two 90° bends.

In a multi-building and multi-operator campus, an Underground Cable Vault (UCV) may be considered close to entrance facility. Manholes/pull holes may also

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be provided for O and M activity in the outside plant pathway system for the pulling, placing, and splicing of cables. Size of UCV, manholes and pull holes should be decided based on the pathway capacity, number and types of cables, etc. All such points should be covered with properly marked iron covers of appropriate thickness and structural support below them keeping in view the load they are expected to bear due to pedestrian or vehicle movement.

In the planning for underground cabling, the following shall be considered:

1) Limitations dictated by the topology (this includes land development);
2) Grading of the underground pathway to permit proper drainage;
3) Need to vent gaseous vapours; and
4) Amount of vehicle traffic to determine the amount of cover over the pathway and whether or not concrete encasement is required.

3.3.2.2 *Direct buried inter-building backbone pathways*

In this case, the telecommunications cables are completely covered in earth. Direct burial of telecommunications cables is achieved by trenching, augering or boring (pipe-pushing). When selecting a route for the pathway, it is important to consider the landscaping, fencing, trees, paved areas and other possible services. Direct burial has the challenges of cable repair in case of faults and also in future upgradation.

3.3.2.3 *Aerial inter-building backbone pathways*

An aerial pathway consists of poles, cable-support strand and support system. Some considerations to make when using aerial backbone include the following:

a) Appearance of the building and surrounding areas;
b) Separation and clearances for electrical installations and roads;
c) Span length, building attachments, storm loading and mechanical protection; and
d) Initial number of cables and future growth potential.

3.3.2.4 *Tunnel inter-building backbone pathways*

Tunnels provide pathways for conduit, trays, wire-ways or support strand. Normally tunnels support other building services too. Hence, the location of telecom pathways within a tunnel should be planned to allow for accessibility as well as for separation from other services. In general, tunnelling inside the premises for telecom services alone may not be cost effective.

3.3.3 *Backbone Building Pathways*

Backbone building pathways can be built in various ways depending upon the building layout, locations of TR/TE, etc. While designing and implementing such pathways, certain requirements need to be met and precaution taken. Typical topologies and requirements/ precautions relating to these are described below:

a) *Vertically pathway topology* — Vertically aligned TRs with connecting sleeves or slots are the most common type of backbone pathway though it is not a necessary condition. Vertical alignment is desirable because the building planner can stack them with other mechanical spaces, and it makes distribution of telecom cables more efficient because of shorter conduits and cabling runs.

   If the TRs/TEs are not aligned vertically above one another, the conduits interconnecting them will have horizontal offsets. There shall be not more than two 90° bends in any such conduit run. Any bend shall have an inside radius 10 times the diameter of the conduit (typically 1 m). If these conditions cannot be met, then intermediate pull boxes shall be used wherever a non-standard transition is required. This pull box shall be at least 600 mm × 600 mm in the plane of the attached conduits, and 150 mm deep. All conduits other than simple sleeves between floors shall be fitted with a continuous 1.5 mm nylon pull rope, or a 0.6 mm steel fish wire or a 0.5 mm fibre composite fish wire.

b) *Conduits, trays, slots, sleeves, and ducts* — All rigid metallic conduit pipes shall be of steel and shall be conforming to accepted standard [8-6(1)]. The wall thickness of the pipe shall be not less than 1.6 mm (16 SWG) for conduits up to 32 mm diameter and not less than 2 mm (14 SWG) for conduits above 32 mm diameter. These shall be solid drawn or reamed by welding, and finished with galvanized or stove enamelled surface.

   All non-metallic conduit pipes and accessories shall be of suitable material complying with the accepted standards [8-6(2)] for rigid conduits, and accepted standards [8-6(3)] for flexible conduits. Such pipes shall not be exposed.

   The vertical backbone pathway consists of telecommunications rooms located on each floor, tied together by sleeves or slots. In this context, the term ‘sleeve’ refers to a circular opening in a wall, ceiling or floor to permit the passage of cables between adjacent spaces.

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A 'slot' is the same as a 'sleeve', except that the shape of the opening is usually rectangular. The cable sleeves or slots are positioned adjacent to a wall on which the backbone cables can be supported. The recommendation in respect of slots and sleeves are as under:

1) Slots with a minimum 25 mm high curb.
2) Sleeves to extend a minimum of 25 mm above the floor level and a maximum of 77 mm above the floor level. Sleeves should be located at a minimum of 25 mm from the wall or between adjacent sleeves to provide room for bushings, but not so far from the wall that it becomes a tripping hazard or create too large a cable span from the sleeve to the backboard/tray.

c) *Riser systems* — For connectivity to TR/TE on upper floors from the building EF, conduit or raceway should preferably be provided vertically. Vertically mounted ladder rack shall be mounted on the wall between incoming and outgoing sleeves within the TR/TE. The ladder rack should be used to provide strain-relief for cables transiting TR/TE within the riser system. If the building plan is large enough to require a second communications TR/TE on one or more floors, then the riser pathway should preferably be duplicated from the EF up to second set of TR/TE.

d) *Vertical pathway size* — A minimum of three 100 mm diameter conduits, or equivalent raceway cross section, should be provided between the TR/TE on adjacent floors and between the EF and the first floor TR/TE.

e) *Access to the roof* — For installations like antenna, powering the roof top/tower top equipment, access shall be provided through suitable number of conduits. This connectivity from the roof should be seepage and rodent proof. A minimum of two 75 mm and one 20 mm conduit shall extend from the topmost TR/TE to the roof terminated in a weatherproof metal enclosure. Sometimes, it may not be feasible or desirable to have direct vertical access, thus requiring horizontal extension from the rooms before vertical extension, the user may keep this in view for taking action with respect to architectural considerations.

f) *Pathway finish details* — Conduit shall be free of burrs or sharp edges. Sheet metal sleeves, if used, shall have rolled edges. Conduits or sleeves shall protrude at least 25 mm from the surface they penetrate but not more than 75 mm. Conduits shall be fitted with a smooth bushing.

g) *Fire protection of shafts* — All penetrations shall be filled with fire resistant material. Fire compartment plan and integrity of compartment should be maintained by either blocking permanently or by recognized systems automatically responding to temperature increase.

h) *Open cable shafts* — Open cable shafts should be used when available and where large quantities of cables are required on a floor that is distant from the main ER. Backbone cable pathways shall not be located in elevator shafts.

j) *Enclosed metallic raceways or conduits* — Enclosed metallic raceways or conduits are also used as vertical and horizontal cable pathways. It should be bonded to form a common bonding network.

k) *Cable trays* — A cable tray can be used as a vertical cable pathway within shafts or as part of the pathway between vertically aligned TRs. A cable tray can be open or covered and provides a means for attaching vertical cable runs to the cable tray members. The cable tray can also accommodate ethernet LAN cables running from building management system and other low voltage automation system in the building.

3.3.4 *Ethernet in the First Mile (EFM)*

Ethernet in the first mile (EFM), also known as ethernet to the last mile, describes the access network from the access point to the subscriber's premise. The first mile is the critical connection from business and residential users to the public and the public network.

Ethernet is the dominant mode of digital connectivity to user computers and other devices. Local Area Network (LAN) connectivity is extended to the end user computers through ethernet cable and connector. Ethernet cables generally used are Cat 5e and Cat 6. However, higher categories of cables are available (Cat 7 and Cat 8), which supports data rates of 10 Gbps and 40 Gbps. In many implementations, backbone and horizontal cabling may be on optical fibre. Such implementations address the Cat 5e/Cat 6 cable length limitations as only the last drop from TR/TE to the work area will use Cat 5e/ Cat 6 cable.

However, in many large buildings, optical to ethernet converters/switches may be required to be installed beyond TR/TE also, which may be installed in safe places in corridors false ceiling, work area, etc, where provision for supply of power should also be made. This holds true for Cat 5e/Cat 6 backbone and/or horizontal cabling also. Cabling to work area may be

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through conduits inside the wall or conduits on open surfaces. In cases where multiple tenants want to set up their own LAN, they may set up their system and horizontal cabling. However, they should preferably use backbone cabling of the building to reach EF for further connectivity to a telecom service provider for internet/leased bandwidth, etc.

3.4 Horizontal Cabling Media Distribution and Building Pathways

A horizontal distribution system consists of the horizontal cabling, the horizontal pathways supporting the horizontal cabling, and the telecom spaces that support the horizontal pathways. As horizontal distribution systems, cabling, and pathways often change direction, elevation, or physical orientation to accommodate obstructions, barriers, and other building systems, the use of the term horizontal in the name of the element does not require that the elements be placed or installed parallel to the ground or floor.

3.4.1 *Horizontal Cabling Systems*

3.4.1.1 The horizontal cabling is the portion of the telecommunications cabling system that extends from the work area telecommunications outlet/connector to the horizontal cross-connect in the telecommunications room (TR). The horizontal cabling includes horizontal cables, telecommunications outlet/connectors in the work area, mechanical terminations, and patch cords or jumpers located in the telecommunications room, and may include multi-user telecommunications outlet assemblies and consolidation points.

The following media types can be considered as options for horizontal cabling:

a) Four-pair 100 Ω unshielded twisted-pair (UTP) or screened twisted-pair (ScTP) cables with a distance limit of 90 m taking care of 10 m patch cord/jumper cable required for work area.

b) In case of optical fibre, OM cable normally of grade lower than or equal to the backbone cable may be selected. Such limitation is not faced if OS or appropriate ITU-T standard single-mode cables as mentioned in **3.2.4.2** are used. Distance limits with respect to data rate to be supported on horizontal cabling system may be seen from table under **3.2.4.2**. Care should be taken that the equipment for corresponding fibre interface is selected.

While laying cables, maximum recommended length of cable by including provision for jumper cables/patch cords in TR and extension in work area should be kept in view.

3.4.2 The requirements for horizontal pathways, measures for avoiding electromagnetic interference in the design of cabling pathways are described in **3.4.2.1** and **3.4.2.2**.

3.4.2.1 *Horizontal pathways*

Horizontal pathways are used for distributing, supporting, and providing access to horizontal cabling and telecom associated connecting hardware between the telecom outlets/connectors and the HC, typically located in the ER, TR or TE. Horizontal cabling is contained within horizontal pathways. Generally, the horizontal pathways are one of two types:

a) Continuous pathways (for example, conduit, cable tray, cable matting) used for containment of telecom cabling.

b) Non-continuous pathways (for example, the space between cable supports such as J-hooks) through which cables are placed between physical supports or containment components.

A pathway component should be designed to accommodate all standards compliant cabling and address the potential need for change and expansion during the life cycle of the cabling system and building. The emphasis should be first on the design of pathway systems and then on the cabling systems design. This approach helps to ensure a robust pathway system that supports the cabling installation over the facility's life cycle. As frequently accessing or changing the horizontal cabling leads to disruption to occupants, the choice and layout of horizontal cabling types are important to the design of the building structured cabling system. The following should be considered for the horizontal distribution system's design:

1) Allow for the accommodation of change over the facility's life cycle with the goal of reducing long-term maintenance and operational costs.
2) Utilize standardized cabling, components and systems.
3) Include appropriate pathway and cabling components to accommodate ease of access and a variety of user specified technology applications.

The horizontal cabling system should be designed in order to support various telecom applications, including,

i) voice services;
ii) data services;
iii) audio and video services; and
iv) building signalling systems [for example, smart building ICT systems, building

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automation systems (BAS), and fire safety and security systems].

It is preferable to have provision for conduits, junction box, etc, during planning and construction stage for providing radio/wireless data equipment at the centre line of rooms and corridors to avoid unplanned provisions later on.

3.4.2.2 *Avoiding electromagnetic interference (EMI)*

Avoiding electromagnetic interference (EMI) is an important consideration in the design of cabling pathways. Providing physical separation from sources of EMI for these elements of the telecom infrastructure inherently provides separation of their contents (for example, cable and connecting hardware).

The telecom pathways should be located away from sources of EMI to the extent feasible, including,

a) electrical power cabling and transformers;
b) rf sources;
c) large motors and generators;
d) induction heaters;
e) arc welders;
f) X-ray equipment; and
g) photocopy equipment.

3.4.2.3 *Topology*

Horizontal cabling should be installed in a physical star topology. Each telecom outlet/connector should be cabled directly to an HC (FD) in the appropriate telecom space. Exceptions to this practice are possible, when,

a) a consolidation point (CP) or multi-user telecommunications outlet assembly (MUTOA) is used to connect the open office cabling;
b) a transition point (TP) is required the connect to under-carpet cabling; or
c) centralized optical fibre cabling is implemented from main cross-connect (campus distributor) [MC (CD)] to the work area(s).

Some applications may utilize a bus, ring, or tree topology, which can be implemented within a physical star topology. However, in case of large number of work areas, ring or tree topology may require intermediate distribution points like MUTOA, etc. Typical horizontal and work area cabling using a star topology is shown in Fig. 4.

3.4.2.4 *Work areas and open office cabling*

3.4.2.4.1 The work area includes those spaces in a building where occupants normally work and interact

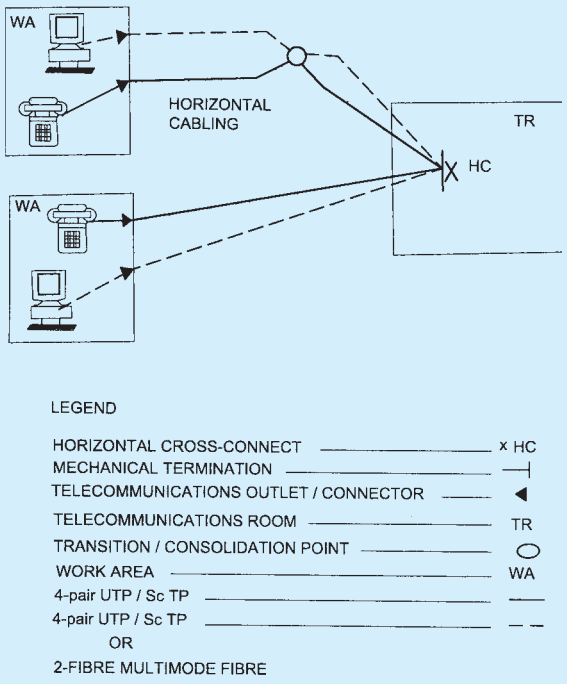


FIG. 4 TYPICAL HORIZONTAL AND WORK AREA CABLING USING A STAR TOPOLOGY

with their ICT equipment. While work areas have traditionally been fixed, discrete locations, open office cabling design practices have introduced flexible layouts to support collaborative work by small teams. Such spaces are often rearranged to meet changing requirements of group work. Many other open office work situations also require frequent reconfiguration. An interconnection in the horizontal cabling allows open office spaces to be reconfigured frequently without disturbing horizontal system cabling runs. Work area equipment that may require access to the horizontal cabling includes,

a) telephones;
b) networking equipment;
c) fax machines;
d) computers;
e) network peripherals; and
f) any device plugged into a telecom outlet/ connector that is located within the work area.

3.4.2.4.2 The key elements of open office cabling are the MUTOA and CP. To accommodate equipment in the work area, following components are typically used as needed:

a) Telecom outlet/connector.
b) Work area equipment cords.
c) MUTOAs and CPs.
d) WAPs.

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Some of these components and requirements or recommendations relating to them are described below:

1) *Multi-user telecom outlet assembly (MUTOA)* — The MUTOA serves as a method of connecting more than one user (work area) to the horizontal cabling system. MUTOAs may be advantageous in open office spaces that are moved or reconfigured frequently. A MUTOA facilitates the termination of horizontal cabling system cables in a common location within a furniture cluster or similar open area. The use of MUTOAs allows the horizontal cabling to remain unchanged when the open office plan is changed. Work area equipment cords originating from the MUTOA should be routed through work area pathways (for example, furniture pathways). Each furniture cluster should have one MUTOA which may typically serve 12 work spaces. The work area equipment cords shall be connected directly to work area equipment without any additional connections. For copper cables, any combination of horizontal, work area cables and equipment cords may not exceed 100 m. The work area cables shall be connected directly to work station equipment without the use of any additional intermediate connections (*see* Fig. 5).

2) *Consolidation point (CP)* — The consolidation point (CP) is an interconnection point within the horizontal cabling system. Like the MUTOA, a CP may be used for balanced twisted-pair cabling or optical fibre cabling. The functional difference between the CP and the MUTOA in the open office environment is that the CP introduces an additional connection for each horizontal cabling run. A CP may be useful when reconfiguration is not so frequent as to require the flexibility of the MUTOA. The CP may be located in the suspended ceilings, access floors, modular office furniture or work area. Further CPs may serve a zone consisting of number of work areas even in different rooms.

Some additional considerations and guidelines that apply specifically to the CP are as under:

i) Cross-connections should not be used at a CP. Not more than one CP should be used within the same horizontal system cable run so as to avoid additional points of failure. Depending upon the size and number of the cables, there can be a single CP for all cables or separate CPs for different sets of cables.

ii) For balanced twisted-pair cabling, the CP should be located at least 15 m from the HC (FD) in order to reduce the effect of Near End Cross Talk (NEXT) and return loss from multiple connections in close proximity.

iii) CPs shall be located in fully accessible and permanent locations. CPs shall not be located in an obstructed area.

iv) The CP should be sized and cabled so that it meets the telecom requirements of the zone it serves. If the floor space requirements change for an existing CP, then the CP should be reconfigured to accommodate the new requirements (*see* Fig. 6).

3.4.2.5 *Centralized optical fibre cabling (fibre to the desk)*

The HCs (FD), deployed throughout a building and located on each floor of a building, offers maximum flexibility to the user, especially in the deployment of distributed electronics or in multi-tenant buildings. In spite of the advantages of distributed cross-connections, some users may prefer data networks with centralized electronics which requires centralized cabling to provide connections from the work areas to the centralized cross-connect. Any of the following methods can be used for cabling:

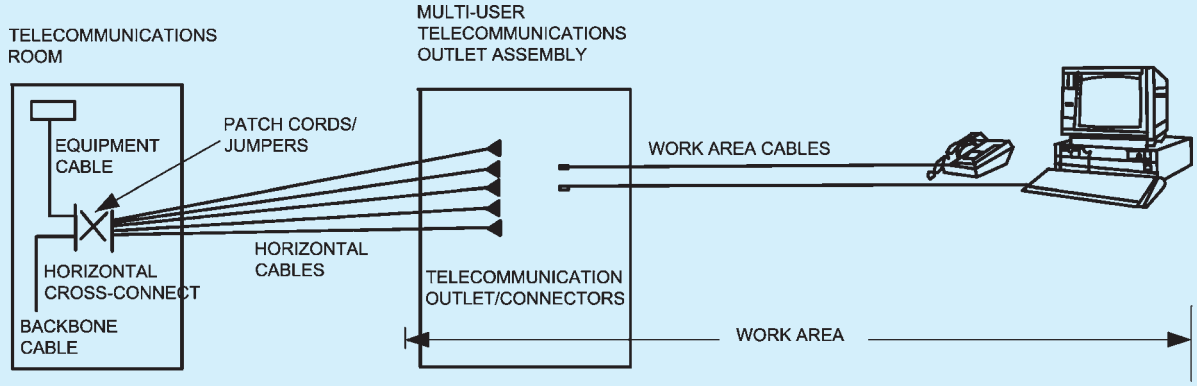


FIG. 5 APPLICATION OF MULTI-USER TELECOMMUNICATIONS OUTLET ASSEMBLY

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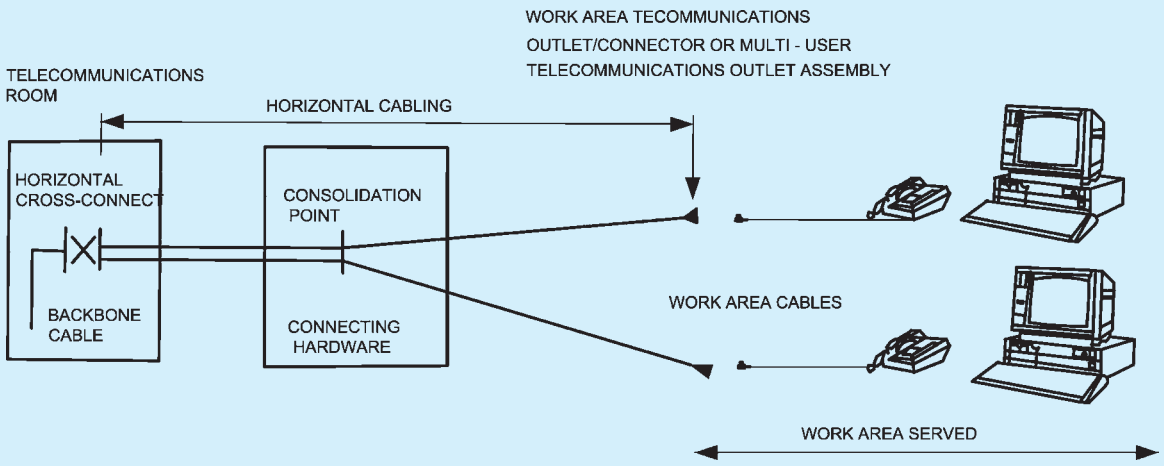


FIG. 6 APPLICATION OF CONSOLIDATION POINT

a) Pull-through cabling from the centralized cross-connection;
b) Interconnection cabling in a floor-serving telecom space; and
c) Spliced cabling in a floor-serving telecom space.

However, flexibility for rearrangement of work areas and need for additional work areas in future by the user should be kept in view while adopting any of the above methods.

4 SPECIFIC REQUIREMENTS FOR TELECOM INFRASTRUCTURE CABLING

4.1 Telecommunications Bonding and Grounding

The bonding and grounding (earthing) infrastructure of a telecom installation is an essential part of an information technology systems (ICT) design. Grounding systems are an integral part of the signal or telecommunications cabling system that they support. In addition to helping protect personnel and equipment from hazardous voltages, a proper grounding system may reduce electromagnetic interference (EMI) to and from the telecommunications cabling system. Improper grounding can produce induced voltages and those voltages can disrupt other telecommunications circuits. Grounding and bonding shall meet the appropriate requirements and practices of applicable standards.

The overall purpose for the ICTs bonding infrastructure is to equalize potentials between metallic surfaces predominantly in the event of lightning, a.c. electrical system faults, electromagnetic induction, or electrostatic discharge.

The Telecommunication Main Grounding Bus Bar (TMGB) serves as the dedicated extension of the building a.c. grounding (earthing) electrode system for the ICTs infrastructure. It serves as the central attachment point for the Telecom Bonding Backbone (TBB). A Telecom Grounding Bus Bar (TGB) is the grounding (earthing) connection point for ICTs infrastructure systems (for example, cabling, pathways) and ICTs equipment in the area served by an ER or TR. The TMGB and TGB should be a pre-drilled copper bus bar with holes for use with standard-sized lugs. A TBB is a ICTs bonding conductor to connect equipment/TRs/TEs on multiple floors of a building with an ultimate connection to the TMGB. Typical telecommunication grounding and bonding arrangement is shown in Fig. 7.

TMGB is recommended for minimum dimensions of 6.35 mm (¼ inch) thick, 101.6 mm (4 inch) wide and variable in length. The TBB dimensions are as under:

TBB Length Linear m	*TBB Size AWG*
Less than 4	6 (13.29)
4 to 6	4 (21.14)
6 to 8	3 (26.65)
8 to 10	2 (33.61)
10 to 13	1 (42.39)
13 to 16	1/0 (53.46)
16 to 20	2/0 (67.40)
Greater than 20	3/0 (84.97)

NOTE — The figures given in parentheses are in mm^2.

4.2 Installation and Workplace Safety

4.2.1 *Cabling Installation Guidelines*

The installation of system components has a tremendous effect on the final performance level of the network; therefore, it is essential to ensure that the performance of the entire network is not diminished through improper installation. The cables can be easily

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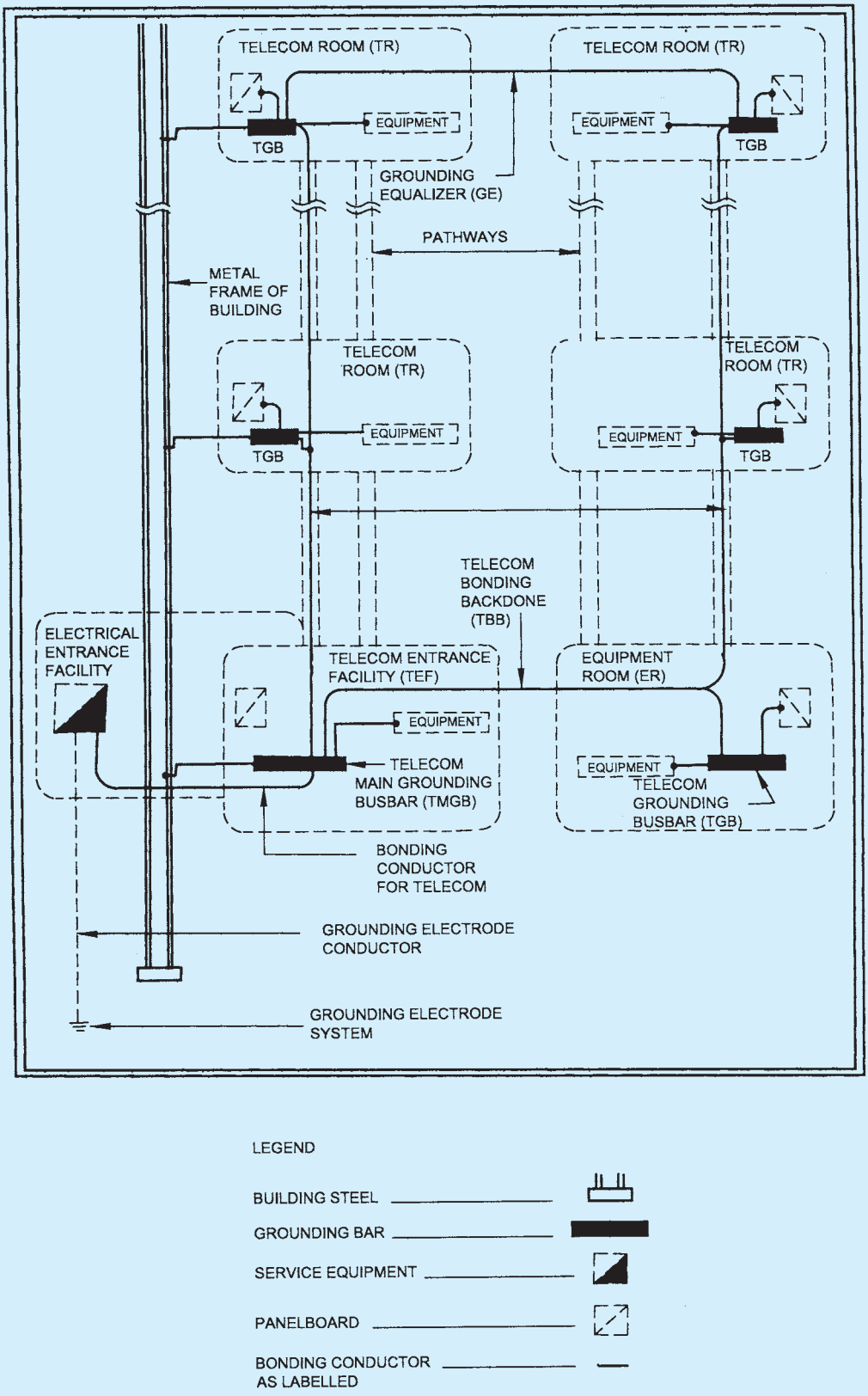


FIG. 7 TYPICAL TELECOMMUNICATION GROUNDING AND BONDING ARRANGEMENT

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damaged if they are improperly handled or installed. It is imperative that certain procedures be followed in the handling of these cables to avoid damage and/or limiting their usefulness.

Care shall be taken not to stretch or abrade cables during installation, that is, the pulling tension for cables shall not be exceeded. Cables that pass through the infrastructure of the building shall be suitably protected against damage. Through walls and floors, this shall involve an appropriate type of sleeve; through any form of metalwork or stiff plastic then a rubber grommet shall be used.

To ensure cable management and also strain relief, cables shall be properly dressed using velcro cable ties. However, cable's ties should never be over tightened. On vertical runs, the cables shall be dressed and tied from the bottom up, thus putting minimum strain on the cables. In order that the system may be easily re-routed, or damaged sections quickly replaced, free access to the cable should be ensured and where possible, it is important to leave draw cords in ducting, piping etc, for future use.

4.2.1.1 *Improvement areas*

a) *Do not exceed the maximum tensile load* — On runs from 40 m to 100 m, use proper lubricants and make sure they are compatible with the cable jacket. On runs over 100 m, use proper lubricants and pull from the middle out to both ends. If possible, use an automated puller with tension control or at least a breakaway-pulling eye.

b) *Maintaining minimum bending radius* — Sharp bends in the cable may damage the insulating material, thus causing unacceptable losses in the transmission medium. Therefore, the internal radius of every bend in a cable shall be such as not to cause damage to the cable, nor impair the characteristics of the cable.

c) *Proper cable slack at outlet points and patch panels* — Install the system such that sufficient slack remains to enable re-termination of the outlets, a minimum of twice, and a limited scope for movement of the cabinets.

d) *Patch panels and cable management* — Where possible, patch panels shall be installed within the communications units from the top, continuing downwards.

e) *Electromagnetic compatibility (EMC)* — As a passive medium, structured cabling need not comply with the EMC regulations. However, telecom designers should be aware that cabling, when connected to transmission equipment, could radiate, receive and conduct electromagnetic disturbances and act accordingly. When crossing mains cables, this shall be done at right angles.

f) *Maintaining proper cable routes* — Cable shall not be routed over pipes, conduits, other cabling, ceiling tiles, etc, but shall rest directly on the supporting surface so as to minimize the potential for sharp bends, kinks, etc. Every cable used shall be supported in such a way that it is not exposed to undue mechanical strain so that there is no appreciable mechanical strain on the terminations.

g) *Labelling* — The cable shall be clearly labelled at both ends, as outlined in the documentation and/or drawing. Each 8P8C connector (information outlet) shall be individually labelled. The label shall contain a unique identification, as outlined in the documentation and/or drawing, and shall be indelible and placed behind a transparent cover. At the patch panels, each socket shall be labelled according to its corresponding outlet identification.

4.2.2 *Workplace Safety*

Following measures shall be ensured for workplace safety:

a) To maintain work place safety, personal protective equipment (PPE) like protective clothing, helmets and goggles should be used to protect the personnel from injury or infection from hazards such as physical, electrical, heat, chemical and biohazards.

b) Lighting in telecom spaces shall be provided in an adequate amount such that continuing work operations, routine observations, and the passage of employees can be carried out in a safe and healthful manner. Certain specific tasks in centres, such as splicing cable and the maintenance and repair of equipment frame line-ups, may require a higher level of illumination and adequate provisioning should be provided for the purpose.

c) While working with optical fibre installation, the real issue of eye safety is getting fibre scraps into the eye. The broken ends of fibres and scraps of fibre created during the termination and splicing may also be dangerous. Therefore, protective eyewear such as safety glasses should be worn by personnel while carrying out splicing and termination operations. Further, fibre optic splicing and termination use various chemical cleaners and adhesives as part of the processes. Therefore, careful handling

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of fibre, cleaner and adhesive shall be ensured by the use of safety gloves and respiratory masks.

5 OTHER APPLICATIONS IN TELECOM INFRASTRUCTURE CABLING

5.1 Electronic Access Control (EAC)

EAC is important for overall personal safety and the protection of physical and intellectual property. EAC devices can include locks, integrated electronic devices controlling a single door or room, or a complex system of interconnected electronic devices controlling a zone, building, or campus. Access to private or secured spaces can be controlled in a great variety of methods. In addition, the user often has multiple levels of access required within a space. Personnel may have access to any given number of these. This access level may be required to change during the course of the day, week, or month. In contrast to a lock-and-key system, a modern computer-supported control system can meet these and many other user goals. This system employs programmable EAC. Time-of-day and day-of-the-week access levels can be applied to all personnel who have authorized entry. Additional precautions should be taken against weaknesses in the EAC system (for example, piggybacking, tailgating, unauthorized entry). A great number of possibilities exist from the passive card to biometrics and any combination in between. A user may issue smart cards.

A typical EAC cable consists of four individually shielded pairs that are used for the door strike, card reader, door contact, and request for exit. The four individual wire pairs may be supplied individually or in a group. Coloured foil shields or jacket colours may be used to designate the intended purpose of each of the wire pairs within the cables.

In a shared communication environment, the EAC data travels along with other building systems and data networks packets on the same physical network. This is often accomplished through an ethernet connection. It may also use building automation networks. Another media for shared communication relies on a private branch exchange and local analog telephone line. *See* Annex A for details.

5.2 Video Surveillance

Video surveillance is the extension of human vision to areas requiring surveillance. Some primary applications of this technology include investigation, prosecution, deterrence, observation and intrusion detection. In addition to traditional capture devices that operate within the visible band of the electromagnetic spectrum, other technologies provide unique viewing capabilities using IR, thermal and film cameras. *See* Annex A for details.

ANNEX A

(*Clauses* 3.2.4, 3.2.4.1, 3.2.6, 5.1 *and* 5.2)

ADDITIONAL GUIDELINES FOR INFORMATION AND COMMUNICATION ENABLED INSTALLATIONS

A-1 GENERAL

This annex contains information which supplements the text of this Section. The information can be used to make decisions while exercising options from among various types of hardware, cables, etc, and also for guidance.

A-2 CONNECTORS AND CONNECTING HARDWARE

Various types of connecting hardware may be as described below.

A-2.1 Balanced Copper Twisted-Pair Connectors

a) *Insulation displacement contact (IDC) connectors* — The insulation displacement contact (IDC) is a gas-tight physical contact between two electrical conductors. The gas-tight contact is established by a cold weld with the elimination of the air gap between the conductor and the IDC and therefore the possibility of contact interface corrosion. Such contact creates a reliable, long-lasting connection with stable electrical properties. IDC connectors also eliminate conductor preparation (for example, insulation removal), reducing the termination time and the number of tools.

b) *Modular plug* — Modular plugs have IDC contacts designed for either stranded or solid conductors as well as connectors having universal contacts that accept both stranded and solid conductors. Materials used to build

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modular plugs are typically flame retardant polycarbonate (body) and phosphor bronze with gold plating over nickel in contact area (contacts).

c) *Modular jack* — Modular jacks are available in various sizes and shapes (keyed and unkeyed). The number of positions indicates the connector's width, while the number of contacts installed into the available positions indicates the maximum number of conductors the connector can terminate.

A-2.2 Optical Fibre Connectors

The most common optical fibre interfaces include,

a) *LC connector* — It is a simplex connector that can be converted to a duplex using a clip. It is keyed, low-loss, pull-proof and wiggle-proof. It can be terminated in many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp, and hot melt. This is often referred to as a small form factor (SFF) connector. The LC connector provides a pull-proof design and small size perfect for high-density applications. It is available in simplex or duplex versions. The LC connector is provided with a 1.25 mm ferrule. It also incorporates a unique latching mechanism providing stability in system rack mounts.

b) *Subscriber connector (SC)* — It is a simplex connector that can be converted to a duplex using a clip. It is keyed, low-loss, pull-proof, and wiggle-proof. It can be terminated in many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp, and hot melt. The SC connector is a snap-in connector that latches with a simple push-pull motion, with a 2.5 mm ferrule and is widely used for its excellent performance. It is also available in a duplex configuration.

c) *Straight tip (ST) compatible* — It is a simplex connector. It is a keyed, low loss connector. It can be terminated many different ways, including using anaerobic (quick cure) adhesive, cleave and crimp and hot melt.

d) *Splices (Optical fibre connectors)* — These are used for adding optical fibre cable lengths. There are two primary splicing methods for optical fibres, fusion and mechanical. Both methods are field proven and have excellent long-term reliability when completed according to the manufacturer's instructions. Splices and stripped optical fibre cables are protected and secured by a splice enclosure. When a splice enclosure is used for splicing inside a building, it is generally secured to a rack or wall. In both cases, the splice enclosure contains the optical fibre splices in splice trays or organizers, typically in groups of 6, 12, 24, or more optical fibres per splice tray or organizer.

A-2.3 Coaxial Connectors

Connectors are installed on the end of a coaxial cable to provide electrical and mechanical connection to a system component. Either male or female connectors can be attached to coaxial cable, but most installations use male connectors on cable ends.

There are many styles of coaxial cable connectors. Three popular styles are:

a) BNC-style connector,
b) F-style connector, and
c) N-style connector.

A-2.4 Connecting Hardware

Cables are terminated in outlets in work areas or intermediate equipment through connecting hardware. Basic connecting hardware styles are:

a) Telecom outlets/connectors, including multiuser outlets;
b) Patch panels;
c) Connecting (wiring) blocks;
d) Cable assemblies;
e) Optical distribution frames; and
f) Splices.

To facilitate their installation, servicing, administration and maintenance, connecting hardware of different styles of connectors may be considered to be grouped in one unit. However, depending upon the given situation, one or more type of connecting hardware (copper pair, coaxial or optical) may be installed on separate panels/frames.

A-3 CLASSIFICATION OF CABLES BY FIRE SAFETY PROPERTIES

A-3.1 Twisted Pair Cables

Different communication cable types and their markings on cable sheath are as given below:

Marking	*Cable Type*
CMP	Communications plenum cable
CMR	Communications riser cable
CMG/CM	Communications general-purpose cable
CMX	Communications cable, limited use
CMUC	Under carpet communications wire and cable

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A-3.1.1 *Type CMP (Communications Plenum Cable)*

Type CMP communications plenum cables are suitable for use in ducts and plenums and they have adequate fire-resistant and low smoke-producing characteristics.

A-3.1.2 *Type CMR (Communications Riser Cable)*

Type CMR communications riser cables are suitable for use in a vertical run in a shaft when penetrating one or more floors as they have fire-resistant characteristics and thus be capable of preventing the carrying of fire from floor to floor.

A-3.1.3 *Type CMG/CM (Communications General-Purpose Cable)*

Type CMG general-purpose communications cables are suitable for general-purpose communications use, with the exception of risers and plenums, and these cables are resistant to the spread of fire.

A-3.1.4 *Type CMX (Communications Cable, Limited Use)*

Type CMX limited-use communications cables are suitable for use in dwellings and raceways as being resistant to flame spread.

A-3.1.5 *Type CMUC (Under Carpet Communications Wire and Cable)*

Type CMUC under carpet communications wires and cables are suitable for under carpet use and they are resistant to flame spread.

A-3.2 Optical Fibre Cables

Different optical fibre cable types and their markings on cable are as given below:

Marking	*Cable Type/Suitability*
OFNP	Non-conductive optical fibre plenum cable
OFCP	Conductive optical fibre plenum cable
OFNR	Non-conductive optical fibre riser cable
OFCR	Conductive optical fibre riser cable
OFNG	Non-conductive optical fibre general-purpose cable
OFCG	Conductive optical fibre general-purpose cable
OFN	Non-conductive optical fibre general-purpose cable
OFC	Conductive optical fibre general-purpose cable

A-3.2.1 *Types OFNP and OFCP*

Types OFNP and OFCP non-conductive and conductive optical fibre plenum cables are suitable for use in ducts and plenums and they have adequate fire-resistant and low smoke-producing characteristics.

A-3.2.2 *Types OFNR and OFCR*

Types OFNR and OFCR non-conductive and conductive optical fibre riser cables are suitable for use in a vertical run in a shaft when penetrating one or more floors and have the fire-resistant characteristics capable of preventing the carrying of fire from floor to floor.

A-3.2.3 *Types OFNG and OFCG*

Types OFNG and OFCG non-conductive and conductive general-purpose optical fibre cables are suitable for general-purpose use, with the exception of risers and plenums, and these cables are resistant to the spread of fire.

A-3.2.4 *Types OFN and OFC*

Types OFN and OFC non-conductive and conductive optical fibre cables are suitable for general-purpose use, with the exception of risers and plenums and have resistance to the spread of fire.

A-4 BALANCED TWISTED-PAIR CABLE NOMENCLATURE

Details of nomenclatures of twisted pair cables using various combinations of overall screen type and individual pair screen type, as follows, are given in Table 2:

Overall Screen Type (*x*)	*Individual Pair Screen Type* (*y*)
Overall screen absent (*U*)	Individual screens absent (*U*)
Overall foil screen (*F*)	Individual foil screens (*F*)
Overall braid screen (*S*)	
Dual overall screen (*SF*) (foil + braid)	

A-5 ELECTRONIC ACCESS CONTROL (EAC) AND VIDEO SURVEILLANCE

A-5.1 Electronic Access Control (EAC)

An EAC system allows several levels of security. Once the number and type of people are determined, a user or access level for each person is established. Access levels are incorporated into the system integration and the areas of access are determined. Factors affecting the user level include security clearances, job title, rank, short-term employee and employee type. The access level is determined by the physical layout of building and is directly related to the doors and other portals it controls.

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Table 2 Balanced Cable Nomenclature

(*Clause* A-4)

Sl No.	Global Abbreviations (*x*/*y*)	North American Abbreviation	Overall Braid Screen	Overall Foil Screen	Individual Foil Screen
(1)	(2)	(3)	(4)	(5)	(6)
i)	*U*/*U* TP	*U* TP	No	No	No
ii)	*U*/*F* TP	*S* TP	No	No	Yes
iii)	*F*/*U* TP	*F* TP, *Sc*TP, PiMF	No	Yes	No
iv)	*F*/*F* TP	*S* TP, *SS* TP	No	Yes	Yes
v)	*S*/*U* TP	*S* TP	Yes	No	No
vi)	*S*/*F* TP	*S* TP, *SS* TP	Yes	No	Yes
vii)	*SF*/*U* TP	*S* TP, *SS* TP	Yes	Yes	No
viii)	*SF*/*F* TP	*S* TP, *SS* TP	Yes	Yes	Yes

NOTE — The abbreviations represent as follows:

a) F/F TP — Foil-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall foil screen).

b) F/U TP — Foil-screened unscreened twisted-pair (Unscreened twisted-pair in overall foil screen).

c) S/F TP — Braid-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall braid screen).

d) S/U TP — Braid-screened unscreened twisted-pair (Unscreened twisted-pair in overall braid screen).

e) Sc TP Screened twisted-pair.

f) SF/F TP — Braid-screened-foil-screened foil-screened twisted-pair (Individually foil-screened twisted-pair in overall foil and braid screen).

g) SF/U TP — Braid-screened-foil-screened unscreened twisted-pair (Unscreened twisted-pair in overall foil and braid screen).

h) U/F TP — Unscreened foil-screened twisted-pair (Individually foil-screened twisted-pair).

j) U/U TP — Overall unshielded twisted-pair with unshielded twisted-pair.

The basic components of an EAC system include,

a) a computer,
b) one or more control panels, and
c) one or more peripheral devices connected to the control panels (for example, card reader, siren and sensor).

The host computer runs the EAC software, manages the system parameters, maintains the system database, and controls all communication with the control panels. The host computer receives all event and alarm transactions from the control panels. It then saves them into separate history files that may be used to run reports by specific criteria.

The control panels manage the activation of peripheral devices by turning the devices on or off and controlling access to certain areas through card readers and door-locking hardware.

Media for communications may include the following:

1) *Balanced twisted-pair* — Shielded twisted-pair, unshielded twisted-pair, and screened twisted-pair.
2) *Optical fibre* — Multi-mode and single-mode.
3) *Wireless* — Microwave, radio frequency (RF), and infrared (IR).
4) Cellular networks connection.

A-5.2 Video Surveillance

A-5.2.1 In addition to traditional capture devices that operate within the visible band of the electromagnetic spectrum, other technologies that provide unique viewing capabilities are, as follows:

a) *IR cameras* — These refer to specially designed imagers capable of seeing into the low IR bandwidth. They are sometimes referred to as starlight cameras because of their night time viewing capabilities.
b) *Thermal cameras* — They capture heat or temperature values of a scene rather than light values, regardless of how bright or dark the scene appears to the human eye. Although the identification of colours and details are impossible with thermal cameras (because they only view temperature), these cameras are quite useful in viewing dark scenes for activities that have heat signatures.
c) *Film cameras* — They have been on the market for many years. These self-sustaining units are equipped with traditional camera film, which permanently stores the scenes. The film requires replacement when exhausted.

A-5.2.2 Camera placement is based on security objectives identified through a need-assessment. Video surveillance applications include two typical types of camera mounts, as follows:

a) *Fixed* — It refers to a camera dedicated to single view that does not change unless the camera is physically moved.
b) *Pan and tilt* — It refers to a camera with a pan and tilt that allows for a 180° or 360° view, which is controlled electronically from a remote viewing station.

From a practical standpoint, the trade-off between the two types is that a pan and tilt provides a more flexible area of coverage at a higher cost than a fixed camera. Pan and tilt technology allows for auto-panning where the camera moves in a predefined cycle. Camera mounting locations are typically dictated by the available physical infrastructure and are balanced against the required field of views. Connectivity of cameras to the main system in a building environment is generally through coaxial cables.

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of reference in this Section.

IS No.	*Title*
(1) 9537 (Part 2) : 1983	Specification for conduits for electrical installations: Part 2 Rigid steel conduits
(2) 9537 (Part 3) : 1983	Specification for conduits for electrical installations: Part 3 Rigid plain conduits for insulating materials
3419 : 1989	Specification for fittings for rigid non-metallic conduits (*second revision*)
(3) 9537 (Part 5) : 2000	Specification for conduits for electrical installations: Part 5 Pliable conduits of insulating materials

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 1 Water Supply

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 9/Section 1) covers the requirements of water supply in buildings. The water supply provisions covered in this Section encompass the requirements of water supply, plumbing connected to public water supply, design of water supply systems, principles of conveyance and distribution of water within the premises, hot water supply system, inspection and maintenance of water supply systems. It also covers design of water supply systems in high altitudes and/or sub-zero temperature regions.

In the first version of the Code formulated in 1970, three separate sections of Part 9 Plumbing Services were brought out, namely, Section 1 Water supply, Section 2 Drainage and sanitation, and Section 3 Gas supply. These sections were subsequently revised in 1983. The major changes incorporated in the first revision in Section 1 Water supply, were: rationalization of definitions and addition of definitions for more terms; addition of universal pipe friction diagram and nomogram of Hazen and Willam's equation for discharge computation, deleting the discharge curves based on Chezy's formula; introduction of a detailed clause giving guidance on the design of water supply system for multi-storeyed buildings; modification to indicate that no separate storage need be provided for flushing and domestic purposes for health reasons and a single storage tank may be provided; modification/ amplification of provisions relating to domestic hot water supply installations; introduction of a detailed clause covering recommendations to be considered while planning and designing water supply systems peculiar to high altitude and/or sub-zero temperature regions of the country; and addition of requirements relating to inspection, testing and maintenance applicable to hot water supply system.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the standards based on which this Section was formulated, a need to revise this Section was felt. The last revision was therefore formulated to take care of these. In the last revision, the erstwhile two sections were merged and a combined and comprehensive Section, namely Section 1 Water supply, drainage and sanitation (including solid waste management), was brought out. Gas supply was brought out as Section 2. Following significant changes were incorporated in the last revision of Section 1 on water supply, drainage and sanitation, in respect to water supply: modification of provision of water supply requirement; addition of a new clause on water supply for other than residential purposes; addition of a new clause on quality of water, also including therein a sub-clause on waste water reclamation; modification of the provision regarding storage of water and introduction of guidelines for calculating storage capacity; modification, in the design of distribution system provisions for discharge computation, to include designed consumer pipes based on fixtures unit also taking into account probable simultaneous demand instead of earlier computation based on Reynold's Number; introduction of an alternative option of variable speed drive pumping system to hydro pneumatic system; addition of a new clause on backflow prevention; addition of provision for suitability of galvanized mild steel tanks on the basis of *p*H of the water; detailing of types of hot water heater; and restructuring of the section was done to make it more user friendly.

The last revision also incorporated for the first time the provisions on solid waste management.

In this revision, to address the various and distinct features related to the plumbing aspects and solid waste management comprehensively, this Part 9 has been rearranged as follows:

Section 1 Water supply
Section 2 Drainage and sanitation
Section 3 Solid waste management
Section 4 Gas supply

Further, in this revision of the Section 1, the following significant changes/modifications have been incorporated:

1) Provisions on water supply requirements for buildings have been related to the estimated occupancy in the chosen type of building.
2) Table 1 on water requirements for buildings other than residences has been updated with respect to type

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of buildings and it now also includes domestic and flushing requirements separately.

3) Water demand for landscaping purposes has been included.
4) Requirements related to treatment of waste water and usage of recycled waste water have been included.
5) Materials used for storage water tanks have been updated.
6) Provisions related to quantity of water to be stored have been updated.
7) Provisions have been included for protection of water supply by avoiding cross-connection between treated and raw water supplies and back flow prevention, and securing identification of non-potable water supply pipes.
8) List of materials used to manufacture pipes has been updated.
9) General requirements for design of distribution systems have been included.
10) Table 2 on fixture unit for different types of fixtures has been updated.
11) Table 3 on probable simultaneous demand has been updated with demand values included various intermediate and up to 10 000 fixture units, along with graphs for probable demand.
12) Maximum flow rate and flush volumes have been included.
13) Provisions related to inadequate and excessive water pressure have been included.
14) Guidance on water hammer effects have been included.
15) Provisions for distribution systems in multi-storeyed buildings have been updated along with illustrations therefor.
16) Provisions related to zoning of distribution systems have been included.
17) Hot water supply systems have been included under the existing clause on hot water supply installations.
18) Detailed provisions related to swimming pools have been included.
19) Guidance on allowance for expansion of water pipes have been included.
20) A new clause on colour coding for different types of water pipes has been included.
21) Provisions have been reviewed and updated from the point of view of accessibility by elderly and persons with disabilities, also, in this context, duly giving cross-reference to **13** of Part 3 'Development Control Rules and General Building Requirements'.
22) Certain terminologies have been included and some have been updated.
23) Cross-references to Indian Standards have been updated.

This Section is largely based on the following Indian Standards:

IS 1172 : 1993	Code of basic requirements for water supply, drainage and sanitation (*fourth revision*)
IS 2065 : 1983	Code of practice for water supply in buildings (*second revision*)
IS 6295 : 1986	Code of practice for water supply and drainage in high altitudes and or sub-zero temperature regions (*first revision*)
IS 7558 : 1974	Code of practice for domestic hot water installations
IS 12183 (Part 1) : 1987	Code of practice for plumbing in multi-storeyed buildings : Part 1 Water supply

A reference to SP 35 : 1987 'Handbook on Water Supply and Drainage' may be useful, from where also, assistance has been derived.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the formulation of this Section, reference has also been made to the following:

International Plumbing Code 2015, International Code Council, and

Uniform Plumbing Code 2015, International Association of Plumbing and Mechanical Officials

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 1 Water Supply

1 SCOPE

1.1 This Code (Part 9/Section 1) covers the basic requirements of water supply for residential, business and other types of buildings, including traffic terminal stations. This Section also deals with general requirements of plumbing connected to public water supply and design of water supply systems along with general guidelines about expansion in piping systems, and swimming pools.

1.1.1 This Section does not take into consideration the requirements of water supply for industrial plants and processes, which have to be provided for separately. It also does not provide the requirements of water supply for other purposes, such as firefighting and street cleaning.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply in addition to the definitions given in accepted standards [9-1(1)].

2.1 Definitions Relating to Water Supply

2.1.1 *Access Panel* — A removable panel mounted in a frame, normally secured with screws and mounted in a wall or ceiling, to provide access to concealed valves or items which may require maintenance.

2.1.2 *Air Gap, Water Distribution* — Unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet conveying water to a tank or plumbing fixture and flood level rim of the receptacle.

2.1.3 *Air Valve* — A valve that releases air from a pipeline automatically without loss of water, or introduce air into a line automatically if the internal pressure becomes less than that of the atmosphere.

2.1.4 *Authority Having Jurisdiction* — The authority which has been created by a statute and which for the purpose of administering the Code/Part may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.1.5 *Available Head* — The head of water available at the point of consideration due to mains' pressure or overhead tank or any other source of pressure.

2.1.6 *Anti-Siphon*— A device or mechanism to prevent siphonage.

2.1.7 *Backflow*

a) The flow of water or other liquids, mixtures or substances into the distributing pipes of a system of supply of potable water from any source or sources other than its intended source.
b) The flow of a liquid in a direction reverse of that intended.

2.1.8 *Backflow Prevention Device* — Any approved measure or fitting or combination of fittings specifically designed to prevent backflow or back siphonage in a water service.

2.1.9 *Back Pressure Back Flow* — Due to an increased pressure above the supply pressure, which may be due to pumps, other equipment, gravity or other source of pressure.

2.1.10 *Back Siphonage* — The flowing back of used, contaminated, or polluted water from a plumbing fixture or vessel into a water supply due to a reduced pressure in such pipe (*see* **2.1.7**).

2.1.11 *Barrel* — This portion of a pipe in which the diameter and wall thickness remain uniform throughout.

2.1.12 *Base* — The lowest portion or lowest point of a stack of vertical pipe.

2.1.13 *Bath Room Group* — Group of fixtures consisting of water closet, lavatory, bath tub or shower and other fittings with a floor drain located together.

2.1.14 *Bedding* — The material on which the pipe is laid and which provides support for the pipe. Bedding can be concrete, granular material or the prepared trench bottom.

2.1.15 *Chair* — A bed of concrete or other suitable material on the trench floor to provide a support for the pipes at intervals.

2.1.16 *Channel* — The open waterway through which sewage, storm water or other liquid wastes flow at the invert of a manhole or an inspection chamber.

2.1.17 *Communication Pipe* — That part of a service pipe which vests in the water undertakes. It starts at the water main and terminate at a point which differs according to the circumstances of the case.

2.1.18 *Consumer* — Any person who uses or is supplied

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water or on whose application such water is supplied by the Authority.

2.1.19 *Consumer's Pipe* — The portion of service pipe used for supply of water and which is not the property of the Authority (*see* Fig. 1).

2.1.20 *Cover*

a) A removable plate for permitting access to a pipe, fitting, vessel or appliance.

b) The vertical distance between the top of the barrel of a buried pipe or other construction and the surface of the ground.

2.1.21 *Cross-Connection* — A connection between two normally independent pipelines which permits flow from either pipeline into the other.

2.1.22 *Direct Tap* — A tap which is connected to a supply pipe and is subject to pressure from the water main.

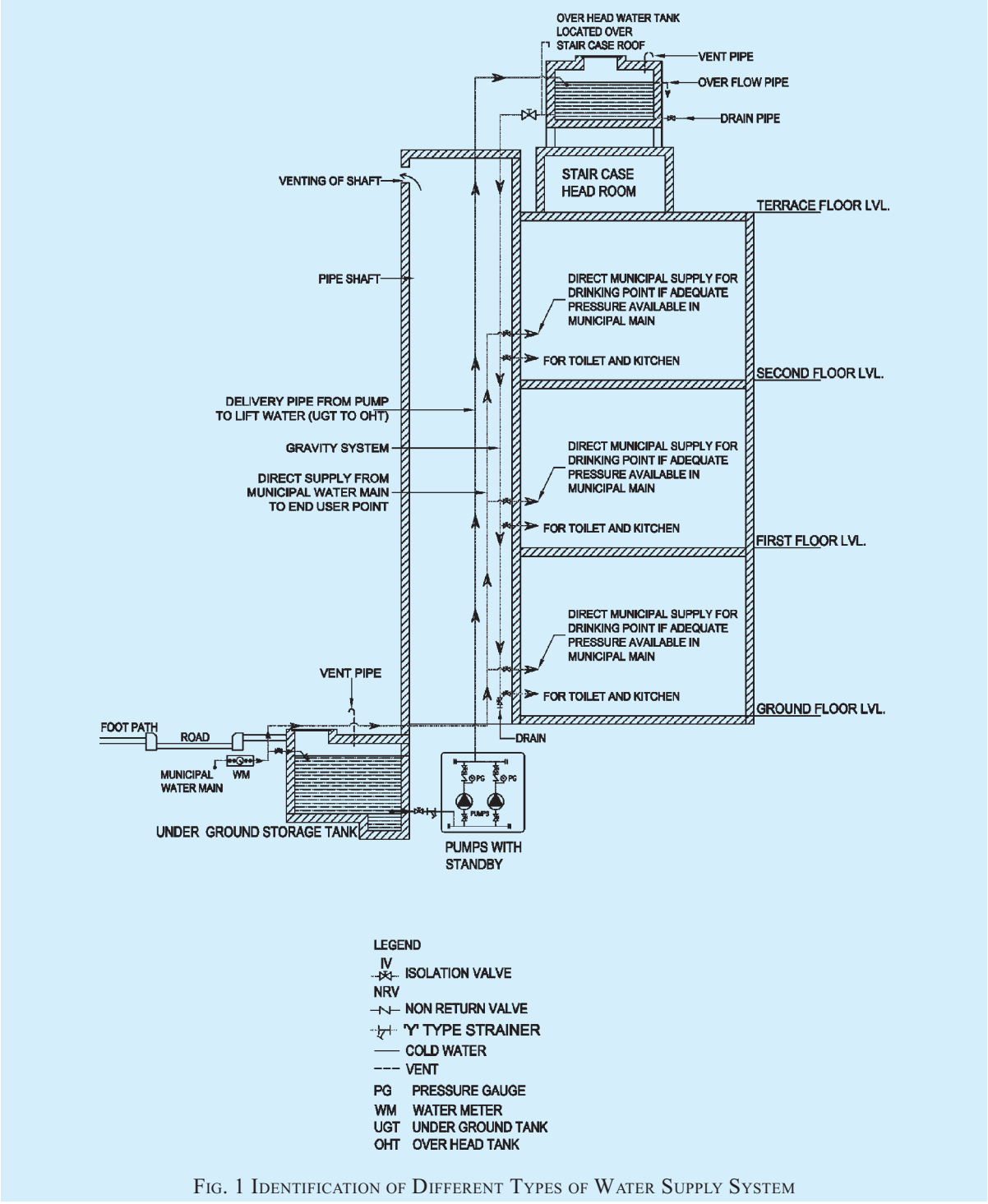


FIG. 1 IDENTIFICATION OF DIFFERENT TYPES OF WATER SUPPLY SYSTEM

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2.1.23 *Down Take Tap* — A tap connected to a system of piping not subject to water pressure from the water main.

2.1.24 *Effective Opening* — The minimum cross-sectional area at the point of water supply, measured or expressed in terms of,

a) the diameter of a circle; and

b) the diameter of a circle of equivalent cross-sectional area, if the opening is not circular.

2.1.25 *Feed Cistern* — A storage vessel used for supplying cold water to a hot water apparatus, cylinder or tanks.

2.1.26 *Fittings* — The appurtenances such as coupling, flange, branch, bend, tees, elbows, unions, waste (with or without plug), P or S trap (with or without vent), stop ferrule, bib tap, pillar tap, bath faucet, water meter, garden hydrant, valves and any other article used in connection with water supply, drainage and sanitation.

2.1.27 *Fixture Unit* — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.1.28 *Float Operated Valve* — Ball valves or ball taps and equilibrium valves operated by means of a float.

2.1.29 *Flushing Cistern* — A cistern provided with a device for rapidly discharging the contained water and used in connection with a sanitary appliance for the purpose of cleaning the appliance and carrying away its contents into a drain.

NOTE — The nominal size of a cistern is the quantity of water discharged per flush.

2.1.30 *Flushometer Tank* –A tank integrated with an air accumulator vessel that is designed to discharge a predetermined quantity of water to fixtures for flushing purposes.

2.1.31 *Formation* — The finished level of the excavation at the bottom of a trench or heading prepared to receive the permanent work.

2.1.32 *Frost Line* — The line joining the points of greatest depths below ground level up to which the moisture in the soil freezes.

2.1.33 *General Washing Place* — A washing place provided with necessary sanitary arrangement and common to more than one tenement.

2.1.34 *Geyser* — An apparatus for heating water with supply control on the inlet side and delivering it from an outlet.

2.1.35 *Haunching* — Outward sloping concrete support to the sides of a pipe or channel above the concrete bedding.

2.1.36 *Heel Rest Bend or Duck-Foot Bend* — A bend, having a foot formed integrally in its base, used to receive a vertical pipe.

2.1.37 *High Altitudes* — Elevations higher than 1 500 m above mean sea level (MSL).

2.1.38 *Highway Authority* — The public body in which is vested, or which is the owner of, a highway repairable by the inhabitants collectively; otherwise the body or persons responsible for the upkeep of the highway.

2.1.39 *Horizontal Pipe* — Any pipe of fitting which makes an angle of more than 45° with the vertical.

2.1.40 *Hot Water Tank* — A vessel for storing hot water under pressure greater than atmospheric pressure.

2.1.41 *Hydro-Pneumatic System*–The water supply pumping system which operates automatically in conjunction with pump(s), pressure vessel and pressure switch.

2.1.42 *Junction Pipe* — A pipe incorporating one or more branches.

2.1.43 *Lagging* — Thermal insulation or pipes.

2.1.44 *Licensed (or Registered) Plumber* — A person licensed (or registered) under the provisions of this Code.

2.1.45 *Offset* — A pipe fitting used to connect two pipes whose axes are parallel but not in line.

2.1.46 *Period of Supply* — The period of the day or night during which water supply is made available to the consumer.

2.1.47 *Pipe Work* — Any installation of piping with its fittings.

2.1.48 *Plumbing*

a) The pipes, fixtures and other apparatus inside a building for bringing in the water supply and removing the liquid and water borne wastes.

b) The installation of the foregoing pipes, fixtures and other apparatus.

2.1.49 *Plumbing System* — The plumbing system shall include the water supply and distribution pipes; plumbing fittings and traps; soil, waste, vent pipes and anti-siphonage pipes; building drains and building sewers including their respective connections, devices and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.1.50 *Potable Water* — Water which is satisfactory for drinking, culinary and domestic purposes and meets the requirements of the Authority.

2.1.51 *Premises* — Premises shall include passages, buildings and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private in respect of which a water rate or charge is payable to the Authority or for which an application is made for supply of water.

2.1.52 *Pressure Balancing Valve* – Mixing valve that senses incoming hot and cold water pressures and compensates for fluctuations.

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2.1.53 *Residual Head* — The head available at any particular point in the distribution system.

2.1.54 *Residual Pressure* — The pressure available at the fixture after allowance is made for pressure drop due to friction loss and head in the system during maximum demand periods.

2.1.55 *Saddle* — A purpose made fitting, so shaped as to fit over a hole cut in a sewer or drain used to form connections.

2.1.56 *Service Pipe* — Pipe that runs between the distribution main in the street and the riser in case of a multi-storeyed building or the water meter in the case of an individual house and is subject to water pressure from such main.

2.1.57 *Static Pressure* — The pressure exerted by a fluid that is not moving or flowing.

2.1.58 *Stop-Cock* — A cock fitted in a pipe line for controlling the flow of water.

2.1.59 *Stop Tap* — Stop tap includes stop-cock, stop valve or any other device for stopping the flow of water in a line or system of pipes at will.

2.1.60 *Storage Tank* — A container used for storage of water which is connected to the water main or tube-well by means of supply pipe.

2.1.61 *Studio Apartment*— An apartment unit consisting of a single room and a bathroom, the single room functioning as living room, bedroom and kitchen.

2.1.62 *Subsoil Water*— Water occurring naturally in the subsoil.

2.1.63 *Subsoil Water Drain*

a) A drain intended to collect and carry away subsoil water.

b) A drain intended to disperse into the subsoil from a septic tank.

2.1.64 *Sub-Zero Temperature Regions* — Regions where temperatures fall below 0°C and freezing conditions occur.

2.1.65 *Supply Pipe* — So much of any service pipe as is not a communication pipe.

2.1.66 *Supports* — Hangers and anchors or devices for supporting and securing pipe and fittings to walls, ceilings, floors or structural members.

2.1.67 *Surface Water* — Natural water from the ground surface, paved areas and roofs.

2.1.68 *Surface Water Drain* — A drain conveying surface water including storm water.

2.1.69 *Thermostatic/Pressure Balancing Valve*— Mixing valve that senses outlet temperature and incoming hot and cold water pressure and compensates for fluctuations for stabilization.

2.1.70 *Vertical Pipe* – Any pipe or fitting which is installed in a vertical position or which makes an angle or not more than 45° with the vertical.

2.1.71 *Warning Pipe* — An overflow pipe so fixed that its outlet, whether inside or outside a building, is in a conspicuous position where the discharge of any water there from can be readily seen.

2.1.72 *Wash-Out Valve* — A device located at the bottom of the tank for the purpose of draining a tank for cleaning, maintenance, etc.

2.1.73 *Water Hammer Arrestor* — A device designed to provide protection against hydraulic shock in the building water supply system.

2.1.74 *Water Main (Street Main)* — A pipe laid by the water undertakers for the purpose of giving a general supply of water as distinct from a supply to individual consumers and includes any apparatus used in connection with such a pipe.

2.1.75 *Water Outlet* — A water outlet, as used in connection with the water distributing system, is the discharge opening for the water: (a) to a fitting; (b) to atmospheric pressure (except into an open tank which is part of the water supply system); and (c) to any water-operated device or equipment requiring water to operate.

2.1.76 *Water Supply System* — Water supply system of a building or premises consists of the water service pipe, the water distribution pipes, and the necessary connecting pipes, fittings, control valves, and all appurtenances in or adjacent to the building or premises.

2.1.77 *Waterworks* — Waterworks for public water supply include a lake, river, spring, well, pump with or without motor and accessories, reservoir, cistern, tank, duct whether covered or open, sluice, water main, pipe, culvert, engine and any machinery, land, building or a thing used for storage, treatment and supply of water.

2.2 Definitions Relating to Swimming Pool

2.2.1 *Appurtenance* — An accessory facility or feature at a swimming pool, such as a diving board, slide, wading pool, plunge pool, spray pool.

2.2.2 *Bather Load* — The maximum number of persons that may be allowed in the pool area at one time without creating undue health or safety hazards.

2.2.3 *Deep Area* — An area of a swimming pool in which the water depth exceeds 1.5 m.

2.2.4 *Diving Pool* — A pool designed and intended for use exclusively for diving.

2.2.5 *Inlet* — An opening or fitting through which filtered water enters the pool.

2.2.6 *Main Drain* –The outlet or outlets for drain provided in the pool.

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2.2.7 *Make-Up Water* — The water added to a pool to replace that which is lost.

2.2.8 *Pool* — A swimming pool or other recreational water basin utilized in conjunction with or as an appurtenance to a swimming pool.

NOTE — The term does not refer to spas and therapy pools not designed or intended for swimming or to basins for individual use that are drained after each use.

2.2.9 *Pool Depth* — The vertical distance between the pool floor and the water level.

2.2.10 *Shallow Area* — An area in a swimming pool, in which the water depth does not exceed 1.5 m at any point.

2.2.11 *Skimmer* — A mechanical device connected to the recirculation piping which is used to skim the pool surface.

2.2.12 *Swimming Pool User Load* — The number of bathers using the pool in a 24 h period for which a certain per capita capacity is often considered.

NOTE — The capacity of a swimming pool in terms of its user load is dictated by the capacity of water treatment equipment.

2.2.13 *Transition Point* — A location in a shallow area of a swimming pool where an area, having a floor slope of no more than 300 mm vertical in 3.65 m horizontal, adjoins an area where the floor slope exceeds 1 in 12.

2.2.14 *Turnover Period* — The time required to recirculate a volume of water equivalent to the water volume of the pool through the filtration system.

2.2.15 *Wading Pool* — A pool having a maximum water depth not exceeding 76 cm.

2.2.16 *Water Level* — The level of the overflow lip of a perimeter overflow system or the mid-level of surge weirs, if present, or the mid-level of the skimmer operating range.

2.2.17 *Zero-Depth Edge* — That portion of the perimeter of a zero-depth pool where the pool floor intersects the pool water surface.

2.2.18 *Zero-Depth Pool* — A swimming pool where the pool floor intersects the water surface along a portion of its perimeter.

3 GENERAL

3.1 Basic Principles

The design of water supply takes the following into consideration:

a) Number of occupants;

b) Minimum water requirements for different purposes;

c) Treatment of water based on the quality of water;

d) Quantity of water stored; and

e) Sizing of pipes.

The basic principles of water supply, drainage and sanitation are given below, and the design of water supply should in general be guided by the applicable principles.

3.1.1 *Potable Water*

All premises intended for human habitation, occupancy, or use shall be provided with supply of potable water. This water supply shall not be connected with unsafe water resources, nor shall it be subject to the hazards of backflow.

3.1.2 *Water Provision*

Plumbing fixtures, devices and appurtenances shall be provided with water in sufficient volume and at pressures adequate to enable them to function properly and without undue noise under normal conditions of use.

There should be at least a residual head of 0.018 N/mm^2 at the consumer's tap. There may be certain fixtures or appliances in the installation that may require a higher pressure, such as 0.05 N/mm^2 or even higher (such as 0.1 N/mm^2 in case of flush valves), in which case the system shall be designed using pumps, tanks or both to achieve the required minimum pressure.

NOTE — The residual head shall be taken at the highest/farthest outlets in the building.

3.1.3 *Water Efficiency*

Plumbing system shall be designed, installed and adjusted to use the optimum quantity of water consistent with proper performance and cleaning.

3.1.4 *Safety Devices*

Plumbing system shall be designed and installed with safety devices to safeguard against dangers from contamination, explosion, overheating, etc.

3.1.5 *Minimum Water Amenities*

It is recommended that each dwelling unit should have at least one water closet, one lavatory, one kitchen wash place or a sink, and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in **13** and **B-9** of Part 3 'Development Control Rules and General Building Requirements' of the Code shall also be complied with.

3.1.6 *Drainage System*

The drainage system shall be designed, installed and maintained to guard against fouling, deposit of solids and clogging and with adequate cleanouts so arranged that the pipes may be readily cleaned.

3.1.7 *Materials and Workmanship*

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The plumbing system shall have durable material, free from defective workmanship and so designed and installed as to give satisfactory service for its reasonable expected life. The accessories of the plumbing system should be of such specifications as to meet the functional requirements of the installation, so as to also avoid any inconsistency leading to leakage and resultant seepage.

3.1.8 *Fixture Traps and Vent Pipes*

Each fixture directly connected to the drainage system shall be equipped with a liquid seal trap. Trap seals shall be maintained to prevent sewer gas, other potentially dangerous or noxious fumes, or vermin from entering the building. Further, the drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use by providing vent pipes throughout the system.

3.1.9 *Foul Air Exhaust*

Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building, as it conveys potentially noxious or explosive gases to the outside atmosphere. All vent pipes shall be provided with a cowl.

3.1.10 *Testing*

The plumbing system shall be subjected to required tests to effectively disclose all leaks and defects in the work or the material.

3.1.11 *Exclusion from Plumbing System*

No substance that will clog or accentuate clogging of pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the drainage system.

3.1.12 *Light and Ventilation*

Wherever water closet or similar fixture is located in a room or compartment, it should be properly lighted and ventilated.

3.1.13 *Individual Sewage Disposal Systems*

If water closets or other plumbing fixtures are installed in buildings where connection to public sewer is not possible, suitable provision shall be made for acceptable treatment and disposal.

3.1.14 *Maintenance*

Plumbing systems shall be maintained in a safe and serviceable condition.

3.1.15 *Approach for Use and Cleaning*

All plumbing fixtures shall be so installed with regard to spacing as to be approachable for their intended use and for cleaning. All doors, windows and any other device needing access within the toilet shall be so located that they have proper approach.

3.1.16 *Accessibility for Persons with Disabilities*

All doors, windows and fixtures, including WC, urinals, grab bars, washbasin, mirror and all other accessories for use by persons with disabilities shall be so installed/ located that they have proper access with appropriate width, height, space, centerlines, and ease of operation (*see* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code).

3.1.17 *Structural Safety*

Plumbing system shall be installed with due regard to preservation of the structural members and prevention of damage to walls and other surfaces.

3.1.18 *Protection of Ground and Surface Water*

Sewage or other waste shall not be discharged into surface or sub-surface water without acceptable form of treatment.

3.2 Water Supply Connection

3.2.1 *Application for Obtaining Supply Connection*

Every consumer, requiring a new supply of water or any extension or alteration to the existing supply shall apply in writing in the prescribed form (*see* Annex A) to the Authority.

3.2.2 *Bulk Supply*

In the case of large housing colonies or campuses, or where new services are so situated that it will be necessary for the Authority to lay new mains or extend an existing main, full information about the proposed scheme shall be furnished to the Authority. Information shall also be given regarding their phased requirements of water supply with full justification. Such information shall include site plans, showing the layout of roads, footpaths, building and boundaries and indicating thereon the finished line and level of the roads or footpaths and water supply lines and appurtenances.

3.2.3 *Completion Certificate*

On completion of the plumbing work for the water supply system, the licensed/registered plumber shall give a completion certificate in the prescribed form (*see* Annex B) to the Authority for getting the water connection from the mains.

3.3 Licensing/Registration of Plumbers

3.3.1 *Execution of Work*

The work which is required to be carried out under the provisions of this Section, shall be executed only by a licensed/registered plumber under the control of the Authority and shall be responsible to carry out all lawful directions given by the Authority. No individual shall engage in the business of plumbing unless so licensed/ registered under the provisions of this Section.

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3.3.1.1 No individual, firm, partnership or corporation shall engage in the business of installing, repairing or altering plumbing unless the plumbing work performed in the course of such business is under the direct supervision of a licensed/registered plumber.

3.3.2 *Examination and Certification*

The Authority shall establish standards and procedure for the qualification, examination and licensing/ registration of plumbers and shall issue licences to such persons who meet the qualifications thereof and successfully pass the examination.

3.3.3 For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences/registration, reference may be made to good practice [9-1(2)]. The Authority may also utilize the services of the certified plumbers who are certified for the required skill level under the appropriate scheme of the Government.

4 WATER SUPPLY

4.1 Water Supply Requirements for Buildings

The total quantity of water per day is estimated based on the proposed occupancy and activities catered. Designer has to identify all the possible sources for augmenting the shortfall in water supply. The analysis of available water is done to decide the treatment for consumption and treatment process depends on the quality of water and the purpose for which it is used.

Projection of population for each building shall be made on the basis of its usage. Population for each type of building shall be estimated on the basis of information obtained from the users. Alternatively, population may be worked on the following basis, for different type of buildings:

a) *Residential buildings:*

Accommodation	*Population Requirements*
1 bedroom dwelling unit	4
2 bedroom dwelling unit	5
3 bedroom dwelling unit	6
4 bedroom dwelling unit and above	7

NOTES

1 The above figures consider a domestic household including support personnel, wherever applicable.

2 For plotted development, the population may be arrived at after due consideration of the expected number and type of domestic household units.

3 Dwelling unit under EWS category shall have population requirement of 4 and studio apartment shall have population requirement of 2.

b) *Other than residential buildings:*

Occupancy	*Population Requirement*
Offices	1 person per 10 m^2 of floor area (*see* Note 1)
Schools	Strength of school + Teaching and non-teaching staff
Hostels	Number of beds + 4.5 x (warden's residence) + staff
Hotels	Number of beds + Staff + Requirement of restaurant seats
Hospitals	Number of beds + Staff + Patient attendants (generally population density per bed in secondary care hospital is 5, tertiary care is 7 and quaternary care is 9)
Mercantile	1 person per 3 m^2 of street floor and sales basement areas + 1 person per 6 m^2 of upper sale floors (Total population may be segregated into 10 percent for fixed and 90 percent for floating/visitors)
Traffic terminal stations	Average number of users per day (Total annual passenger traffic/365) + Staff + Vendors

NOTES

1 Wherever there are multiple work shifts, the number of users within a 24 h period may be considered as per actuals.

2 Population of 5 to 15 percent, depending on the usage of building, shall be considered for visitors and floating population likely to use the buildings facilities.

4.1.1 *Water Supply for Residences*

A minimum of 70 to 100 litre per head per day may be considered adequate for domestic needs of urban communities, apart from non-domestic needs as flushing requirements (which varies based on type of building occupancy). As a general rule the following rates per capita per day may be considered for domestic and non-domestic needs:

a) For communities with population up to 20 000:
   1) Water supply through stand post: 40 lphd (*Min*)
   2) Water supply through house service connection: 70 to 100 lphd

b) For communities with: 100 to 135 lphd
   population 20 000 to 100 000 together with full flushing system

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c) For communities with population above 100 000 together with full flushing system: 150 to 200 lphd

NOTE — The value of water supply given as 150 to 200 litre per head per day may be reduced to 135 litre per head per day for houses for Medium Income Group (MIG) and Lower Income Groups (LIG) and Economically Weaker Section of Society (EWS), depending upon prevailing conditions and availability of water.

4.1.1.1 Out of the 150 to 200 litre per head per day, 45 litre per head per day may be taken for flushing requirements and the remaining quantity for other domestic purposes.

4.1.2 *Water Supply for Buildings Other than Residences*

Minimum requirements for water supply for buildings other than residences shall be in accordance with Table 1.

Table 1 Water Requirements for Buildings Other than Residences
(*Clause* 4.1.2)

Sl No.	Type of Building	Domestic Per Day litre	Flushing Per Day litre	Total Consumption Per Day litre
(1)	(2)	(3)	(4)	(5)
i)	Factories including canteen where bath rooms are required to be provided	30 per head	15 per head	45 per head
ii)	Factories including canteen where no bath rooms are required to be provided	20 per head	10 per head	30 per head
iii)	Hospital (excluding laundry and kitchen) (*see* Note 2):			
	a) Number of beds not exceeding 100	230 per head	110 per head	340 per head
	b) Number of beds exceeding 100	300 per head	150 per head	450 per head
	c) Out patient department (OPD)	10 per head	5 per head	15 per head
iv)	Nurses' homes and medical quarters	90 per head	45 per head	135 per head
v)	Hostels	90 per head	45 per head	135 per head
vi)	Hotel (up to 3 star) excluding laundry, kitchen, staff and water bodies	120 per head	60 per head	180 per head
vii)	Hotel (4 star and above) excluding laundry, kitchen, staff and water bodies	260 per head	60 per head	320 per head
viii)	Offices (including canteen)	25 per head	20 per head	45 per head
ix)	Restaurants and food court including water requirement for kitchen:			
	a) Restaurants	55 per seat	15 per seat	70 per seat
	b) Food court	25 per seat	10 per seat	35 per seat
x)	Clubhouse	25 per head	20 per head	45 per head
xi)	Stadiums	4 per head	6 per head	10 per head
xii)	Cinemas, concert halls and theatres and multiplex	5 per seat	10 per seat	15 per seat
xiii)	Schools/Educational institutions:			
	a) Without boarding facilities	25 per head	20 per head	45 per head
	b) With boarding facilities	90 per head	45 per head	135 per head
xiv)	Shopping and retail (mall)			
	a) Staff	25 per head	20 per head	45 per head
	b) Visitors	5 per head	10 per head	15 per head
xv)	Traffic terminal stations (*see* Notes 3 and 4)			
	a) Airports	40 per head	30 per head	70 per head
	b) Railway stations (Junctions) with bathing facility	40 per head	30 per head	70 per head
	c) Railway stations (Junctions) without bathing facility	30 per head	15 per head	45 per head
	d) Railway Stations (Intermediate) with bathing facility	25 per head	20 per head	45 per head
	e) Railway Stations (Intermediate) without bathing facility	15 per head	10 per head	25 per head
	f) Interstate bus terminals	25 per head	20 per head	45 per head
	g) Intrastate Bus Terminals/Metro Stations	10 per head	5 per head	15 per head

NOTES

1 For calculating water demand for visitors, consumption of 15 litre per head per day may be taken.

2 The water demand includes requirement of patients, attendants, visitors and staff. Additional water demand for kitchen, laundry and clinical water shall be computed as per actual requirements.

3 The number of persons shall be determined by average number of passengers handled by stations, with due considerations given to the staff and vendors who are using these facilities.

4 Consideration should be given for seasonal average peak requirements.

5 The hospitals may be categorized as Category A (25 to 50 beds), Category B (51 to 100 beds), Category C (101 to 300 beds), Category D (301 to 500) and Category E (501 to 750 beds).

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The water demand for the laboratory facilities will depend on actual requirements based on functional point of view.

4.1.3 *Water Supply Requirements of Traffic Terminal Stations*

The water supply requirements of traffic terminal stations (railway stations, bus stations, harbours, airports, etc) include provisions for waiting rooms and waiting halls. They do not, however, include requirements for retiring rooms. Requirements of water supply for traffic terminal stations shall be as per Table 1.

4.1.4 *Water Supply for Fire Fighting Purposes*

4.1.4.1 The Authority shall make provision to meet the water supply requirements for fire fighting in the city/ area, depending on the population density and types of occupancy. *See also* Part 4 'Fire and Life Safety' of the Code.

4.1.4.2 Provision shall be made by the owner of the building for water supply requirements for fire fighting purposes within the building, depending upon the height and occupancy of the building, in conformity with the requirements laid down in Part 4 'Fire and Life Safety' of the Code.

4.1.4.3 The requirements regarding water supply in storage tanks, capacity of fire pumps, arrangements of wet riser-cum-down comer and wet riser installations for buildings, depending upon the occupancy use and other factors, shall be in accordance with Part 4 'Fire and Life Safety' of the Code.

4.1.5 *Water Supply for Other Purposes*

4.1.5.1 Water supply in many buildings is also required for many other applications other than domestic use, which shall be identified in the initial stages of planning so as to provide the requisite water quantity, storage capacity and pressure as required for each application. In such instances information about the water use and the quality required may be obtained from the users. Some typical uses other than domestic use and fire fighting purposes are air conditioning, swimming pools and water bodies, and gardening. Treated water from sewage treatment plant, with suitable tertiary treatment, should be used for flushing purpose (with dual piping system), gardening purpose, cooling tower make up, and/or for other non potable usage.

4.1.5.2 The water demand for landscaping purposes is generally taken as 6 to 8 litre/m^2/day for lawns. For shrubs and trees the above value can be reduced considerably.

4.2 Water Sources and Quality

4.2.1 *Sources of Water*

The origin of all sources of water is rainfall. Water can be collected as it falls as rain before it reaches the ground; or as surface water when it flows over the ground or is pooled in lakes or ponds; or as ground water when it percolates into the ground and flows or collects as ground water; or from the sea.

Contamination of water supplies can occur in the source water as well as in the distribution system after water treatment has already occurred. There are many sources of water contamination, including naturally occurring chemicals and minerals (for example, arsenic, radon, uranium), local land use practices (fertilizers, pesticides, concentrated animal feeding operations), manufacturing processes, and sewer overflows or wastewater releases. The presence of contaminants in water can lead to adverse health effects, including gastrointestinal illness, reproductive problems, and neurological disorders.

4.2.2 The water supplied shall be free from pathogenic organisms, clear, free from undesirable taste and odour, neither corrosive nor scale forming and free from minerals which could produce undesirable physiological effects. The quality of water to be used for drinking shall be as per accepted standard [9-1(3)].

4.2.3 For purposes other than drinking water if supplied separately, shall be absolutely safe from bacteriological contamination so as to ensure that there is no danger to the health of the users due to such contaminants.

For purposes other than drinking, where there is an overall risk of legionella growth, it is advisable that for cold water supplies, the temperature does not exceed 20°C and a minimum temperature of 55°C for hot water supplies be maintained at all points of network so as to ensure that it is absolutely safe from bacteriological contamination and there is no danger to the health of the users due to such contaminants.

4.2.4 *Waste Water Reclamation*

Treated sewage or other waste water of the community may be utilized for non-domestic purposes such as water for flushing, landscape irrigation, cooling towers of HVAC system, in fountains and recreational lakes where swimming is not allowed, and for certain industrial purposes after its necessary treatment to suit the nature of the use. This supply system shall be allowed in residences only if proper provision is made to avoid any cross-connection of this treated waste water with domestic water supply system. During use of treated waste water, it is recommended to have dual piping system to avoid cross-contamination.

4.2.4.1 *Treatment of waste water and usage of recycled water*

Waste water is generated by residential and other establishments like institutional, business, mercantile

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and industrial. It includes household waste liquid from toilets, baths, showers, kitchens and sinks that is disposed of *via* sewers. Waste water treatment is the process of removing contaminants from wastewater, including household sewage and runoff (effluents). It includes physical, chemical, and biological processes to remove contaminants. Treatment of waste water and usage of recycled waste water may be done to make it usable for appropriate applications. The objective is to produce an environmentally safe fluid waste stream (or treated effluent) and a solid waste (or treated sludge) suitable for disposal or reuse.

Separation of household waste into grey water and black water (and draining of black water into sewerage system) is becoming more common with grey water being permitted to be used for watering plants or recycled for flushing toilets after proper treatment. Waste water collection and treatment is typically subject to statutory regulations. Treatment depends on the characteristics of influent and the treatment requirements that are needed for treating the same. Waste water treatment generally involves the following three stages:

a) *Primary treatment* — It consists of temporarily holding the wastewater for settlement of heavy solids at the bottom while oil, grease and lighter solids float to the surface.
b) *Secondary treatment* — It removes dissolved and suspended biological matter.
c) *Tertiary treatment* — It is more intensive treatment done in order to allow rejection into a highly sensitive or fragile ecosystem. The tertiary treatment is generally followed by disinfection.

4.2.5 *Water Conservation, Water Balance and Use of Recycled Water*

Water conservation encompasses the policies, strategies and activities to manage fresh water as a sustainable resource, to protect the water environment and to meet current and future demand. Population, household size, and growth and affluence all affect the quantity of water used. Water balance studies should be carried out to study the availability of water from different sources and its usage for different purposes.

4.2.6 Whenever a building is used after long intervals, the water quality of the stored water shall be checked so as to ensure that the water is safe for use as per water quality requirements specified in this Code.

4.3 Estimate of Demand Load

4.3.1 Estimates of total water supply requirements for buildings shall be based on the occupant load consistent with the provisions of **4.1**.

4.3.2 In making assessment of water supply requirements of large complexes, the future occupant load shall be kept in view. The following methods may be used for estimating future requirements:

a) Demographic method of population projection,
b) Arithmetic progression method,
c) Geometrical progression method,
d) Method of varying increment or incremental increase,
e) Logistic method,
f) Graphical projection method, or
g) Graphical comparison method.

4.4 Storage of Water

4.4.1 In a building, provision is required to be made for storage of water for the following reasons:

a) To provide against interruptions of the supply caused by repairs to mains, etc;
b) To reduce the maximum rate of demand on the mains;
c) To tide over periods of intermittent supply; and
d) To maintain a storage for the fire fighting requirement of the building

4.4.2 The water may be stored in overhead tanks (OHT) and/or underground tanks (UGT).

4.4.3 *Materials Used*

Reservoirs and tanks for the storage of water shall be constructed of reinforced concrete, brick masonry, ferrocement, mild steel, stainless steel, plastic or glass reinforced panels.

4.4.3.1 Tanks made of steel may be of welded, riveted or panel/pressed construction. The metal shall be galvanized or coated externally with a good quality anti-corrosive weather-resisting paint. Lead-based paint shall not be used in the tank. Lead-lined tanks shall not be used. Rectangular pressed steel tanks shall conform to good practice [9-1(4)].

4.4.4 Each tank shall be provided with the following:

a) *Manholes* — Adequate number of manholes for access and repair. The manholes shall be made of corrosion resistant material (for example, cast iron, reinforced cement concrete, steel fibre reinforced concrete, galvanized steel, high density polyethylene, fibre glass reinforced plastic or such other materials) acceptable to the Authority. Manholes shall be provided with locking arrangement to avoid misuse and tampering.

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b) *Ladders* — Tanks higher than 900 mm deep shall be provided with corrosion resistant ladders according to the depth to enable a person to reach the bottom of the tank.

c) *Overflow pipe* — Each tank shall be provided with an overflow pipe terminating above the ground/terrace level to act as a 'Warning Pipe' to indicate overflow conditions. The size of the overflow pipe shall be adequate to accept the flow. Normally the overflow pipe size shall be one size higher than the inlet pipe. When the inlet pipe diameter is large, two or more overflow pipes of equivalent cross-section may be provided.

d) *Vent pipes* — Tanks larger than 5 000 litre capacity shall be provided with vent pipes to prevent development pressure in the tank which might result in 'NO FLOW' condition or inward collapse of the tank.

e) *Scour pipe* — Each tank shall be provided with a scour pipe with an accessible valve for emptying the tank.

f) *Connection of overflow and scour pipe* — Under no circumstances tank overflow and scour pipe shall be connected to any drain, gully trap or manhole to prevent back flow and contamination of the water. All such connections shall be discharged over a grating with an air gap of 50 mm. All overflow and vent pipes shall be provided with a mosquito proof brass grating to prevent ingress of mosquito, vermin and other insects.

g) The top slab of the tank shall be suitably sloped away from its centre for proper drainage of the rainwater.

h) Tanks on terraces and above ground shall be supported by appropriate structural members so as to transfer the load of the tank and the water directly on the structural members of the building.

4.4.5 Every storage tank shall be easily accessible and placed in such a position as to enable thorough inspection and cleaning to be carried out. If the storage capacity required is more than 5 000 litre, it is advantageous to arrange it in a series of tanks so interconnected that each tank can be isolated for cleaning and inspection without interfering with the supply of water. In large storage tanks, the outlet shall be at the end opposite the inlet to avoid stagnation of the water.

4.4.6 The outlet pipe shall be fixed 50 mm to 75 mm above the bottom of the tank and fitted with a strainer, preferably of brass.

4.4.7 In the case of underground storage tanks, the design of the tank shall be such as to provide for the draining of the tank when necessary and water shall not be allowed to collect around the tank. The tank shall be perfectly water-proof and shall be provided with a cement concrete cover, having a manhole opening, with a properly fitting hinged cast iron cover on a leak-proof cast iron frame.

The underground tanks should not be located in low lying areas or near any public or private sewer, septic tank, leaching pool or soakage pit to prevent any contamination. The overflow of the tank should be well above (preferably 600 mm) the external surface level and terminate as a warning pipe with a mosquito proof grating. Care shall be taken to prevent backflow of local surface water into the tank in case of local flooding. Otherwise the overflow shall be terminated in a safer manner as per the site conditions. For tanks with at least one side exposed to a basement, it is safer to discharge the overflow into the basement level.

The tank top slab shall also be designed to carry the load due to fire tender movement where anticipated as in the case of an extended basement.

There should be no common wall between the tanks storing safe water and tanks storing water from unsafe sources.

4.4.8 In case of overhead tanks, bottom of the tanks shall be placed clear off the terrace slab such that the elevation difference between the outlet pipe of the tank and the highest fixture at the top floor of the building is minimum 2 m, which shall also prevent leakage into the structural slab. In tall buildings, the top of the tank shall be provided with the safe ladder or staircase. The top slab shall be provided with railing or a parapet wall.

4.4.9 For jointing steel pipe to a storage tank, the end of the pipe shall be screwed, passed through a hole in the tank and secured by backnuts, both inside and outside. The pipe end shall be flush with the face of the inside backnut. For jointing copper pipe to steel or copper tank, a connector of non-ferrous material shall be used. The connector shall have a shoulder to bear on the outside of the tank and shall be secured by a backnut inside.

4.4.10 The quantity of water to be stored shall be calculated taking into account the following factors:

a) Hours of supply at sufficiently high pressure to fill up the overhead storage tanks;

b) Frequency of replenishment of overhead tanks, during the 24 h;

c) Rate and regularity of supply; and

d) Consequences of exhausting storage particularly in case of public buildings like hospitals.

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In case of intermittent water supply, the following guidelines should be adopted for calculation of capacity:

1) When the supply is from main OHT, the capacity of individual OHT may be taken as half a day demand.
2) In case of all the other buildings (apartments, hotels, hospitals, and commercial), the capacity of UGT and OHT may be taken as one and a half days and half a day demand. Wherever raw water and treated water are stored in separate UGTs, the combined storage capacity shall be of one and a half days demand.
3) In case of sewage treatment plant, for treated water storage in respect of flushing, one day flushing demand shall be stored in UGT or treated effluent storage tank which is part of the plant, and half a day demand shall be stored in OHT.

For additional requirement of water storage for fire fighting purposes, reference may be made to Part 4 'Fire and Life Safety' of the Code.

NOTE — Minimum requirements for calculation of capacity of these storage tanks are as follows:

a) In case only OHT is provided, it may be taken as 33.33 to 50 percent of one day's requirement;

b) In case only UGT is provided, it may be taken as 50 to 150 percent of one day's requirement; and

c) In case combined storage is provided, it may be taken as 66.6 percent UGT and 33.33 percent OHT of one day's requirement.

4.4.11 Where the water supply distribution system is catering for separate potable water and flushing water supply, and where reclaimed or recycled treated water is being used within the building, it shall be considered as dual water supply system. In such cases, storages for flushing/reclaimed/recycled water shall be separated proportionately. Adequate measures and precautions shall be taken for physical segregation for sanitary purposes and to avoid cross-contamination in the distribution system and to prevent back contamination of water supply sources (*see* **4.5**).

4.4.12 When only one communication pipe is provided for water supply to a building, it is not necessary to have separate storage for flushing and sanitary purposes for health reasons. In such cases when only one storage tank has been provided, tapping of water may be done at two different levels (the lower tapping for flushing) so that a part of the water will be exclusively available for flushing purposes.

4.5 Protection of Water Supply

4.5.1 *General*

The water supply system shall be designed, installed and maintained in such a manner so as to prevent contamination from non-potable liquids, solids or gases being introduced into the potable water supply system through cross-connections or any other connection to the system.

4.5.2 *Plumbing Fixtures*

The water supply lines and fittings for plumbing fixtures shall be installed so as to prevent back flow and shall provide required back flow protections in accordance with **4.11**.

The devices, appurtenance intended for special function such as sterilization, processing, distillation, etc, shall be provided with back flow protection devices.

The water supply for hospital fixtures shall be protected against backflow with a reduced pressure principle back flow assembly, an atmospheric or spill resistant vacuum breaker assembly, or an air gap. Vacuum breakers for bed pan washer hoses shall not be located less than 1 525 mm above floor. Vacuum breakers for hose connections in health care or laboratory areas shall not be less than 1 800 mm above floor.

4.5.3 *Cross-Connection Control*

Cross-connections shall be prohibited, except where approved back flow prevention assemblies/devices are installed to protect the potable water supply (*see* **4.11**).

Potable water outlets and combination stop and waste valves shall not be installed underground or below grade. Freeze proof yard hydrants that drain the riser into the ground are considered to be stop and waste valves.

Back flow prevention can be achieved by means of providing proper air gap, reduced pressure principle back flow prevention assemblies, back flow preventer with intermediate atmospheric vent, barometric loop, pressure vacuum breaker assemblies, atmospheric type vacuum breakers, double check back flow prevention assemblies, spill resistant pressure vacuum breaker, dual check back flow preventer, etc.

4.5.4 *Identification of Non-Potable Water Systems*

Where non-potable water systems are installed, the piping conveying the non-potable water shall be identified either by colour marking, metal tags or tapes in accordance with the relevant standards and good engineering practices.

4.6 Materials, Fittings and Appliances

4.6.1 *Standards for Materials, Fittings and Appliances*

All materials, water fittings and appliances shall conform to Part 5 'Building Materials' of the Code.

4.6.2 *Materials for Pipes*

Pipes may be of any of the following materials:

a) Cast iron, vertically cast or centrifugally (spun) cast;
b) Steel (internally lined or coated with bitumen or a bituminous composition, and out-coated with cement concrete or mortar, where necessary);

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c) Ductile iron, internally lined;
d) Reinforced concrete;
e) Prestressed concrete;
f) Galvanized mild steel tubes;
g) Copper;
h) Brass;
j) Wrought iron;
k) Stainless steel;
m) Polyethylene;
n) Unplasticized PVC;
p) Chlorinated PVC;
q) Polypropylene-random copolymer (PPR);
r) Composite pipes (PE-AL-PE) or any other combination;
s) Cross-linked polyethylene (PEX); or
t) Polybutylene pipe.

4.6.2.1 The material chosen shall be resistant to corrosion, both inside and outside or shall be suitably protected against corrosion.

4.6.2.2 Polyethylene and unplasticized PVC pipes shall not be installed near hot water pipes or near any other heat sources. For temperature limitations in the use of polyethylene and unplasticized PVC pipes to convey water, reference may be made to accepted standards [9-1(5)].

4.7 Design of Distribution Systems

4.7.1 *General*

For designing the distribution system, the following guidelines, in addition to those given in **4.7.2** to **4.7.6** shall be followed:

a) All plumbing systems in buildings shall conform to the general requirements given in **3.1**.
b) Peak factor for calculation in case of intermittent flows may generally be adopted in design as 2 to 3.
c) The residual head at consumer's tap shall be as per **3.1.2.**

4.7.2 *Rate of Flow*

One of the important items that needs to be determined before the sizes of pipes and fittings for any part of the water piping system may be decided upon, is the rate of flow in the service pipe which in turn depends upon the number of hours for which the supply is available at sufficiently high pressure. If the number of hours for which the supply is available is less, there will be large number of fittings in use simultaneously and the rate of flow will be correspondingly large.

The data required for determining the size of the communication and service pipes are,

a) the maximum rate of discharge required;
b) the length of the pipe; and
c) the head loss by friction in pipes, fittings and meters.

4.7.3 *Discharge Computation*

4.7.3.1 *Design of consumer's pipes based on fixture units*

The design of the consumers' pipes or the supply pipe to the fixtures is based on,

a) the number and kind of fixtures installed;
b) the fixture unit flow rate; and
c) the probable simultaneous use of these fixtures.

The rates at which water is desirably drawn into different types of fixtures are known. These rates become whole numbers of small size when they are expressed in fixture unit.

The water supply fixture units (WSFU) for different sanitary appliances or groups of appliances are given in Table 2.

4.7.3.2 *Probable simultaneous demand*

The possibility that all water supply taps in any system in domestic and commercial use will draw water at the same time is extremely remote. Designing the water mains for the gross flow will result in bigger and uneconomical pipe mains and may not be necessary. A probability study made by Hunter suggests the relationship shown in Fig. 2 and Table 3. In the absence of similar studies in India, the curves based on Hunter's study may be followed. In making use of these curves, special allowances are made as follows:

a) Demands for service sinks are ignored in calculating the total fixture demand.
b) Demands of supply outlets such as hose connections and air conditioners through which water flows more or less continuously over a considerable length of time shall be added to the probable flow rather than the fixture demand.
c) Fixtures supplied with both hot and cold water exert reduced demands upon main hot water and cold water branches (not fixture branches).

4.7.3.3 The maximum flow rate and flush volumes shall be as given below:

Plumbing Fixtures/Fittings	*Maximum Flow Rate*
Water closets	6 litre/flush
Urinals	3.8 litre/flush
Lavatory, metered faucet (Public)	1 litre/use
Lavatory, faucet (Private)	8 litre/min
Sink, faucet	8 litre/min
Bidet, hand held spray	8 litre/min
Shower head	10 litre/min

NOTE — The maximum flow rates of plumbing fixtures and fittings provided are at the pressure of 0.42 N/mm ^{2}. Water closet with dual flush cistern and urinals with reduced flush volumes are recommended. Further, users/ designers are encouraged to use low flow fixtures.

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4.7.4 *Pipe Size Computation*

Commercially available standard sizes of pipes are only to be used against the sizes arrived at by actual design. Therefore, several empirical formulae are used, even though they give less accurate results. The Hazen and William's formula and the charts based on the same may be used without any risk of inaccuracy in view of the fact that the pipes normally to be used for water supply are of smaller sizes. Nomogram of Hazen and William's equation has been provided in Annex C.

4.7.5 *Adequate and Excessive Water Pressure*

The requirements shall be as follows:

a) *Adequate water pressure* — A minimum water pressure in accordance with **3.1.2** shall be ensured in the distribution system. The maximum pressure shall be maintained at 0.42 N/mm^2. Also, while designing, the maximum/minimum pressure required for operation of special fixtures and fittings is to be maintained as per the technical data sheet.

b) *Excessive water pressure* — Whenever pressure exceeds 0.42 N/mm^2, and the distribution system may not be able to withstand the same, pressure reducing valves shall be installed for reduction of pressure.

4.7.6 *Water Hammer Effects*

Water hammer is recognized by the noise that is heard when valves are shut off. This occurs when flow of moving water is suddenly stopped due to closure of valve. Water hammer arrestors may be used to absorb high pressures resulting from sudden closure of valves.

Table 2 Water Supply Fixture Units (WSFU) for Different Fixtures with Minimum Pipe Sizes
(*Clause* 4.7.3.1)

Sl No.	Type of Fixture	Application		Minimum Pipe Size
		Private	Public	mm
(1)	(2)	(3)	(4)	(6)
i)	Bathtub	4	–	15
ii)	Ablution faucet/Bidet	1	1	15
iii)	Clothes washer	4	4 (*see* Note 7)	15
iv)	Dishwasher	1.5	1.5	15
v)	Drinking fountain	–	0.5 (0.75)	15
vi)	Hose bib	2.5	2.5	15
vii)	Wash basin (with metered faucet)	1	1	15
viii)	Wash basin (with standard faucet)	1.5	1.5 (2)	15
ix)	Service sink	1.5	3	15
x)	Kitchen sink	2	4	15
xi)	Surgical sink	–	2	15
xii)	Scrub station in hospital (per outlet)	–	3	15
xiii)	Shower	2	3	15
xiv)	Bathroom group (flush tank)	5	6	20
xv)	Bathroom group (flush valve)	8	10	25/32
xvi)	Urinal (flush valve)	3	5 (6)	20
xvii)	Urinal (flush tank)	2	2 (3)	15
xviii)	Urinal (sensor operated)	2	2 (3)	15
xix)	Water closet (flush valve)	6	8 (10)	25/32
xx)	Water closet (flush tank)	2	3 (5)	15
xxi)	Combination fixture (faucet)	3	–	15
xxii)	Laundry trays (faucet)	3	–	15

NOTES

1 The above table is based on Hunter's method.

2 Hunter's method of estimating load in plumbing systems is based on assigning a fixture unit (FU) weight to the plumbing fixtures and then converting these to equivalent litre per minute, based on the theory of probability of usage and based on the observation that all fixtures are not used simultaneously.

3 The fixture unit concept is a method of calculating maximum probable water demand within large buildings based on theory of probability. The method is based on assigning a fixture unit (FU) value to each type of fixture based on its rate of water consumption, on the length of time it is normally in use and on the average period between successive uses.

4 The values of probable demand will not change in respect of systems with flush valves and flush tanks for fixture units more than 1 000.

5 The fixtures or appliances which are not included in the above table may be sized referring to fixtures having similar flow rate and frequency of usage.

6 The minimum supply branch pipe sizes for individual fixtures are nominal sizes.

7 The clothes washer for public does not include large washer extractors, and in such cases the pipe sizing shall be determined as per manufacturer's recommendations.

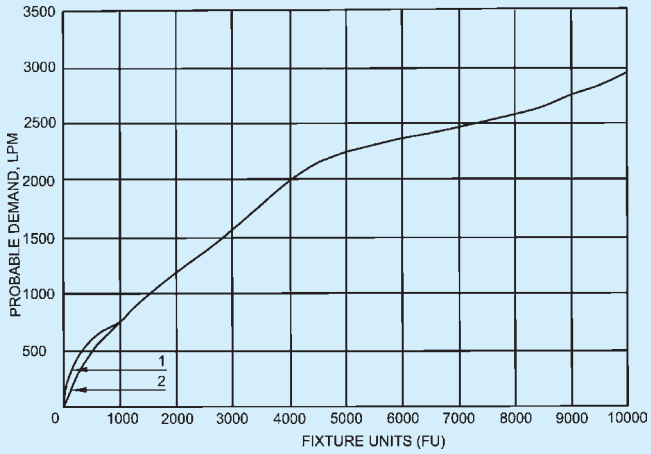
8 For more information on bathroom groups, reference may be made to specialist literature.

9 The fixture units listed in the above table represent the load for cold water service. The separate cold and hot water fixture unit value for fixtures having both hot and cold water connections may each be taken as three quarter of the listed total value of fixture.

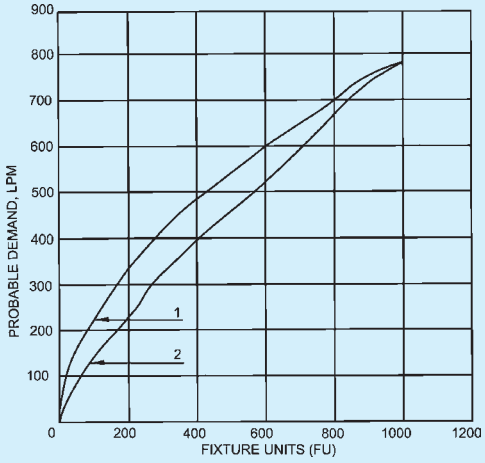
10 A shower head over a bath tub does not increase the fixture unit value.

11 The values given in parentheses pertain to such public use buildings (congregation halls) where an enhanced requirement is expected to be encountered as compared to the normal maximum use in public use buildings.

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2A GRAPH FOR PROBABLE DEMAND UP TO 10 000 FU



2B GRAPH FOR PROBABLE DEMAND UP TO 1 000 FU

Curve 1 — System With Flush Valves
Curve 2 — System With Flush Tanks

FIG. 2 GRAPH FOR PROBABLE DEMAND

4.8 Distribution Systems in Multi-Storeyed Buildings

4.8.1 There are following four basic methods of distribution of water to a multi-storeyed buildings:

a) Direct supply system from mains — public or private.
b) Gravity distribution system.
c) Pressurized distribution system (Hydro-pneumatic pumping system).
d) Combined distribution system.

4.8.2 *Direct Supply System from Mains — Public or Private*

This system is adopted when adequate pressure is available in the mains to supply water at adequate pressure at the topmost floor. With limited pressure available in most city mains, water from direct supply is normally not available above two or three floors. However, in gated communities or large campuses, this system can be adopted for taller buildings by incorporating design parameters such as elevated centralized water tank(s) or central hydro-pneumatic pumping system(s). For details of this system, reference may be made to good practice [9-1(6)] may be referred.

4.8.3 *Gravity Distribution System*

This is the most common water distribution system. The system comprises pumping water to one or more overhead water tanks. Water transferred to overhead tank(s) is distributed by gravity to various parts of the building by the system of piping network.

4.8.4 *Pressurized Distribution System (Hydro-pneumatic Pumping System)*

4.8.4.1 Pressurized distribution system is a direct pumping system incorporating a recharge diaphragm vessel.

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Table 3 Probable Simultaneous Demand
(*Clause* 4.7.3.2)

Sl No.	Demand in Fixture Units	Demand with Flush Tanks litre/min	Demand with Flush Valves litre/min
(1)	(2)	(3)	(4)
i)	1	0	—
ii)	2	3.8	—
iii)	3	11.4	—
iv)	4	15.1	—
v)	5	22.7	—
vi)	6	25.5	—
vii)	8	28.1	—
viii)	10	30.3	102.20
ix)	20	53.0	132.48
x)	30	75.7	155.19
xi)	40	94.6	177.90
xii)	50	109.8	196.82
xiii)	60	121.1	208.18
xiv)	70	132.5	223.32
xv)	80	143.8	234.67
xvi)	90	155.2	246.03
xvii)	100	166.5	257.38
xviii)	140	200.6	295.23
xix)	180	230.9	329.30
xx)	200	246.0	348.22
xxi)	250	283.9	382.29
xxii)	300	321.7	416.35
xxiii)	400	397.4	476.91
xxiv)	500	473.1	537.47
xxv)	750	643.5	673.73
xxvi)	1 000	787.3	787.28
xxvii)	1 250	908.4	908.40
xxviii)	1 500	1 010.6	1 010.60
xxix)	1 750	1 112.8	1 112.79
xxx)	2 000	1 215.0	1 214.99
xxxi)	2 500	1 419.4	1 419.38
xxxii)	3 000	1 635.1	1 635.12
xxxiii)	3 500	1 811.1	1 811.12
xxxiv)	4 000	1 987.1	1 987.13
xxxv)	4 500	2 115.8	2 115.82
xxxvi)	5 000	2 244.5	2 244.51
xxxvii)	5 500	2 312.6	2 312.64
xxxviii)	6 000	2 380.8	2 380.77
xxxix)	6 500	2 411.0	2 411.05
xl)	7 000	2 479.2	2 479.18
xli)	7 500	2 547.3	2 547.31
xlii)	8 000	2 615.4	2 615.44
xliii)	8 500	2 683.6	2 683.57
xliv)	9 000	2 751.7	2 751.70
xlv)	9 500	2 831.2	2 831.18
xlvi)	1 0000	2 910.7	2 910.67

4.8.4.2 The system may incorporate multiple pumps with suction and discharge manifolds and a control panel to facilitate automatic operation. Total discharge capacity required may be shared by a number of pumps, where the pumps operate in duty, assist and standby configuration.

4.8.4.3 The system shall also incorporate automatic sequencing of pumps to ensure even wear and tear also a low level cutoff, to prevent dry run of the pumps. The system shall be provided with continuous power supply with provision of emergency power backup.

4.8.4.4 Modern hydro-pneumatic systems are available with variable frequency drive, where the pump is efficiently used to deliver water at rates of flow as required by the system, by varying its speed with the assistance of an electronic device, thereby meeting the demand flow through variation in speed of the motor from 960 rpm to 3 000 rpm. With this arrangement, the same pump is able to deliver water at required pressure and flow as required at different times of the day. The system consumes energy in proportion to the work done and also helps in controlling the water surge in the distribution line.

4.8.4.5 Hydro-pneumatic system generally eliminates the need of an overhead tank. As a good engineering practice and to take care of emergencies, an overhead of smaller capacity should be provided which feeds by gravity to the system (*see* Fig. 3).

4.8.5 *Combined Distribution System*

4.8.5.1 In this system, a combination of gravity and pressurized distribution is adopted. A few upper floors are provided with a pressure booster pumping system to achieve the desired residual pressure, while the lower floors are fed by gravity supply.

4.8.5.2 Water collected in the overhead tank is distributed to the various parts of the building. To achieve required residual pressure for top 2 to 4 floors for proper functioning of the fixtures, a pressure booster pumping system is installed on the dedicated outlet from overhead tank with its own distribution piping serving the top 2 to 4 floors. For lower floors, water is distributed by gravity system.

4.8.5.3 Water distribution is accomplished by providing down take pipes in the shaft from the terrace ring mains (*see* Fig. 4).

4.8.6 *Zoning of Distribution Systems*

The zoning of water distribution network may be adopted for 7 to 9 floors, while conforming to the adequate pressure requirements and excessive pressure limitations in the hydraulic design (*see* **4.7.5**). *See* Fig. 5 and Fig. 6 for zoning of gravity distribution system and pressurized distribution system (hydro-pneumatic pumping system), respectively.

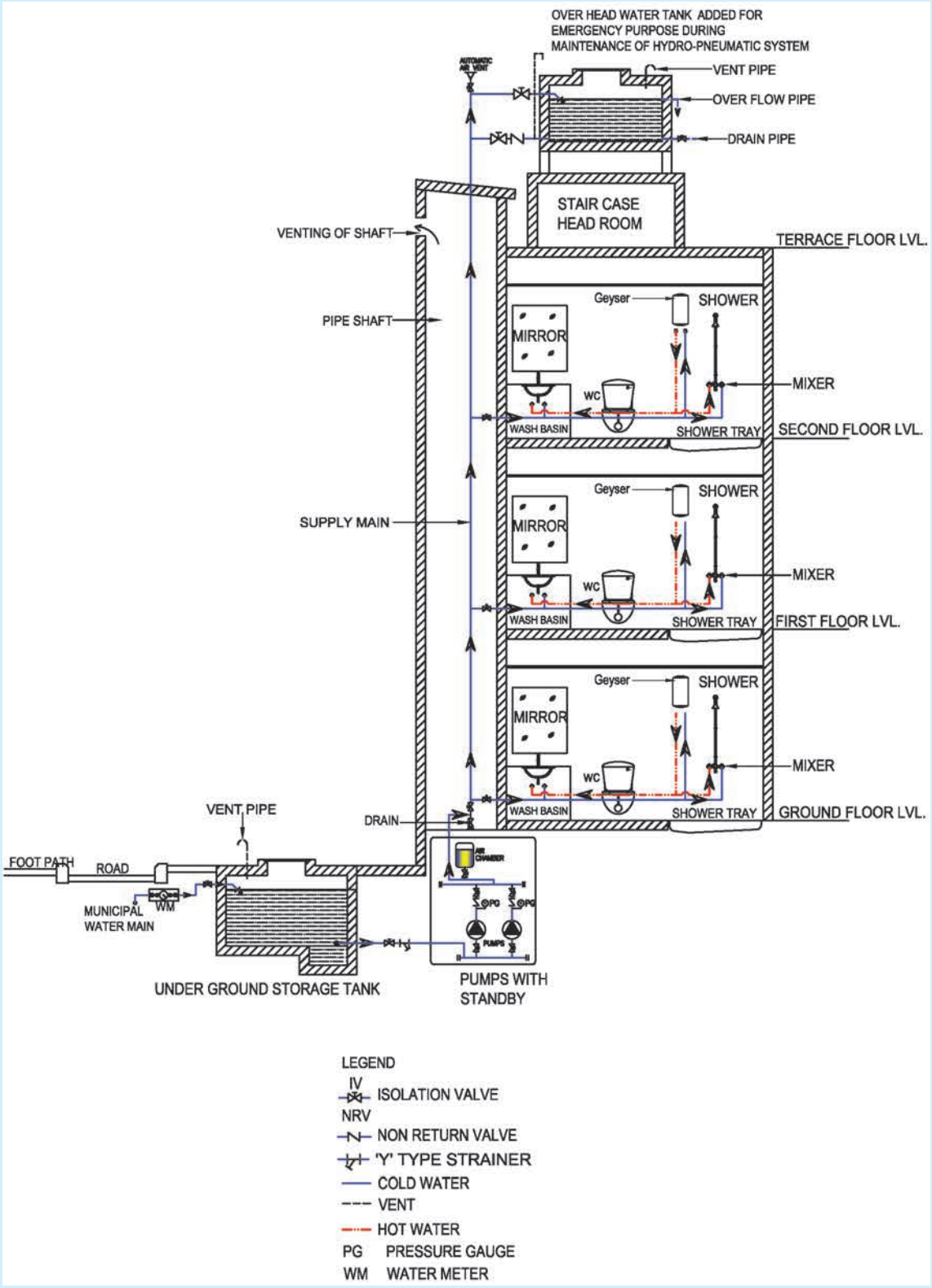
The recommended maximum permissible velocity is 2.4 m/s for water distribution. In case of hot water distribution through copper pipes, the velocity is restricted to 1.5 m/s due to concern of erosion of the piping material.

4.9 General Requirements for Pipe Work

4.9.1 *Mains*

The following principles shall apply for the mains:

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NOTES

1 Hot water supply to be planned as per requirement by provision of geyser and hot water piping.

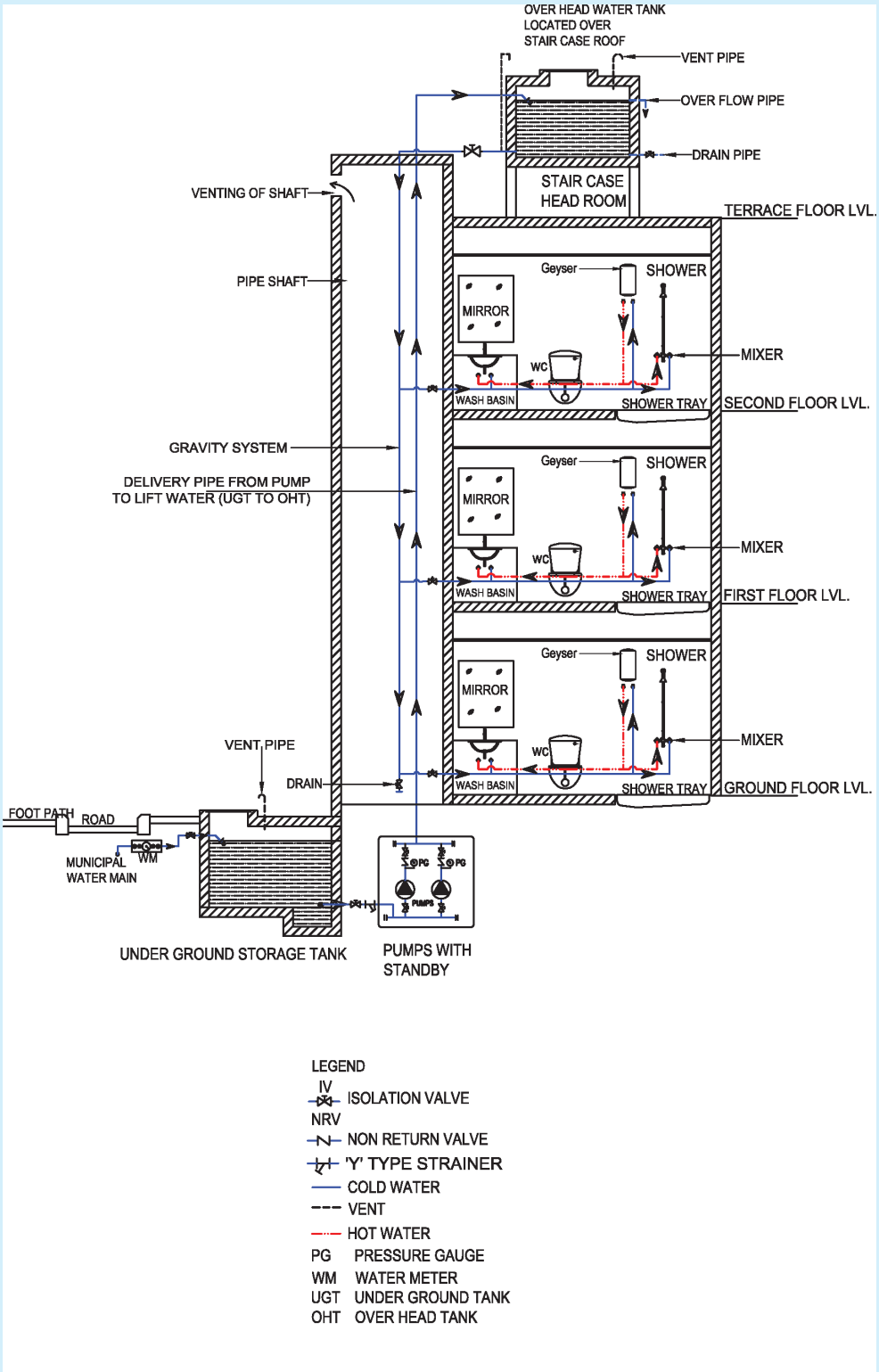
2 Flushing water supply from WC to be planned in case availability of recycled waste water.

3 For large and commercial buildings, water supply to be based on zone-based distribution for domestic and flushing water supply.

4 Presentation of layout and location of fixtures/appliances are only typical in nature.

FIG. 3 HYDRO-PNEUMATIC SYSTEM

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NOTES

1 Pump operation to be by level controller or air vessel/pressure switch at motorized valve at OHT.

2 Hot water supply to be planned as per requirement by provision of geyser and hot water piping.

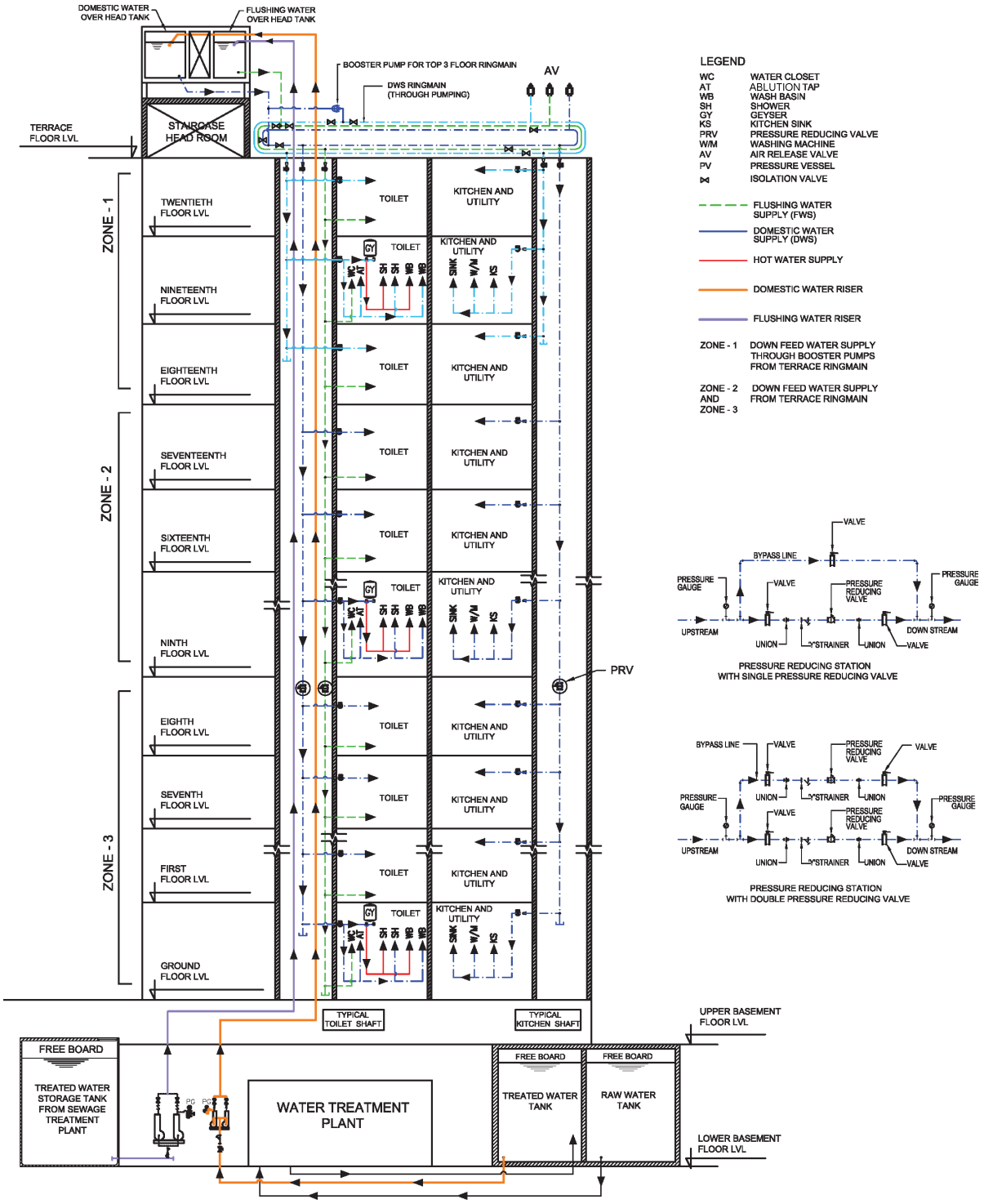
3 Flushing water supply from WC to planned in case of availability of recycled waste water.

4 For large and commercial buildings, water supply to be based on zone-based distribution for domestic and flushing water supply.

5 Presentation of layout and location of fixtures/appliances are only typical in nature.

FIG. 4 OVER HEAD TANK DISTRIBUTION

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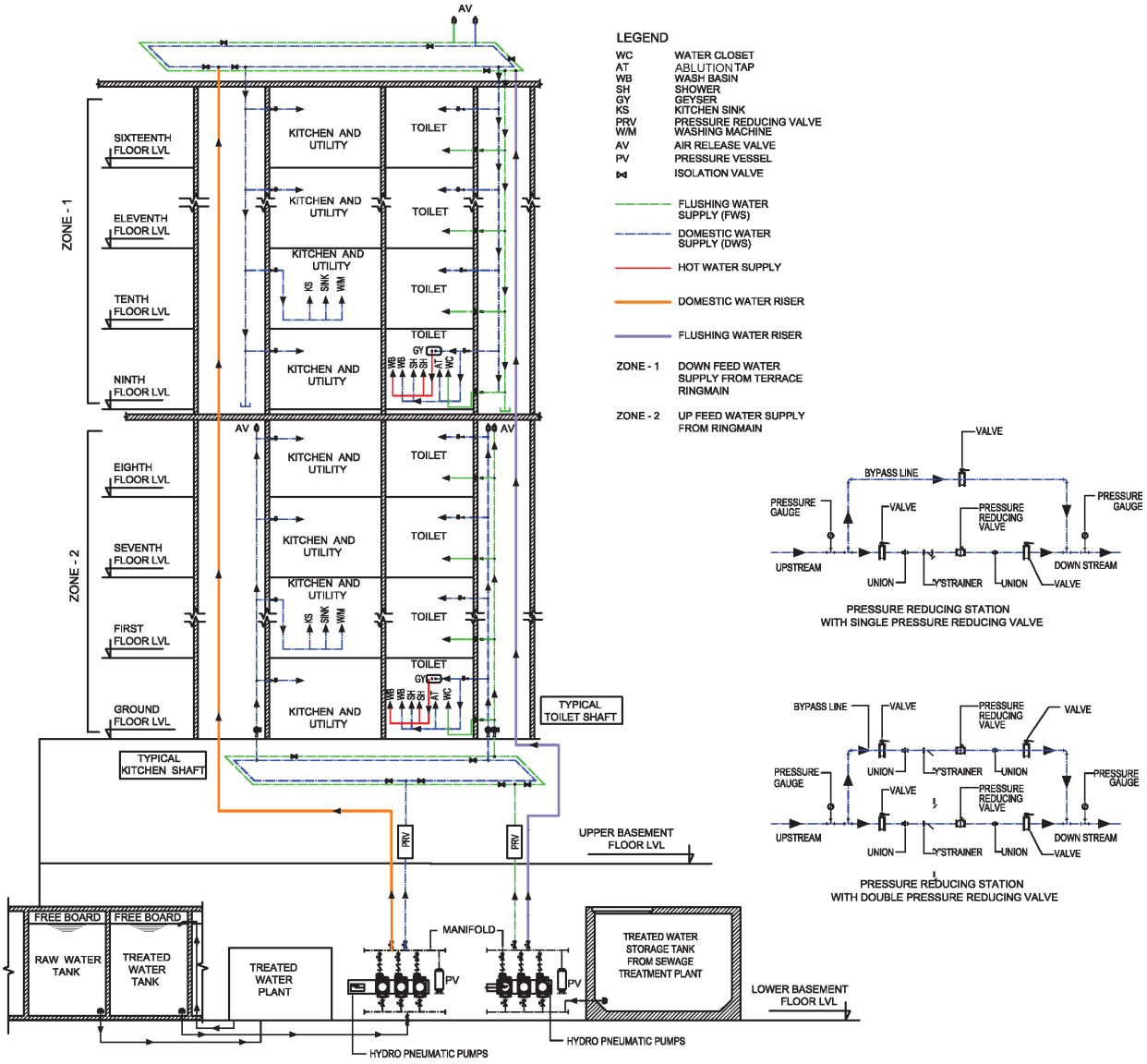
NOTES

1 Appurtenance, such as PRV should be planned in main piping network or branch piping, as required, to restrain pressure to upper limits.

2 Requirements for storage and usage of fire water shall be as per Part 4 'Fire and Life Safety' of the Code.

FIG. 5 SCHEMATIC DIAGRAM SHOWING THE DISTRIBUTION SYSTEM IN RESPECT OF GRAVITY SYSTEM FOR A MULTI-STOREYED BUILDING

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NOTES

1 The given example is for 16 storeyed building with concept of upfeed and down feed ringmains. The choice of ringmain is on designer proposal. For taller building, zones and ringmains shall be planned to meet maximum and minimum pressure requirements. Appurtenance, such as PRV should be planned in main piping network or branch piping, as required, to restrain pressure to upper limits.

2 Requirements for storage and usage fo fire water shall be as per Part 4 'Fire and Life Safety' of the Code.

FIG. 6 SCHEMATIC DIAGRAM SHOWING THE DISTRIBUTION SYSTEM IN RESPECT OF HYDRO-PNEUMATIC SYSTEM FOR A MULTI-STOREYED BUILDING

a) Service mains shall be of adequate size to give the required rate of flow.

b) Mains shall be divided into sections by the provisions of sluice valves and other valves so that water may be shut off for repairs.

c) To avoid dead ends, the mains shall be arranged in a grid formation or in a network.

d) Where dead ends are unavoidable, a hydrant shall be provided to act as a wash-out.

e) Wash-out valve shall not discharge directly into a drain or sewer, or into a manhole or chamber directly connected to it; an effectively trapped chamber shall be interposed, into which the wash-out shall discharge.

f) Air valves shall be provided at all summits, and wash-out at low points between summits.

g) Mains need not be laid at unvarying gradients,

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but may follow the general contour of the ground. They shall, however, fall continuously towards the washout and rise towards the air valves. The gradient shall be such that there shall always be a positive pressure at every point under working conditions.

h) Cover for the mains shall be at least 900 mm under roadways and 750 mm in the case of footpaths. This cover shall be measured from the top of the pipe to the surface of the ground.

j) Mains shall be located sufficiently away from other service lines like electric and telegraph cables to ensure safety and where the mains cannot be located away from such lines, suitable protective measures shall be accorded to the mains. As far as possible, water supply and sewerage mains should be isolated from each other with certain minimum horizontal distance as per good engineering practice.

4.9.2 *Communication Pipes*

a) Every premises that is supplied with water by the Authority shall have its own separate communication pipe. In the case of a group or block of premises belonging to the same owner the same communication pipe may supply water to more than one premises with the prior permission of the Authority.

b) The communication pipe between the water main and the stop-cock at the boundary of the premises shall be laid by the Authority.

c) Connections up to 50 mm diameter may be made on the water main by means of screwed ferrules, provided the size of the connections does not exceed one third the size of the water main. In all other cases, the connection shall be made by a T-branch off the water main.

d) As far as practicable, the communication pipe and the underground service pipe shall be laid at right angles to the main and in approximately straight lines to facilitate location for repairs. It is also recommended that the communication pipe be laid in a pipe in pipe sleeve of larger diameter made of non-corrosive material to protect the communication pipe.

e) Every communication pipe shall have a stop-cock and meter inserted in it. The waterway of each such fitting shall not be less than the internal sectional area of the communication pipe and the fittings shall be located within the premises at a conspicuous place accessible to the Authority which shall have exclusive control over it.

4.9.3 *Consumer Pipes*

a) No consumer pipe shall be laid in the premises to connect the communication pipe without the approval of the Authority.

b) The consumer pipe within the premises shall be laid underground with a suitable cover to safeguard against damage from traffic and extremes of weather.

c) To control the branch pipe to each separately occupied part of a building supplied by a common service pipe, a stop valve shall be fixed to minimize the interruption of the supply during repairs. All such stop valves shall be fixed in accessible positions and properly protected. To supply water for drinking or for culinary purposes, direct taps shall be provided on the branch pipes connected directly to the consumer pipe. In the case of multi-storeyed buildings, down take taps shall be supplied from overhead tanks.

d) Pumps shall not be allowed on the service pipe, as they cause a drop in pressure on the suction side, thereby affecting the supply to the adjoining properties. In cases where pumping is required, a properly protected storage tank of adequate capacity shall be provided to feed the pump.

e) No direct boosting (by booster pumps) shall be allowed from the service pipes (communication and consumer pipes).

f) Consumer pipes shall be so designed and constructed as to avoid air-locks. Draining taps shall be provided at the lowest points from which the piping shall rise continuously to draw-off taps.

g) Consumer pipes shall be so designed as to reduce the production and transmission of noise as much as possible.

h) Consumer pipes in roof spaces and unventilated air spaces under floors or in basements shall be protected against corrosion.

j) Consumer pipes shall be so located that they are not unduly exposed to accidental damage and shall be fixed in such positions as to facilitate cleaning and avoid accumulations of dirt.

k) All consumer pipes shall be so laid as to permit expansion and contraction or other movements.

4.9.4 *Prohibited Connections*

a) A service pipe shall not be connected into any distribution pipe; such connection may permit the backflow of water from a cistern into the service pipe, in certain circumstances, with

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consequent danger of contamination and depletion of storage capacity. It might also result in pipes and fittings being subjected to a pressure higher than that for which they are designed, and in flooding from overflowing cisterns.

b) No pipe for conveyance or in connection with water supplied by the Authority shall communicate with any other receptacle used or capable of being used for conveyance other than water supplied by the Authority.

c) Where storage tanks are provided, no person shall connect or be permitted to connect any service pipe with any distributing pipe.

d) No service or supply pipe shall be connected directly to any water-closet or a urinal. All such supplies shall be from flushing cisterns/ flush valves which shall be supplied from storage tank.

e) No service or supply pipe shall be connected directly to any hot water system or to any other apparatus used for heating other than through a feed cistern thereof.

4.10 Jointing of Pipes

4.10.1 *Cast Iron Pipes*

Jointing may be done by any of the following methods:

a) Spigot and socket joints, or
b) Flanged joints.

in accordance with good practice [9-1(7)]. The lead shall conform to the accepted standards [9-1(8)].Alternative jointing materials which are found to be equally effective, may be used in place of lead joints, with the approval of the Authority.

4.10.2 *Steel Pipes*

Plain-ended steel pipes may be jointed by welding. Electrically welded steel pipes shall be jointed in accordance with good practice [9-1(9)].

4.10.3 *Wrought Iron and Steel Screwed Pipes*

Screwed wrought iron or steel piping may be jointed with screwed and socketed joints. Care shall be taken to remove any burr from the end of the pipes after screwing. A jointing compound approved by the Authority and containing no red lead composition shall be used. Screwed wrought iron or steel piping may also be jointed with screwed flanges.

4.10.4 *Asbestos Cement Pipes*

Asbestos cement pipes may be jointed in accordance with good practice [9-1(10)].

4.10.5 *Copper Pipes*

Copper pipes shall be jointed by internal solder ring joint, end-brazing joint or by use of compression fitting. The flux used shall be non-toxic and the solder used shall be lead free. The use of dezincification fittings shall be made in case of jointing of copper pipe and steel pipe. The jointing technology shall be used as per good engineering practice and as per manufacturers recommendations.

4.10.6 *Concrete Pipes*

Concrete pipes shall be jointed in accordance with good practice [9-1(11)].

4.10.7 *Polyethylene and Unplasticized PVC Pipes*

Polyethylene and unplasticized PVC pipes shall be jointed in accordance with good practice[9-1(12)].

4.11 Backflow Prevention

4.11.1 The installation shall be such that water delivered is not liable to become contaminated or that contamination of the public water supply does not occur.

4.11.2 The various types of piping and mechanical devices acceptable for backflow protection are:

a) Barometric loop,
b) Air gap,
c) Atmosphere vacuum breaker,
d) Pressure vacuum breaker,
e) Double check valve, and
f) Reduced pressure backflow device.

4.11.3 The installation shall not adversely affect drinking water,

a) by materials in contact with the water being unsuitable for the purpose;
b) as a result of backflow of water from water fittings, or water using appliances into pipework connected to mains or to other fittings and appliances;
c) by cross-connection between pipes conveying water supplied by the water undertaker with pipes conveying water from some other source; and
d) by stagnation, particularly at high temperatures.

4.11.4 No pump or similar apparatus, the purpose of which is to increase the pressure in or rate of flow from a supply pipe or any fitting or appliance connected to a supply pipe, shall be connected unless the prior written permission of the water supplier has been obtained in each instance.

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The use of such a pump or similar apparatus is likely to lead to pressure reduction in the upstream pipe work which, if significant, increase the risk of backflow from other fittings.

4.11.5 The water shall not come in contact with unsuitable materials of construction.

4.11.6 No pipe or fitting shall be laid in, on or through land fill, refuse, an ash pit, sewer, drain, cesspool or refuse chute or any manhole connected with them.

4.11.7 No pipe susceptible to deterioration by contact with any substance shall be laid or installed in a place where such deterioration is likely to occur. No pipe that is permeable to any contaminant shall be laid or installed in any position where permeation is likely to occur.

4.11.8 If a liquid (other than water) is used in any type of heating primary circuit, which transfers heat to water for domestic use, the liquid shall be non-toxic and non-corrosive.

4.11.9 A backflow prevention device shall be arranged or connected at or as near as practicable to each point of delivery and use of water. Appliances with built-in backflow prevention shall be capable of passing the test. All backflow prevention devices shall be installed so that they are accessible for examination, repair or replacement. Such devices shall be capable of being tested periodically by the Authority to ensure that the device is functioning efficiently and no backflow is occurring at any time.

4.12 Conveyance and Distribution of Water Within the Premises

4.12.1 *Basic Principles*

Wholesome water supply provided for drinking and culinary purposes shall not be liable to contamination from any less satisfactory water. There shall, therefore, be no cross-connection whatsoever between the distribution system for wholesome water and any pipe or fitting containing unwholesome water, or water liable to contamination, or of uncertain quality, or water which has been used for any other purpose. The provision of reflux or non-return valves or closed and sealed stop valves shall not be construed as a permissible substitute for complete absence of cross-connection.

4.12.2 The design of the pipe work shall be such that there is no possibility of backflow towards the source of supply from any cistern or appliance, whether by siphonage or otherwise. Reflux non-return valves shall not be relied upon to prevent such backflow.

4.12.3 Where a supply of less satisfactory water than wholesome water becomes inevitable as an alternative or is required to be mixed with the latter, it shall be delivered only into a cistern and by a pipe or fitting discharging into the air gap at a height above the top edge of the cistern equal to twice its nominal bore and in no case less than 150 mm. It is necessary to maintain a definite air gap in all appliances or taps used in water-closets.

4.12.4 All pipe work shall be so designed, laid or fixed and maintained as to remain completely water-tight, thereby avoiding wastage, damage to property and the risk of contamination.

4.12.5 No water supply line shall be laid or fixed so as to pass into or through any sewer, scour outlet or drain or any manhole connected therewith, nor through any ash pit or manure pit or any material of such nature that is likely to cause undue deterioration of the pipe.

4.12.5.1 Where the laying of any pipe through corrosive soil or pervious material is unavoidable, the piping shall be properly protected from contact with such soil or material by being carried through an exterior pipe sleeves as approved by the Authority. Any existing piping or fitting laid or fixed, which does not comply with the above requirements, shall be removed immediately by the consumer and re-laid by him in conformity with the above requirements and to the satisfaction of the Authority.

4.12.5.2 Where lines have to be laid in close proximity to electric cables or in corrosive soils, adequate precautions/protection should be taken to avoid corrosion.

4.12.6 Underground piping shall be laid at such a depth that it is unlikely to be damaged by frost or traffic loads and vibrations. It shall not be laid in ground liable to subsidence, but where such ground cannot be avoided, special precautions shall be taken to avoid damage to the piping. Where piping has to be laid across recently disturbed ground, the ground shall be thoroughly consolidated so as to provide a continuous and even support. In the case of frost conditions, the pipes shall be laid below the frost line with suitable insulation to the pipes.

4.12.7 In designing and planning the layout of the pipe work, due attention shall be given to the maximum rate of discharge required, economy in labour and materials, protection against damage and corrosion, water hammer, protection from frost, if required, and avoidance of airlocks, noise transmission and unsightly arrangement.

4.12.8 To reduce frictional losses, piping shall be as

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smooth as possible inside. Methods of jointing shall be such as to avoid internal roughness and projection at the joints, whether of the jointing materials or otherwise.

4.12.9 Change in diameter and in direction shall preferably be gradual rather than abrupt to avoid undue loss of head. No bend or curve in piping shall be made which is likely to materially diminish or alter the cross-section.

4.12.10 No boiler for generating steam or closed boilers of any description or any machinery shall be supplied direct from a service or supply pipe. Every such boiler or machinery shall be supplied from a feed cistern.

4.13 Laying of Mains and Pipes on Site

4.13.1 The mains and pipes on site shall be laid in accordance with good practice [9-1(13)]. The pipes laid in buildings situated in seismic zone and across large building expansion joints should be installed with suitable expansion bellows and expansion loops to mitigate expansion of piping system for its intended function without failures.

4.13.2 *Excavation and Refilling*

The bottoms of the trench excavations shall be so prepared that the barrels of the pipes, when laid, are well bedded for their whole length on a firm surface and are true to line and gradient. In the refilling of trenches, the pipes shall be surrounded with fine selected material, well rammed so as to resist subsequent movement of the pipes. No stones shall be in contact with the pipes; when resting on rock, the pipes shall be bedded on fine-selected material or (especially where there is a steep gradient) on a layer of concrete.

4.13.2.1 The pipes shall be carefully cleared of all foreign matter before being laid.

4.13.3 *Laying Underground Mains*

Where there is a gradient, pipe laying shall proceed in 'uphill' direction to facilitate joint making.

4.13.3.1 Anchor blocks shall be provided to withstand the hydraulic thrust.

4.13.4 Iron surface boxes shall be provided to give access to valves and hydrants and shall be supported on concrete or brickwork which shall not be allowed to rest on pipes.

4.13.5 *Laying Service Pipes*

4.13.5.1 Service pipes shall be connected to the mains by means of right-hand screw down ferrule or T-branches. The ferrules shall conform to accepted standards [9-1(14)].

4.13.5.2 Precaution against contamination of the mains shall be taken when making a connection and, where risk exists, the main shall be subsequently disinfected. The underground water service pipe and the building sewer or drain shall be kept at a sufficient distance apart so as to prevent contamination of water. Water service pipes or any underground water pipes shall not be run or laid in the same trench as the drainage pipe. Where this is unavoidable, the following conditions shall be fulfilled:

a) The bottom of the water service pipe, at all points, shall be at least 300 mm above the top of the sewer line at its highest point.
b) The water service pipe shall be placed on a solid shelf excavated on one side of the common trench.
c) The number of joints in the service pipe shall be kept to a minimum.
d) The materials and joints of sewer and water service pipe shall be installed in such a manner and shall possess such necessary strength and durability as to prevent the escape of solids, liquids and gases there from under all known adverse conditions, such as corrosion strains due to temperature changes, settlement, vibrations and superimposed loads.

4.13.5.3 The service pipe shall pass into or beneath the buildings at a depth of not less than 750 mm below the outside ground level and, at its point of entry through the structure, it shall be accommodated in a sleeve which shall have previously been solidly built into the wall of the structure. The space between the pipe and the sleeve shall be filled with bituminous or other suitable material for a minimum length of 150 mm at both ends.

4.13.6 *Pipes Laid through Ducts, Chases, Notches or Holes*

Ducts or chases in walls for piping shall be provided during the building of the walls. If they are cut into existing walls, they shall be finished sufficiently smooth and large enough for fixing the piping.

4.13.6.1 Piping laid in notches or holes shall not be subjected to external pressure.

4.13.7 *Lagging of Pipes*

Where lagged piping outside buildings is attached to walls, it shall be entirely covered all round with water-proof and fire insulating material and shall not be in direct contact with the wall. Where it passes through a wall, the lagging shall be continued throughout the thickness of the wall.

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4.14 Hot Water Supply Installations

4.14.1 *Design Consideration*

4.14.1.1 *General*

In electric water heating practice for domestic purposes, the accepted method is to use storage heaters in which water is steadily heated up to a predetermined temperature and stored until required for use. The heating by electricity of a large quantity of water, such as water required for a hot bath, within the time normally taken to run the water into the bath, requires a heater of too high a rating to be practicable in normal domestic premises. It should be ensured that such vents and pipes are above reach/inaccessible during daily use to avoid accidents such as accidental contact and burning.

4.14.1.2 In modern hotels and apartment blocks and service apartments, centralized storage and distribution systems are adopted, where other energy sources such as oil, gas, solar panels, etc, may be used for the generation of hot water as these options prove more economical and convenient in heating large volumes of water for storage.

4.14.1.3 When water supplied to the buildings contain dissolved salts resulting in hardness of water, measures such as installation of water softening plants, etc, shall be taken to avoid formation of scales in the hot water installations.

4.14.2 *Storage Temperature*

4.14.2.1 The design of hot water supply system and its appliances shall be based on the temperatures at which water is normally required for the various uses, namely:

Scalding	:	65°C
Sink	:	60°C
Hot bath	:	43°C as run for use at 41°C
Warm bath	:	37°C
Tepid bath	:	29.5°C

4.14.2.2 In order to minimize the danger of scalding, precipitation of scale from hard water, standing heat losses, risk of steam formation and the possibility of damage to porcelain or other fittings and to surface finishes, a storage temperature of 60°C is recommended. If storage capacity is limited, a higher temperature up to 65°C may be adopted when soft water is used.

4.14.3 *Storage Capacity*

The size of the storage vessel is governed by the maximum short time demand of the domestic premises. Depending on local conditions this shall be 50 litre to 75 litre at 60°C in a dwelling with a bath tub and 25 litre at 60°C for a shower or a tap (for bucket supply). The capacity of the storage vessel shall not be less than 20 percent in excess of the required maximum short time demand. In larger houses where a single hot water heater is intended to supply hot water to more than one bathroom or kitchen or both, the maximum short time demand shall be estimated and the capacity decided accordingly. Small electric or gas storage heaters of 15 litre to 25 litre capacity may be used to supply one or two points of draw off depending on the use of hot water.

4.14.4 *Rate of Flow*

With storage type installation, the recommended maximum rates of flow for different types of fixtures are given in Table 4.

Table 4 Rate of Hot Water Flow
(*Clause* 4.14.4)

Sl No.	Fixtures	Rate of Flow litre/min
(1)	(2)	(3)
i)	Kitchen sink	5
ii)	Wash basin	5
iii)	Shower (spray type)	6.5

4.14.4.1 *Hot water supply systems*

Identification of water supply system is critical for safe functioning and protection of occupants. The first step is correct labelling of various water systems in the building. The requirements of identification/labelling shall be adhered on every installation where different water systems are provided.

While designing centralized hot water systems in major projects, the following points should be considered:

a) Fuel to be used,
b) Location and dimension of boiler house and calorifier chambers,
c) Location and dimension of fuel storage tank,
d) Means of ash disposal (in case of solid fuel),
e) Location and dimension of chimney,
f) Location of cold water points,
g) Drainage facilities during emptying,
h) Quality of water supply, and
j) Provision for air combustion and ventilation.

In laying hot water piping systems, the pressures of hot and cold water should be made equal at each fixture, especially where mixing faucets/thermostatic mixer are to be used. Otherwise, there would be imbalance of pressure where one pressure would be more than the other. These conditions should be avoided by proper design of the system.

Return circulation systems are recommended for energy conservation and user comfort.

In the inverted systems, hot water heaters and tanks

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are located at the highest point of water supply system and supply and return risers below the level of hot water source.

Environmental and consumer requirements should be considered when planning the installation of a solar hot water system. Factors affecting the performance of a system and decisions about how the system should be installed, include,

1) the climate zone of the site and possibility of,
   i) shading;
   ii) frost and freezing;
   iii) wind;
   iv) dust;
   v) hail; and
   vi) corrosion and scaling.
2) the ambient air temperature.
3) the cold water temperature.
4) the availability of space and pitch of a suitable south-facing roof.
5) the presence and location of an existing hot water service.
6) the available energy sources (for example, gas or electricity).
7) the householder's hot water usage.
8) the householder's budget.

4.14.5 *Design of Storage Vessel*

Storage tanks shall be oblong or cylindrical in shape and shall be installed, preferably with the long side vertical in order to assist the effective stratification or 'layering' of hot or cold water. The ratio of height to width or diameter shall not be less than 2 : 1. An inlet baffle should preferably be fitted near the cold inflow pipe in order to spread the incoming cold water.

4.14.6 *Materials for Storage Vessel and Pipes*

4.14.6.1 Under no circumstances shall ungalvanized (black) mild steel pipes and fittings, such as sockets, bushes, etc, be used in any part of domestic hot water installation, including the cold feed pipe and the vent pipe. Materials resistant to the chemical action of water supplied shall be used in construction of vessels and pipes. Each installation shall be restricted to one type of metal only, such as all copper or all galvanized mild steel. When water supplied is known to have appreciable salt content, galvanized iron vessels and pipes shall not be used. However, it is advisable to avoid use of lead pipes in making connection to wash basins. Where required it is also advisable to use vessels lined internally with glass, stainless steel, etc.

4.14.6.2 In general, tinned copper and other metals such as monel metal, etc, are suitable for most types of water. The suitability of galvanized mild steel for storage tanks depends upon the *p*H value of the water and the extent of its temporary hardness. For values of *p*H 7.2 or less, galvanized mild steel should not be used. For values of *p*H 7.3 and above, galvanized mild steel may be used provided the corresponding temporary hardness is not lower than those given below:

*p*H *Value*	*Minimum Temporary Hardness Required* mg/l
7.3	210
7.4	150
7.5	140
7.6	110
7.7	90
7.8	80
7.9-8.5	70

4.14.7 *Location of Storage Vessel*

The loss of heat increases in proportion to the length of pipe between the storage vessel and the hot water outlet since each time the water is drawn, the pipe fills with hot water which then cools. The storage vessel shall therefore be so placed that the pipe runs to the most frequently used outlets are as short as possible.

4.14.8 *Immersion Heater Installation*

4.14.8.1 If a domestic storage vessel is to be adopted to electric heating by the provision of an immersion heater and thermostat, the following precautions shall be observed:

a) *Location of immersion heaters* — The immersion heater shall be mounted with its axis horizontal, except in the case of the circulation type which is normally mounted with its axis approximately vertical.
b) In a tank with a flat bottom, a space of not less than 75 mm below the immersion heater and 50 mm below the cold feed connection shall be provided to allow for accumulation of sludge and scale, where it will not affect the working of the immersion heater.
c) In a cylindrical storage vessel with inwardly dished bottom, the inlet pipe shall be so arranged that the incoming cold water is not deflected directly into the hot water zone. The lowest point of the immersion heater shall be 25 mm above the centre line of the cold feed inlet, which, in turn, is usually 100 mm above the cylinder rim.
d) *Location of thermostat* — Where the thermostat does not form an integral part of the immersion heater, it shall be mounted with its axis horizontal, at least 50 mm away from

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and not lower than the immersion heater.

e) *Dual heater installations* — If desired, the principle of the dual heater may be adopted. In this case, one heater and its thermostat shall be installed at a low level as indicated in (b) and (c). The second heater and its thermostat shall be similarly disposed in the upper half of the cylinder at a level depending on the reserve of hot water desired for ordinary domestic use. The bottom heater shall be under separate switch control.

f) *Clearance around storage vessel* — Adequate clearance shall be provided between the tank and the cupboard, door or walls to allow convenient insertion and adjustment of the immersion heater and thermostat and to give space for thermal insulation.

4.14.8.2 *Rating of immersion heaters*

The rating of an immersion heater shall be determined according to the following factors:

a) Proposed hot water storage capacity (the maximum with cold water as indicated in **4.14.3** shall be taken into account),
b) Rate of utilization (draw off frequency),
c) Permissible recovery period, and
d) Inlet water temperature.

For details regarding rated input of water, refer to good practice [9-1(15)].

4.14.9 *Thermal Insulation*

The hot water storage vessel and pipes shall be adequately insulated, wherever necessary to minimize heat loss. The whole external surface of the storage vessel including the cover to the man hole shall also be duly insulated.

Insulation may be provided by wrapping storage vessel and pipes with fibre glass, mineral wool or closed cell flexible elastomeric foam based materials of desired thickness, covered with cladding for protection from damage or from weather in case of external use.

4.14.10 *Cold Water Supply to Heaters*

4.14.10.1 A storage water heater (pressure type) shall be fed from a cold water storage tank and under no circumstances connected directly to the water main, except the type which incorporates a feed tank with ball valves and overflow pipe arrangement (cistern type heaters) or non-pressure type heaters.

4.14.10.2 *Storage cisterns*

4.14.10.2.1 The storage capacity of a cold water tank shall be at least twicethe capacity of the hot water heater. The capacity of the storage tank may, however, be 1.5 times when the number of heaters connected to one common tank exceeds 10.

4.14.10.2.2 The storage tank for supply of cold water to hot water heaters shall be separate, if practicable. In the case of a common tank which also supplies cold water to the fixtures, this cold water supply connection shall be so arranged that 50 percent of the net capacity, worked out as in **4.14.10.2.1**, shall be available for supply to the hot water heaters.

4.14.10.2.3 In the case of multi-storeyed buildings where a common overhead tank over the stair/lift well is generally installed, it is advisable to have one or more local tanks for supply to the hot water heaters or a compartment in the tank with required storage always available for hot water heater.

4.14.10.2.4 In tall multi-storeyed buildings where the static pressure increases with the height, the total static pressure on the hot water heaters on the lowest floor shall not exceed the rated working pressure of the hot water heater installed. Should the height of the building so require, additional tanks shall be provided on the intermediate floors to restrict the static head to permissible limits or the pressure shall be reduced to working pressure by providing pressure reducing valves.

4.14.10.2.5 As an alternative to the arrangements stated in **4.14.10.2.3** and **4.14.10.2.4**, an individual storage tank in each flat may be provided for supply to hot water heaters.

4.14.11 *Cold Water Feed*

4.14.11.1 The feed pipe connecting cold water tank with the hot water heater shall not be of less than 20 mm bore and it shall leave the cold water tank at a point not less than 50 mm above the bottom of the tank and shall connect into the hot water heater near its bottom. The feed pipe shall not deliver cold water to any other connection, but into the hot water cylinders only.

4.14.11.2 In the case of multi-storeyed buildings, a common cold water feed pipe may be installed, but each hot water heater shall be provided with a check valve (horizontal type check valve shall be preferred to vertical type for easy maintenance).

4.14.11.3 Care shall be taken in installing the piping to prevent air locks in the piping and negative pressure in the hot water heater. Cold water feed pipe shall not be cross-connected with any other source of supply under pressure.

4.14.12 *Hot Water Piping*

4.14.12.1 *Expansion pipe or vent pipe*

4.14.12.1.1 Each non-pressure type hot water heater or cylinder shall be provided with a vent pipe of not

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less than 20 mm bore. The vent pipe shall rise above the water line of the cold water tank by at least 150 mm plus 10 mm for every 300 mm height of the water line above the bottom of the heater. The vent shall discharge at a level higher than the cold water tank and preferably in the cold water tank supplying the hot water heaters. Care shall be taken to ensure that any accidental discharge from the vent does not hurt or scald any passerby or persons in the vicinity.

It shall be ensured that such vents and pipes are so located so as not to encroach into the minimum maneuvering space and should be suitably insulated to avoid accidental contact and burns.

NOTE — Pressure type water heaters are very commonly used and non-pressure type is slowly phased out.

4.14.12.1.2 The vent pipe shall be connected to the highest point of the heater vessel and it shall not project downwards inside it, as otherwise air may be trapped inside, resulting in surging and consequent noises.

4.14.12.1.3 At no point, after leaving the vessel, shall the vent pipe dip below the level of its connection with the vessel.

4.14.12.1.4 A vent pipe may, however, be used for supply of hot water to any point between the cold water tank and the hot water heaters.

4.14.12.1.5 The vent pipe shall not be provided with any valve or check valves.

4.14.12.2 *Hot water heaters*

4.14.12.2.1 The common hot water delivery pipe shall leave the hot water heater near its top and shall be of not less than 20 mm bore generally, not less than 25 mm bore if hot water taps are installed on the same floor as that on which the hot water heater is situated.

4.14.12.2.2 Hot water taps shall be of such design as would cause the minimum friction. Alternatively, oversized tap may be provided, such as a 20 mm tap on a 15 mm pipe.

4.14.12.2.3 The hot water distributing system shall be so designed as to ensure that the time lag between opening of the draw-off taps and discharge of hot water is reduced to the minimum to avoid wastage of an undue amount of water which may have cooled while standing in the pipes when the taps are closed. With this end in view, a secondary circulation system with flow and return pipes from the hot water tank shall be used where justified. Whether such a system is used or not, the length of pipe to a hot water draw-off tap, measured along the pipe from the tap to the hot water tank or the secondary circulation pipe, shall not exceed the lengths given in Table 5.

Table 5 Maximum Permissible Lengths of Hot Water Draw-Off Pipes
(*Clause* 4.14.12.2.3)

Sl No.	Largest Internal Diameter of Pipe	Length
		m
(1)	(2)	(3)
i)	Not exceeding 20 mm	12
ii)	Exceeding 20 mm but not exceeding 25 mm	7.5
iii)	Exceeding 25 mm	3.0

NOTE — In the case of a composite pipe of different diameters, the largest diameter is to be taken into consideration for the purpose of this table.

4.14.12.2.4 Wherever mixing of hot and cold water is done by a mixing fitting, that is, hot and cold stop-cocks deliver to a common outlet of mixed water (that is, showers, basin or bath supply fittings), the pressure in the cold and hot water systems shall be equal. This can be achieved by connecting the cold water supply from an overhead tank at the same static height as the overhead tank supplying cold water to the hot water heaters. In case this is not possible, hot and cold water should be supplied to the fixtures by separate supply taps.

The hot and cold water thermostatic mixers/diverters/faucets for public use should have 'hot' and 'cold' clearly marked in the form of colour coding and tactile information. The functioning of hot and cold water from the thermostatic mixer/diverter/faucet should be consistent, for example, a clockwise turn should result in discharge of hot water and counter clockwise for cold. It is recommended that a thermostat be installed to limit the temperature of the hot water to a maximum of 40°C in order to prevent scalding. All faucets/mixers/diverts in public use shall be automatic (sensor operated) or lever type (*see also* **B-7** and **B-9** of Part 3 'Development Control Rules and General Building Requirements' of the Code).

4.14.13 *Types of Hot Water Heaters*

The various types of water heaters used for preparation of hot water are as follows:

a) *Electric storage heaters*:
   1) Non–pressure or open outlet type,
   2) Pressure type,
   3) Cistern type, and
   4) Dual heater type.

b) *Gas water heaters*:
   1) Instantaneous type, and
   2) Storage type.

c) *Solar heating systems*:
   1) Independent roof mounted heating units, and

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2) Centrally banked heated system.

d) *Central hot water system*:

1) Oil fired,
2) Gas fired,
3) Electrical coil type, and
4) Heat Pump.

4.14.13.1 The quality and construction of the different types of hot water heaters shall be in accordance with good practice [9-1(16)].

4.14.13.2 Requirements in regard to inspection and maintenance of hot water supply installations shall be in accordance with **4.15.1** to **4.15.4**.

4.15 Inspection and Testing

4.15.1 *Testing of Mains before Commencing Work*

All pipes, fittings and appliances shall be inspected, before delivery at the site to see whether they conform to accepted standards. All pipes and fittings shall be inspected and tested by the manufacturers at their factory and shall comply with the requirements of this Section. They shall be tested hydraulically under a pressure equal to twice this maximum permissible working pressure or under such greater pressure as may be specified. The pipes and fittings shall be inspected on site before laying and shall be sounded to disclose cracks. Any defective items shall be clearly marked as rejected and forthwith removed from the site.

4.15.2 *Testing of Mains after Laying*

After laying and jointing, the main shall be slowly and carefully charged with water by providing a 25 mm inlet with a stop-cock, so that all air is expelled from the main. The main is then allowed to stand full of water for a few days if time permits, and then tested under pressure. The test pressure shall be 0.5 N/mm^2 or double the maximum working pressure, whichever is greater. The pressure shall be applied by means of a manually operated test pump, or, in the case of long mains or mains of a large diameter, by a power-driven test pump, provided the pump is not left unattended. In either case, due precaution shall be taken to ensure that the required test pressure is not exceeded. Pressure gauges shall be accurate and shall preferably have been recalibrated before the test. The pump having been stopped, the test pressure shall maintain itself without measurable loss for at least 5 min. The mains shall be tested in sections as the work of laying proceeds; it is an advantage to have the joints exposed for inspection during the testing. The open end of the main may be temporarily closed for testing under moderate pressure by fitting a water-tight expanding plug of which several types are available. The end of the main and the plug shall be secured by struts or otherwise, to resist the end thrust of the water pressure in the mains.

4.15.2.1 If the section of the main tested terminates into a sluice valve, the wedge of the valve shall not be used to retain the water; instead the valve shall be temporarily fitted with a blank flange, or, in the case of a socketed valve, with a plug, and the wedge placed in the open position while testing. End support shall be given as in **4.15.2**.

4.15.3 *Testing of Service Pipes and Fittings*

When the service pipe is complete, it shall be slowly and carefully charged with water, allowing all air to escape, care being taken to avoid all shock or water hammer. The service pipe shall then be inspected under working conditions of pressure and flow. When all draw-offs taps are closed, the service pipe shall be absolutely water-tight. All piping, fittings and appliances shall be checked for satisfactory support, and protection from damage, corrosion and frost. Because of the possibility of damage in transit, cisterns shall be re-tested for water-tightness on arrival at the site, before fixing.

4.15.4 In addition to the provisions given in **4.15.1**, provisions given in **4.15.4.1** to **4.15.4.3** shall also apply to hot water supply installations in regard to inspection and testing.

4.15.4.1 *Testing of the system after installation*

After the hot water system, including the hot water heaters, has been installed, it shall be carefully charged with water, so that all air is expelled from the system. The entire system shall then be hydraulically tested to a pressure of 0.5 N/mm^2 or twice the working pressure, whichever is greater, for a period of at least 30 min after a steady state is reached. The entire installation shall then be inspected visually for leakages, and sweating. All defects found shall be rectified by removing and remaking the particular section. Caulking of threads, hammering and welding of leaking joints shall not be allowed.

4.15.4.2 *Hot water testing*

After the system has been proved water-tight, the hot water heaters shall be commissioned by connecting the same to the electrical supply. The system shall then be observed for leakage in pipes due to expansion or overheating. The temperature of water at outlets shall be recorded. The thermostats of the appliances shall be checked and adjusted to temperatures specified in **4.14.2.1**.

4.15.4.3 *Electrical connection*

For relevant provisions regarding general and safety requirements for household and similar electrical appliances, reference may be made to good practice

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[9-1(15)]. The metal work of the water heating appliances and installation other than current carrying parts shall be bonded and earthed in conformity with the good practice [9-1(15)]. It should be noted that screwing of an immersion heater into a tank or cylinder cannot be relied upon to effect a low resistance earth connection, a satisfactory separate earthing of heater should be effected.

4.16 Cleaning and Disinfection of the Supply System

4.16.1 All water mains communications pipes, service pipes and pipes used for distribution of water for domestic purposes shall be thoroughly and efficiently disinfected before being taken into use and also after every major repair. The method of disinfection shall be subject to the approval of the Authority. The pipes shall also be periodically cleaned at intervals, depending upon the quality of water, communication pipes and the storage cisterns shall be thoroughly cleaned at least once every year in order to remove any suspended impurities that may have settled in the pipes or the tanks.

4.16.2 *Disinfection of Storage Tanks and Down Take Distribution Pipes*

The storage tanks and pipes shall first be filled with water and thoroughly flushed out. The storage tank shall then be filled with water again and a disinfecting chemical containing chlorine added gradually while the tanks are being filled, to ensure thorough mixing. Sufficient quantities of chemicals shall be used to give the water a dose of 50 parts of chlorine to one million parts of water. If ordinary bleaching powder is used, the proportions will be 150 g of powder to 1 000 litre of water. The powder shall be mixed with water to a creamy consistency before being added to the water in the storage tank. When the storage tank is full, the supply shall be stopped and all the taps on the distributing pipes opened successively working progressively away from the storage tank. Each tap shall be closed when the water discharged begins to smell of chlorine. The storage tank shall then be topped up with water from the supply pipe and with more disinfecting chemical in the recommended proportions. The storage tank and pipes shall then remain charged for at least 3 h. Finally, the tank and pipes shall be thoroughly flushed out before any water is used for domestic purposes.

4.17 Water Supply Systems in High Altitudes and/or Sub-Zero Temperature Regions

4.17.1 *Selection and Source*

In general, the site selected for a water source shall be such as to minimize the length of transmission line so as to reduce the inspection and upkeep. Attempt shall be made, where feasible, to locate the source near the discharge of waste heat, such as of power plants provided it does not affect the potability of water.

4.17.2 *Pumping Installation*

Pump and pumping machinery shall be housed inside well-insulated chambers. Where necessary, arrangements shall be made for heating the inside of pump houses. Pump houses, as far as possible, should be built directly above the water intake structures.

4.17.3 *Protection of Storage Water and Treatment*

Where ambient temperatures are so low as to cause danger of freezing, proper housing, insulation and protection shall be provided for all processes and equipment. If necessary, means shall be provided for proper heating of the enclosure.

4.17.4 *Transmission and Distribution*

Freezing of the buried pipe may be avoided primarily by laying the pipe below the level of the frost line; well consolidated bedding of clean earth or sand, under, around or over the pipe should be provided. For the efficient operation and design of transmission and distribution work, the available heat in the water shall be economically utilized and controlled. If the heat which is naturally present in water is made equate to satisfy heat losses from the system, the water shall be warmed. Where economically feasible, certain faucets on the distribution system may be kept in a slightly dripping condition so as to keep the fluid in motion and thus prevent is freezing. If found unsuitable for drinking purposes, such water may be used for heating purposes. Heat losses shall be reduced by insulation, if necessary. Any material that will catch, absorb or hold moisture shall not be used for insulation purposes. Adequate number of break pressure water tanks and air release valves shall be provided in the distribution system.

NOTE — The level of frost line is generally found to be between 0.9 m and 1.2 m below ground level in the northern regions of India, wherever freezing occurs.

4.17.4.1 *Materials for pipes*

Distribution pipes shall be made of any of the following materials conforming to Part 5 'Building Materials' of the Code:

a) High density polyethylene pipes,
b) Asbestos cement pipes,
c) Galvanized iron pipes,
d) Cast iron pipes,
e) Copper pipes,
f) Chlorinated PVC pipes,
g) Unplasticized PVC pipes (where it is laid before frost line), and
h) Stainless steel pipes.

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4.17.4.2 *Materials for insulation of pipes*

Insulation of pipes may be provided by wrapping the pipe with fibre glass, mineral wool or closed cell flexible elastomeric foam based insulation materials of desired thickness covered with cladding for protection from damage or from weather in case of external use/pipes laid in exposed conditions; other materials, like 85 percent magnesia, preformed pipe sections, etc, may also be used.

4.17.4.3 *Distribution methods*

Distribution by barrels or tank trucks shall be employed, where the water requirements are temporary and small. Utmost care shall be exercised for preventing the water from being contaminated by maintaining a residual of disinfecting agent at all times. Hoses, pails and the tank shall be kept free from dust and filth during all period of operation. Where winter temperatures are low, making frost penetration depths greater during the winter and where adequate facilities for heating the water in the distribution system do not exist, the use of tank trucks or barrels for delivery of water shall be considered only for cold weather; during the warm weather, piping system for seasonal use may be supplemented.

4.17.4.4 In the conventional distribution system involving the use of a network of pipelines requiring no auxiliary heat, it is essential that the pipelines are buried well below the frost line. Adequate facilities for draining the pipelines shall be provided where there is a danger of frost.

4.17.4.5 *House service connections*

House service connections shall be kept operative by the use of adequate insulation at exposed places extending below the frost line. Figure 7 shows a typical arrangement for providing insulation for house service connections.

4.17.5 For detailed information on planning and designing water supply system peculiar to high altitudes and/or sub-zero temperature regions of the country, reference may be made to good practice [9-1(17)].

4.18 Guidelines to Maintenance

4.18.1 Storage tanks shall be regularly inspected and shall be cleaned out periodically, if necessary. Tanks showing signs of corrosion shall be emptied, thoroughly wire brushed to remove loose material (but not scraped), cleaned and coated with suitable bituminous compositions or other suitable anti-corrosive material not liable to impart taste or odour or otherwise contaminate the water. Before cleaning the cistern, the outlets shall be plugged to prevent debris from entering the pipes. Tanks shall be examined for metal wastage and water tightness after cleaning.

4.18.2 Record drawings showing pipe layout and valve positions shall be kept up to date and inspection undertaken to ensure that any maintenance work has not introduced cross-connections or any other undesirable feature. Any addition or alterations to the systems shall be duly recorded from time-to-time.

4.18.3 Any temporary attachment fixed to a tap or outlet shall never be left in such a position that back-siphonage of polluted water may occur into the supply system.

4.18.4 All valves shall periodically be operated to maintain free movement of the working parts.

4.18.5 All taps and ball valves shall be watertight, glands shall be made good, washers shall be replaced and the mechanism of spring operated taps and ball

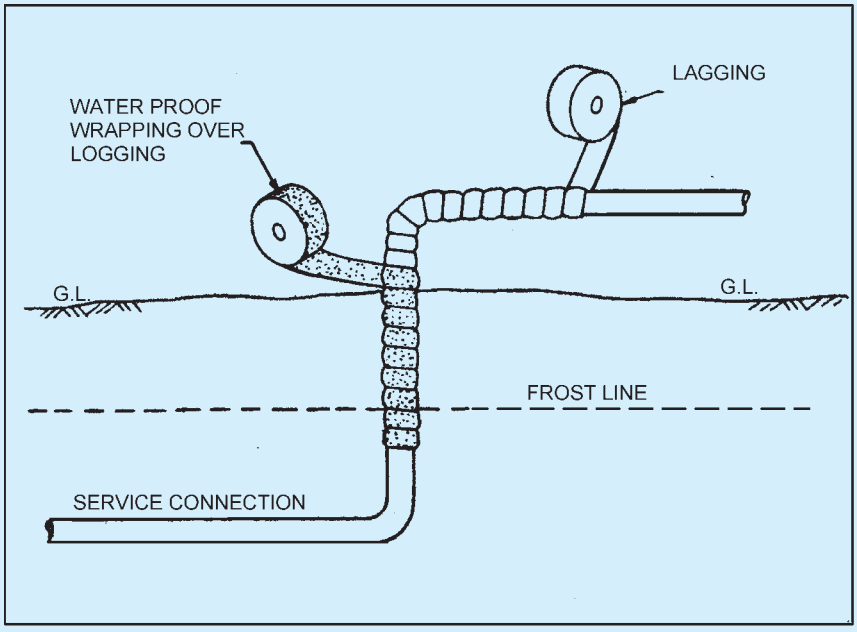


FIG. 7 INSULATION DETAILS AT SERVICE CONNECTION

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valves shall be repaired where required.

4.18.6 All overflow pipes shall be examined and kept free from obstructions.

4.18.7 The electrical installation shall be checked for earth continuity and any defects or deficiencies corrected in the case of hot water supply installations.

4.19 Swimming Pools

4.19.1 *General*

A swimming pool is a container that is filled with water to enable swimming or such other leisure activities. Pools can be sunk into the ground or built above ground (as a freestanding construction or as part of a building or other larger structure), and are also a standard feature aboard ocean liners and cruise ships. In-ground pools are most commonly constructed from materials such as concrete, natural stone, metal, plastic or fiberglass, and can be of a custom size and shape or built to a standardized size.

All pools open to public shall take care of the barrier-free design for accessibility and use by persons with disabilities. Reference shall also be made to **13** of Part 3 'Development Control Rules and General building Requirements' of the Code for applicable requirements.

4.19.1.1 Swimming pools shall be of three types, namely:

Type	*Characteristic*
Fill and draw	Clear water of potable quality is retained till it becomes turbid or unfit for use. Thereafter, the pool is drained, cleaned and refilled with clear water. This type is not recommended considering water conservation
Flow through	Clear water of hygienic quality flows continuously. This type requires more water for replenishment and so cautious decision of usage of such pools should be made; it is not recommended considering water conservation
Recirculating	Recirculation system shall be provided to minimize water wastage and disinfection shall be done to ensure hygiene. The recirculation system shall be based on the nature of usage such as private, public, wading and competition pools. The entire pool water should be filtered based on the turnover period for various types of pools

4.19.1.2 *Turnover rate*

It is the amount of time it would take for the volume of the pool to pass through the filtration system one time. Turnover rate is measured in hours and is expressed as:

Turnover rate, in h = Pool volume (in litre)/Flow (in litre/h)

NOTE— Pool volume comprises volume of the pool water, balancing tank, overflow gutter and circulation pipe.

Typical turnover rates for the following pools are:

Type of Pool	*Turnover Rate* h
Swimming pool:	
a) Private (outdoor)	6
b) Private (indoor)	10
c) Public	6
d) Competition	6
Wading pool	1
Spa (public)	½
Spa (private)	1

4.19.1.3 *Swimming pool user load*

The maximum load for the pool shall be:

a) For pool depth up to 1 m : 2.2 m^2 surface area per user
b) For pool depth up to 1.5 m : 2.7 m^2 surface area per user
c) For pool depth more than 1.5 m : 4.0 m^2 surface area per user

4.19.1.4 Recommended dimensions of the swimming pools shall be:

a) Half sized olympic pools : 25 m (length) × 12 to 13m (width) × 1.8 m (depth)
b) Full size olympic pools : 50 m (length) × 25 m (wide) × 2 m (depth)
c) Diving depth : 3.5 m for 1 m spring board; and 5 m for a 10 m platform
d) Maximum depth : *See* **4.19.2.7**
e) Ladders : 2 treads for 1.2 m depth; 3 treads for 1.2 m to 1.5 m depth; and 4 treads for 1.5 m depth
f) Displacement : 60 litre per user for deeper pools; and 45 litre for shallow pools

4.19.2 *Design*

4.19.2.1 The pool should be so designed to withstand all anticipated hydraulic structural loadings for both full and empty conditions. All appurtenances to the

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pool, such as diving boards and slides, shall be designed to carry the anticipated load. Any obstruction creating a safety hazard shall not extend into or above the pool, or shall not protrude from the floor of the pool. Designers may refer good practice [9-1(18)] for providing the guidance on the procedures and the precautions to be taken during construction of swimming pool to ensure the water tightness of the structure.

4.19.2.2 *Material*

Any suitable material that is non-toxic and provides a rigid watertight shell with a smooth, impervious, light colour finish should be used to construct the pool. The floor of shallow areas shall have a slip-resistant finish. Sand or earth shall not be permitted to use as an interior finish in a swimming pool.

4.19.2.3 *Dimensions*

The shape and size of a pool largely depend on the usage. Shape should be considered from the standpoint of safety and circulation of the pool water.

NOTES

1 A long and rectangular pool may be ideal for sports and exercise as it gives length and breadth, but the shape of a pool for recreation largely depend on the choice of the owners, available space for making the pool and the design of the house.

2 In sports, normally the swimming pools are 50 m long, minimum 21 m wide and 1.8 m overall depth.

4.19.2.4 *Floor slopes*

Slope of the floor of the pool should be made downward toward the main drain. All slopes should be uniform. The slope in shallow areas should not exceed 300 mm vertical in 3.6 m horizontal except for a slope directed downward from a transition point, which shall not exceed 300 mm vertical in 1m horizontal. In portions of the pool with a depth greater than 1.5 m, the front slope of the deep area shall not be steeper than 300 mm in 1 m.

4.19.2.5 *Transition point*

Transition points should be marked with a stripe on the pool floor having a width of at least 100 mm and a colour that contrasts with that of the floor, and with a buoyed safety rope with colour buoys, installed at least 300 mm on the shallow side of the transition point. In other pools having adjoining shallow and deep areas, a safety rope with colour buoys shall be installed where the water depth reaches 1.5 m.

4.19.2.6 *Pool walls*

Where the pool depth is 1 m or less, pool walls shall be vertical to the floor and the junction of the wall with the floor shall consist of a cove with a radius not exceeding 150 mm. Where the pool depth exceeds 1 m, pool walls shall meet one of the following criteria:

a) The wall shall be vertical for a depth of at least 1.5 m below the water level, below which the wall may angle to the floor; or

b) The wall shall be vertical for a depth of at least 1 m below the water level, below which the wall shall form a curve to the floor. The curve shall be tangent to the pool wall.

4.19.2.7 *Water depth*

The depth of a swimming pool depends on the purpose of the pool, and whether it is open to the public or strictly for private use. If it is a private casual, relaxing pool, it may go from 1.0 m to 1.5 m deep. If it is a public pool designed for diving, it may slope from 3.5 m to 5.0 m in the deep end. A children's play pool may be from 0.3 m to 0.6 m deep. Public pools may have differing depths to accommodate different swimmer requirements. Water depths may be clearly marked on the pool walls.

The width between handrails of the pool stairs should be between 500 mm and 600 mm.

4.19.2.8 *Walkways and deck areas*

Pools shall be completely surrounded by a deck that is at least 1.2 m in width and extends completely around and adjacent to the pool. There shall be no obstructions or interruptions of the pool deck within the 1.2 m adjacent to the pool other than necessary structural supports, or appurtenances such as diving boards, slides, perimeter overflow systems, or handrails. A clear, unobstructed walkway at least 1.2 m in width shall be maintained at such obstructions or interruptions. A wheelchair turning space of minimum 1.5 m × 1.5 m shall be provided at key places in the walkway.

Structural supports located within the minimum required deck width or within 1.2 m of the swimming pool shall be no closer than 3 m apart measured parallel to the adjacent perimeter of the pool, with the dimension of any single support in a plane parallel to the adjacent pool perimeter not greater than 1 m and the sum of all such support dimensions not greater than 10 percent of the pool perimeter.

The deck between two adjacent swimming pools shall be at least 2.5 m wide. All decks and walkways shall have an unobstructed overhead clearance of at least 2 m.

Synthetic material which meets the following criteria may be installed for deck coverings:

a) Non-fibrous and allows drainage such that it will not remain wet or retain moisture;

b) Inert and will not support bacterial or fungal growth;

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c) Durable;

d) Cleanable; and

e) Provides a slip-resistant finish.

The decks and walkways shall have a paved surface. The surface of the pool deck and other surfaces used for foot contact, such as gratings of perimeter overflow systems, shall be slip-resistant.

The outer perimeter of the deck for outdoor pools shall be at least 10 cm higher than the surrounding ground surface except where access is provided to adjacent turf areas.

The pool shall have an accessible entry and exit that is accessible to persons with disabilities. Accessible entry/exit may require provision of a transfer wall or/and a sloped entry with an aquatic chair. Installing a pool lifts may be another option for accessible entry/exit.

The transfer wall should have a minimum clear deck space of 1.5 m × 1.5m, with a slope not steeper than 1:48 at the base of the transfer wall. The height of the transfer wall should be 400 mm to 480 mm from the deck floor. The transfer wall should be 300 mm to 400 mm wide. The length should be minimum 1.5 m centered on the clear deck space. Surfaces of transfer walls shall not be sharp and shall have rounded edges.

A grab bar should be provided on the transfer wall. Grab bars shall be perpendicular to the pool wall and shall extend the full depth of the transfer wall. The top of the gripping surface shall be 100 mm to 150 mm above transfer walls. Clearance of 610 mm should be available on both sides of the grab bar.

4.19.2.9 *Starting platforms*

Starting platforms may be from 0.50 m to 0.75 m above the surface of water. The maximum height of the platform above the water shall be 0.75 m where the water depth is 1.2 m or greater, and 0.50 m when the water depth is less than 1.2 m. The surface area of each platform shall be 0.5 m × 0.5 m with a maximum slope of not more than 10º. Surface of each block shall be covered with non-slip material and with back stroke hand grip facility.

4.19.3 *Electrical Installation*

4.19.3.1 *Lighting*

Artificial lighting shall be provided at all indoor pools and at all outdoor pools that are open for use after sunset in accordance with one of the following:

a) Underwater lighting of at least 8.35 lumen or 5.5 W/m^2 of pool water surface area, located to provide illumination of the entire pool floor; plus area lighting of at least 10 lumen or 6.6 W/m^2 of deck area.

b) If underwater lights are not provided, at least 33.5 lumen or 2.2 W/m^2 of pool water surface area and deck area.

Where portable electric vacuum cleaning equipment is used, electrical receptacles with ground-fault circuit interrupter protection shall be provided. Separation between receptacles shall be a maximum of 30 m. All receptacles installed in the swimming pool area shall have waterproof covers and ground-fault circuit interrupter protection. Lighting controls should not be accessible to the public.

4.19.3.2 *Ventilation*

Adequate ventilation shall be provided in facilities to prevent objectionable odor.

4.19.3.3 *Shower and bathroom*

Separate shower, dressing booth and sanitary facilities shall be provided for each gender. This may not be applicable for schools and other institutional use where a pool may be open to one gender at a time. The rooms should be well lit, drained, ventilated, and of good construction, using impervious materials. They should be developed and planned to ensure maintenance of good sanitation throughout the building at all times. Floors should have a slip-resistant surface and sufficiently smooth to ensure ease in cleaning.

Each shower and toilet block provided per pool, open for use by public, shall have a unisex accessible shower, dressing-cum-toilet facility for persons with disabilities. Design specifications of this accessible facility shall be as per **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

4.19.4 *Water Treatment System*

4.19.4.1 *General*

A water treatment system shall be provided to filter, chemically balance and disinfect the swimming pool water.

4.19.4.2 *Hair and lint strainer*

A hair and lint strainer shall be installed on the suction side of the pump except on vacuum filter systems. The strainer basket shall be easily removable. Valves shall be installed to allow the flow to be shut off during cleaning, switching baskets or inspection.

4.19.4.3 *Inlets*

Inlets for filtered water shall be located and directed suitably to produce uniform circulation of water to facilitate the maintenance of a uniform disinfectant residual throughout the entire pool without the existence of dead spots, and to produce surface flow patterns that effectively assist skimming.

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4.19.4.4 *Outlets*

Pools shall be provided with a minimum of two drains (outlets) at the deepest point. Centre-to-centre distance between drains shall not exceed 2.0 m. Drains shall not be more than 3.0 m away from the pool walls. The main drain may be connected to the recirculation system. Openings shall be covered by grating which cannot be removed without the use of tools. Openings of the grating shall be at least four times the area of the main drain pipe or have an open area. The maximum width of grate openings shall not exceed 8 mm. Main drains and all other suction outlets installed in the pool shall be designed to prevent bather entrapment and shall be of anti-vortex type. The velocity at outlet pipe shall not be more than 0.3 m/s.

4.19.4.5 *Velocities*

Maximum permissible velocities for various components of the pools are as follows:

a) Suction pipe — less than 1.5 m/s

b) Return pipe — 1.5 to 2 m/s

c) Return/inlet fittings — 2.4 to 2.75 m/s in private pools and 1.5 to 2 m/s in public pools

4.19.4.6 *Balancing (surge) tank*

Overflow system shall be designed for effective surge capacity. Balancing tank should be provided of capacity to accommodate surge storage and storage for make up water. The volume of the balancing tank shall be the total of the above with equal proportions.

4.19.4.7 *Make-up water*

Make-up water shall be added through a fixed air gap of at least 15 cm to the pool, surge tank, vacuum filter tank, or other receptacle. When make-up water is added directly to the pool, the fill-spout should be located under a low diving board or immediately adjacent to a ladder rail, grab rail, or fixed lifeguard chair.

4.19.4.8 *Filtration*

The design filtration rate in the particular application in which the filter is utilized shall not exceed the maximum design filtration rate for which the filter was installed. Wash or backwash water from diatomaceous earth filters shall be passed through a separation tank designed for removal of suspended diatomaceous earth and solids, prior to disposal.

NOTE — Filtration rates for various types of filters are:

a) Low rate filter — 10 $m^3/m^2/h$

b) Medium rate filter — 11 to 30 $m^3/m^2/h$

c) High rate filter — 31 to 50 $m^3/m^2/h$

d) Minimum flow rate for filter back wash — 30 $m^3/ m^2/h$

4.19.4.9 *Disinfection*

The pool water shall be continuously disinfected by suitable disinfecting agent that imparts easily measured residual. Gaseous chlorine, chlorine compounds, bromine compounds or other bactericidal agents should be used to maintain the quality parameters of water.

4.19.5 *Water Quality*

4.19.5.1 *Disinfectant residual*

Where chlorine is used as a disinfectant, the chlorine residual shall be maintained between 1.0 and 4.0 ppm. as free chlorine residual. A free chlorine residual of at least 2.0 ppm shall be maintained when the pool water temperature exceeds 30ºC.

Where bromine is used as a disinfectant, a bromine residual shall be maintained between 2.0 and 8.0 ppm as total bromine. A bromine residual of at least 4.0 ppm shall be maintained when the pool water temperature exceeds 30ºC.

Where chlorinated cyanurates are used, the cyanuric acid concentration shall not exceed 100 ppm.

Where silver/copper or copper ion generators are used, the concentration of copper shall not exceed 1.3 ppm and the concentration of silver shall not exceed 0.05 ppm.

Where ozone is used, the ambient air ozone concentration shall be less than 0.1 ppm. at all times either in the vicinity of the ozonator or at the pool water surface.

For all other physical, chemical and bacteriological parameters, the quality of water used in swimming pools in continuous circulation type shall conform to good practices [9-1(19)].

4.20 Allowance for Expansion

4.20.1 The allowances for expansion of the water pipes are recommended as given below:

a) All pipes should be installed at ambient temperature.

b) Pipes carrying hot fluids such as water or steam operate at higher temperatures. It follows that they expand, especially in length, with an increase from ambient to working temperatures. This will create stress upon certain areas within the distribution system, such as pipe joints, which, in the extreme, could cause fracture.

c) The pipe work system shall be sufficiently flexible to accommodate the movements of the components as they expand. In many cases, the flexibility of the pipe work system, due to the length of the pipe and number of bends and supports, means that no undue stresses are imposed. In other installations, however, it will be necessary to incorporate some means of achieving this required flexibility.

d) The expansion fitting is one method of accommodating expansion. These fittings are placed within a line and are designed to accommodate the expansion without the total length of the line changing. They are commonly called expansion bellows, due to the bellows construction of the expansion sleeve.

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e) Other expansion fittings can be made from the pipe work itself. This can be a cheaper way to solve the problem, but more space is needed to accommodate the pipe.

4.20.2 *Full Loop*

a) This is simply one complete turn of the pipe and, on steam pipe work, should preferably be fitted in a horizontal rather than a vertical position to prevent condensate accumulating on the upstream side.

b) The downstream side passes below the upstream side and great care shall be taken that it is not fitted wrong way round, as condensate can accumulate in the bottom. When full loops are to be fitted in a confined space, care shall be taken to specify that wrong-handed loops are not supplied.

c) The full loop does not produce a force in opposition to the expanding pipe work as in some other types, but with steam pressure inside the loop, there is a slight tendency to unwind, which puts an additional stress on the flanges.

4.21 Colour Codes for Different Types of Water Pipes

The following colour codes are recommended for pipes {*see also* accepted standard [9-1(20)]}:

Sl No. (1)	*Particulars* (2)	*Ground Colour* (3)	*First Colour Band* (4)	*Second Colour Band* (5)
i)	Cooling water	Sea green	French blue	—
ii)	Boiler feed water	Sea green	Gulf red	—
iii)	Condensate water	Sea green	Light brown	—
iv)	Drinking	Sea green	French blue	Signal red
v)	Treated	Sea green	Light orange	—
vi)	Fire water	Fire red	Crimson red	—
vii)	Water with central heating below 60°C	Sea green	Canary yellow	—
viii)	Water with central heating between 60 to 100°C	Sea green	Dark violet	—
ix)	Water with central heating above 100°C	Sea green	Dark violet	Signal red
x)	Cold water from storage tanks	Sea green	French blue	Canary yellow
xi)	Domestic, hot water	Sea green	Light grey	—
xii)	Hydraulic power water	Sea green	Black	—
xiii)	Untreated sea/river water	Sea green	white	—
xiv)	Filtered water	Sea green	Light brown	—
xv)	Soft water	Sea green	Light brown	Signal red
xvi)	Warm water	Sea green	Light grey	Canary yellow
xvii)	Chilled water	Sea green	Black	Canary yellow
xviii)	Sprinkler and hydrant water	Sea green	White	Signal red
xix)	Waste water	Sea green	Canary yellow	Signal red

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ANNEX A

(*Clause* 3.2.1)

APPLICATION FORM FOR TEMPORARY/PERMANENT SUPPLY OF WATER/FOR ADDITIONS AND/OR ALTERATIONS FOR SUPPLY OF WATER

I/We ……..hereby make application to the* …….. for the temporary/permanent supply of water for the following additions and/or alterations to the water supply requirements and water fittings at the premises……. Ward No. ……..Street No. ……Road/Street known as ……for the purpose described below and agreed to pay such charges as the Authority may from time-to-time be entitled to make and to conform to all their byelaws and regulations…….licensed/registered plumber, has been instructed by me/us to carry out the plumbing work.

Description of the premises:…….

Address :……..

Purpose for which water is required…….

……

The connection/connections taken by me/us for temporary use, shall not be used by me/us for permanent supply unless such a permission is granted to me/us in writing by the Authority.

I/We hereby undertake to give the*…….. due notice of any additions or alterations to the above mentioned supply which I/we may desire to make.

My/Our requirements of water supply are as under:

a) I/We request that one connection be granted for the whole of the premises.

b) I/We request that separate connections may be granted for each floor and I/we undertake to pay the cost of the separate connections.

c) My/Our probable requirements for trade purpose are …….litre per day and for domestic purposes are……..litre per day.

d) Our existing supply is ……..litre per day. Our additional requirement of supply is ……..litre per day.

e) The details as regards proposed additions and alterations in fittings are as follows:

……..

……..

Signature of the licensed/registered plumber…….....

Name and address of the licensed/registered

Plumber…….

Date ……

Signature of the applicant…….....

Name and address of the

Applicant …….....

Date …….....

NOTES

1 Please strike out whatever is not applicable.

2 The application should be signed by the owner of the premises or his constituted attorney and shall be countersigned by the licensed/registered plumber.

---

* Insert here the name of the Authority.

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ANNEX B

(*Clause* 3.2.3)

FORM FOR LICENSED/REGISTERED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of water connection No……. for the premises as detailed below. This may be inspected and connection given.

Ward No…….. Road/Street……..

Locality…….

Block No…… House No……..

Existing water connection No. (if any)…….

Owned by…….

Owner's address…….

Applicant's name…… Son of…….

Address……

Situation……...

Size of main……on…… street

Where main is situated……

Size of service pipe…….

Size of ferrule……

No. of taps…… No. of closets……

No. of other fittings and appliances……..

Road cutting and repairing fee …….

Paid Rs……(Receipt No…….dated……) (receipt enclosed)

Dated ……...

Signature of licensed/registered plumber……..

Name and address of the licensed/registered plumber

……

The Authority's Report

Certified that the communication and distribution pipes and all water fittings have been laid, applied and executed in accordance with the provisions of bye-laws, and satisfactory arrangements have been made for draining off waste water.

Connection will be made on……

Date…… The Authority……

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ANNEX C

(*Clause* 4.7.4)

NOMOGRAM OF HAZEN AND WILLIAM'S EQUATION

C-1 Examples of the use of nomogram are given below:

Example 1

Find the total friction loss in 25 mm diameter G.I. pipe discharging 0.25 litre/s in a total length of 300 m.

Procedure

Discharge, Q	= 0.25 litre/s
Pipe diameter	= 25 mm
Frictional loss (from nomogram)	= 30 m per 1 000 m
Total friction loss in 300 m length	$= \frac{30}{100} \times 300 = 9\text{m}$

Example 2

Find suitable diameter pipe to carry 15 litre/s from service line to overhead tank.

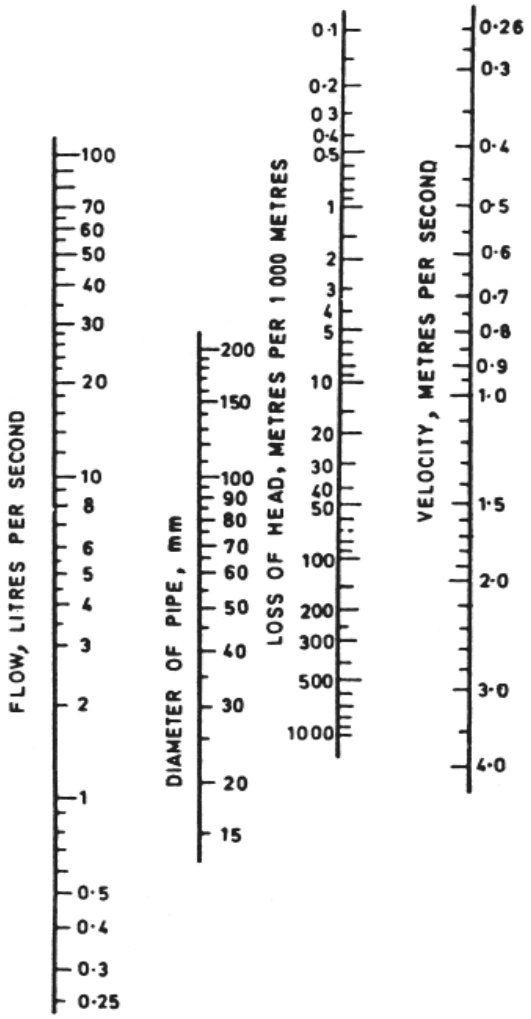
Total length of service main = 200 m

Residual pressure available at the take off point on supply line is 15 m.

Procedure

Available head	= 15 m
Deduct residual head	= 2 m
Deduct 10 percent for losses in bends and specials	= 1.3 m
Friction head available for loss in pipe of 1 000 m	$= \frac{11.7}{200} \times 1\,000$ = 58.5 m per 1 000 m

From the nomogram, for a discharge of 15 litre/s and friction loss of 58.5 m per 1 000 m, nearest commercial size (diameter) of pipe is 100 mm.



Nomogram of Hazen and Williams Equation (c = 100)

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	10446 : 1983	Glossary of terms relating to water supply and sanitation
(2)	11208 : 1985	Guidelines for registration of plumbers
(3)	10500 : 2012	Specification for drinking water (*second revision*)
(4)	2041 : 2009	Specification for steel plates for pressure vessels used at moderate and low temperature (*third revision*)
	804 : 1967	Specification for rectangular pressed steel tanks (*first revision*)
(5)	4984 : 1995	Specification for high density polyethylene pipes for potable water supplies (*fourth revision*)
	4985 : 2000	Specification for unplasticized PVC pipes for potable water supplies (*third revision*)
	15778 : 2007	Specification for chlorinated polyvinyl chloride (CPVC) pipes for portable hot and cold water distribution supplies
(6)	2065 : 1983	Code of practice for water supply in buildings (*second revision*)
(7)	3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
(8)	782 : 1978	Specification for caulking lead (*third revision*)
(9)	5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
(10)	6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(11)	783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
(12)	7634	Code of practice for plastics pipes selection, handling, storage and installation for potable waters supplies:
	(Part 1) : 1975	Choice of materials and general recommendations
	(Part 2) : 2012	Laying and jointing of poly-ethylene (PE) pipes (*first revision*)
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)
(13)	783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
	3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
	5822 : 1994	Code of practice for laying of welded steel pipes for water supply (*second revision*)
	6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
	7634	Code of practice for plastics pipes selection, handling, storage and installation for potable water supplies
	(Part 1) : 1975	Choice of materials and general recommendations
	(Part 2) : 2012	Laying and jointing of polyethylene (PE) pipes (*first revision*)
	(Part 3) : 2003	Laying and jointing of UPVC pipes (*first revision*)
(14)	2692 : 1989	Specification for ferrules for water services (*second revision*)
(15)	302 (Part 1) : 2008	Safety of household and similar electrical appliances: Part 1 General requirements (*sixth revision*)
	2082 : 1993	Stationary storage type electric water heaters (*third revision*)
(16)	7558 : 1974	Code of practice for domestic hot water installations
(17)	6295 : 1986	Code of practice for water supply and drainage in high altitudes and/or sub-zero temperature regions (*first revision*)
(18)	6494 : 1988	Code of practice for water-proofing of underground water reservoirs and swimming pools (*first revision*)
(19)	3328 : 1993	Quality tolerances for water for swimming pools
(20)	2379 : 1990	Colour code for identification of pipe lines

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 2 Drainage and Sanitation

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 9/Section 2) covers the drainage and sanitation requirements of buildings, design, layout, construction and maintenance of drains inside buildings and from the buildings up to the connection to public sewer, private sewer, individual sewage disposal system, cesspool, or to other approved point of disposal/treatment work. It also covers drainage systems peculiar to high altitudes and/or sub-zero temperature regions of the country.

In the first version of the Code formulated in 1970, three separate sections of Part 9 Plumbing services, were brought out, namely, Section 1 Water Supply, Section 2 Drainage and Sanitation, and Section 3 Gas Supply. These sections were subsequently revised in 1983.

The major changes incorporated in the first revision in Section 2 Drainage and sanitation were rationalization of definitions; modification of the requirements for fitments for drainage and sanitation in the case of buildings other than residences; addition of table for sanitation facilities in fruit and vegetable markets; introduction of table giving detailed guidance regarding the selection of plumbing system, depending on the nature of drainage load in buildings and height of buildings; amplification of provision relating to safeguards to be adopted in single stack system; modification of the values of gradients, pipe sizes and the corresponding discharges; rationalization of sizes of manholes/inspection chambers; modification of the sizing of rainwater pipe for roof drainage, to take into account rainfall intensities and recommend sizes on a more rational basis; addition of provisions for drainage and sanitation system peculiar to high altitudes and/or sub-zero temperature regions of the country; and inclusion of requirements of the refuse chute system.

As a result of experience gained in implementation of 1983 version of the Code and feedback received as well as revision of some of the standards based on which this Section was prepared, a need to revise this Section was felt. The last revision was therefore prepared to take care of these. In the last revision, the erstwhile two Sections were merged and a combined and comprehensive section, namely Section 1 Water supply, drainage and sanitation (including solid waste management), was brought out. Gas supply was brought out as Section 2. Following significant changes were incorporated in the last revision of Section 1 on Water supply, drainage and sanitation, in respect to drainage and sanitation: rationalization and addition of new definitions under terminology; enunciation of certain basic principles for water supply and drainage; addition of a new clause on sanitary appliances; updation of Tables 1 to 14 of the existing version, regarding drainage and sanitation requirement; addition of additional requirements under layout clause of design considerations; modification and rationalization of provisions regarding choice of plumbing systems; addition of new clause on drain appurtenances having details on trap, floor drain and cleanout; incorporation of provisions on indirect wastes, special wastes (covering laboratory wastes, infected wastes, research laboratory wastes, etc), grease traps, oil interceptors, radio-active wastes, etc; revision of manhole details on size and enhancement of construction clause; inclusion of provisions on rainwater harvesting; revision of the minimum rainfall intensity which is drain design basis for discharge of storm water drain into a public storm water drain, to 50 mm/h; modification of the table for sizing of rainwater pipes for roof drainage, with inclusion of rainfall data which were not available in the earlier version; inclusion of figure on detail of subsoil drainage; and addition of details on support/protection of pipes.

The last revision also incorporated for the first time the provisions on solid waste management.

In this revision to comprehensively address the various and distinct features related to the plumbing aspects, this Part 9 has been rearranged as follows:

Section 1 Water supply
Section 2 Drainage and sanitation
Section 3 Solid waste management
Section 4 Gas supply

Further, in this revision of the Section 2, following significant changes/modifications have been incorporated:

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1) Various tables on the requirements for fitments for drainage and sanitation for various occupancies have been updated, and a new table for shopping malls and retail buildings has been included.
2) Enabling provisions for use of corrugated pipes, low noise pipes and under slung pipes have been included.
3) Information about bio-toilets has been added.
4) Typical mounting arrangements for various plumbing fixtures, including drainage systems and ventilation have been illustrated.
5) A new table for calculation of single stack sizing has been included.
6) Various additional requirements relating to layout of drainage and sanitation system have been added.
7) Venting system for high rise buildings, along with a comprehensive table on size and developed length of stack vents and vent stacks, has been included.
8) General provisions on design of drainage pipes have been elaborated.
9) Provisions relating to gradients of drainage pipes have been elaborated.
10) The table on fixture unit for different types of fixtures has been updated.
11) The tables on maximum number of fixture units that can be connected to branches and stacks, and to building drains and sewers, have been updated.
12) New provisions on design requirement for high rise buildings drainage system have been included.
13) The minimum diameter for floor drains outlets before connecting to floor trap has been included.
14) Provisions related to manhole covers and recommended locations have been included.
15) Provision for estimation of storm water runoff and coefficient of runoff for various surfaces have been included.
16) The table on sizing of rainwater pipes for roof drainage has been updated.
17) The illustration on artificial ground water recharge structure has been detailed.
18) Guidelines relating to siphonic drainage system for large roofs have been included.
19) Provisions on rainwater harvesting for plotted/group housing developments and deep well/bore well recharging, have been included.
20) Clarifications and recommendations on use of septic tanks have been made.
21) New provisions related to pumping and treatment of sewage have been included.
22) A provision on treatment of waste water and usage of recycled water has been included through cross-reference to Section 1 'Water supply' of this Part of the Code.
23) Provisions have been reviewed and updated from the point of view of accessibility by elderly and persons with disabilities, also, in this context, duly giving cross-reference to **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.
24) Certain terminologies have been included and some have been updated.
25) Cross-referred standards have been updated.

This Section is largely based on the following Indian Standards:

IS 1742 : 1983	Code of practice for building drainage (*second revision*)
IS 4111 (Part 1) : 1986	Code of practice for ancillary structures in sewage system: Part 1 Manholes (*first revision*)
IS 5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
IS 6295 : 1986	Code of practice for water supply and drainage in high altitudes and or sub-zero temperature regions (*first revision*)

A reference to SP 35:1987 'Handbook on Water Supply and Drainage' may be useful, from where also, assistance has been derived.

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this section are encouraged to investigate the possibility of applying the most recent editions of the standards.

In the formulation of this Section, reference has also been made to the following:

International Plumbing Code 2015, International Code Council, and

Uniform Plumbing Code 2015, International Association of Plumbing and Mechanical Officials

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 2 Drainage and Sanitation

1 SCOPE

1.1 This Code (Part 9/Section 2) covers the design, layout, construction and maintenance of drains for foul water, surface water, subsoil water and sewage together with all ancillary works, such as connections, manholes and inspection chambers used within the building and from building to the connection to a public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/ treatment work.

NOTE — A sanitary drainage system consists of a building sewer, a building drain, a soil and/or waste stack, horizontal branches or fixture drain, and vents. The sanitary drainage of a large building may have a number of primary and secondary branches, and several soil and/or waste stacks, each of them in turn may have a number of horizontal branches.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply in addition to the definitions given in accepted standards [9-2(1)].

2.1 Air Admittance Valve — One way valves designed to allow air to enter drainage system when negative pressure develops in the system. The purpose is to provide a method of allowing air to enter the drainage system for prevention of siphonage of traps.

2.2 Air Break — Physical separation which may be a low inlet into the indirect waste receptor from the fixture or device indirectly connected.

2.3 Air Gap, Drainage — Unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe, plumbing fixture or appurtenance conveying waste to flood level of the receptor.

2.4 Back Up — A condition where the waste water may flow back into another fixture or compartment but not back into the potable water system.

2.5 Back Water Valve — Device installed in a drainage system to prevent reverse flow.

2.6 Bath Room Group — Group of fixtures consisting of water closet, lavatories bath tub or shower and other fittings with a floor drain located together**.**

2.7 Battery of Fixtures — Any group of two or more similar adjacent fixtures which discharge into a common horizontal waste or soil pipe.

2.8 Bed Pan Washer — A washer which is to be used for disposing human waste and sterilizing the Bed Pan for reuse. Bed pan washer requires water connection and electrical heating arrangement. This is to be considered as soil appliance.

2.9 Benching — Sloping surfaces constructed on either side of channels at the base of a manhole or inspection chamber for the purpose of confining the flow of sewage, avoiding the accumulation of deposits and providing a safe working platform.

2.10 Branch

a) Special form of sewer pipe used for making connections to a sewer or water main. The various types are called 'T', 'Y', 'T-Y', double Y and V branches, according to their respective shapes.

b) Any part of a piping system other than a main or stack.

2.11 Branch Soil Pipe (BSP) — A pipe connecting one or more soil appliances to the main soil pipe.

2.12 Branch Soil Waste Pipe (BSWP) — A pipe connecting one or more soil and/or waste appliances to the main soil waste pipe (one pipe system).

2.13 Branch Vent Pipe (BVP) — A pipe, one end of which is connected to the system adjacent to the trap of an appliance and the other to a main vent pipe or a drain-vent pipe. It is fitted to prevent loss of water seal from a trap owing to partial vacuum, back-pressure, or surging caused by air movement within the pipe system. It also provides ventilation for the branch waste pipe.

2.14 Branch Waste Pipe (BWP) — A pipe connecting one or more waste appliances to the main waste pipe.

2.15 Building Drain-Combined — A building drain which conveys both sewage and storm water or other drainage.

2.16 Building Drain-Sanitary — A building drain which conveys sewage and sullage only.

2.17 Building Drain-Storm — A building drain which conveys storm water or other drainage but no sewage or sullage.

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2.18 Building Sewer — That part of the horizontal piping of a drainage system which extends from the end of the building drain and which receives the discharge of the building drain and conveys it to a public sewer, private sewer, individual sewage-disposal system or approved point of disposal.

2.19 Building Sub-Drain — That portion of a drainage system which cannot drain by gravity in the building sewer.

2.20 Building Trap — A device, fitting or assembly of fittings installed in the building drain to prevent circulation of air between the drainage of the building and the building sewer. It is usually installed as running trap.

2.21 Cesspool

a) An underground chamber for the reception and storage of foul water, the contents of which are periodically removed for disposal.
b) A box-shaped receiver constructed in a roof or gutter for collecting rainwater which then passes into a rainwater pipe connected thereto.

2.22 Cleaning Eye — An access opening in a pipe or pipe fitting arranged to facilitate the cleaning of obstructions and fitted with removable cover.

2.23 Clear Waste Water — Cooling water and condensate drainage from refrigeration and air conditioning equipment, cooled condensate from steam heating systems, cooled boiler blow-down water, waste water drainage from equipment rooms and other areas where water is used without an appreciable addition of oil, gasoline, solvent, acid, etc, and treated effluent in which impurities have been reduced below a minimum concentration considered harmful.

2.24 Collection Chamber — A compartment situated at the lower end of the chute for collecting and housing the refuse during the period between two successive cleanings.

2.25 Connection — The junction of a foul water drain, surface water drain or sewer from building or building with public sewer treatment works, public sewer, private sewer, individual sewage-disposal system, cess-pool, soakaway or to other approved point of disposal/ treatment work.

2.26 Consumer — Any person who discharges waste or sewage to the public sewer installed by the Authority.

2.27 Crown of Trap — The topmost point of the inside of a trap outlet.

2.28 Deep Manhole — A manhole of such depth that an access shaft is required in addition to the working chamber.

2.29 Depth of Manhole — The vertical distance from the top of the manhole cover to the outgoing invert of the main drain channel.

2.30 Developed Length — The length measured along the centre line of a pipe and fittings.

2.31 Diameter — The nominal internal diameter of pipes and fittings.

2.32 Drain — A conduit, channel or pipe for the carriage of storm water, sewage, waste water or other water-borne wastes in a building drainage system.

2.33 Drain Vent Pipe (DVP) — A pipe installed to provide flow of air to or from a drain to prevent undue concentration of foul air in the drain. The main soil pipe or main waste pipe may serve as drain vent pipe wherever their upper portions, which do not receive discharges, are extended to the roof level and let open to air.

2.34 Drainage — The removal of any liquid by a system constructed for the purpose.

2.35 Drainage Fixture Unit (DFU) — A measure of probable discharge into the drainage system by various types of plumbing fixtures. The drainage fixture unit value for a particular fixture depends on its volume rate of drainage discharge, on the time duration of a single drainage operation and on the average time between successive operations.

2.36 Drainage Work — The design and construction of a system of drainage.

2.37 Drop Connection — A length of conduit installed vertically immediately before its connection to a sewer or to another drain.

2.38 Drop Manhole — A manhole installed in a sewer where the elevation of the incoming sewer considerably exceeds that of the outgoing sewer; a vertical waterway outside the manhole is provided to divert the waste from the upper to the lower level so that it does not fall freely into the manhole except at peak rate of flow.

2.39 Eco-toilet (or Bio-toilet) — The dry toilet that uses a predominantly aerobic processing system to treat human excreta, by composting or managed-aerobic decomposition. It generally uses little to no water and may be used as an alternative to flush toilets.

2.40 Fittings — The appurtenances such as coupling, flange, branch, bend, tees, elbows, unions, waste (with or without plug), P or S trap (with or without vent), stop ferrule, bib tap, pillar tap, bath faucet, water meter, garden hydrant, valves and any other article used in connection with water supply, drainage and sanitation.

2.41 Fixture Unit — A quantity in terms of which the load producing effects on the plumbing system of different kinds of plumbing fixtures is expressed on some arbitrarily chosen scale.

2.42 Formation — The finished level of the excavation at the bottom of a trench or heading prepared to receive the permanent work.

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2.43 French Drain or Rubble Drain — A shallow trench filled with coarse rubble, clinker, or similar material with or without field drain pipes.

2.44 Frost Line — The line joining the points of greatest depths below ground level up to which the moisture in the soil freezes.

2.45 Grease Interceptor (or Grease Trap) — A chamber, on the line of a drain or waste pipe, for preventing grease from passing into the drainage system. It reduces non-petroleum fats, oils and grease in effluent by separation and volume reduction to improve sewage treatment efficiency.

As it is used to intercept fats, oils and grease (FOG) from a waste water discharge, it is also known as FOG interceptor.

2.46 Gully Chamber — The chamber built of masonry round a gully trap for housing the same.

2.47 Gully Trap — A trap provided in a drainage system with a water seal fixed in a suitable position to collect waste water from the scullery, kitchen sink, wash basins, baths and rainwater pipes.

2.48 High Altitudes — Elevations higher than 1 500 m above mean sea level (MSL).

2.49 Highway Authority — The public body in which is vested, or which is the owner of, a highway repairable by the inhabitants collectively; otherwise the body or persons responsible for the upkeep of the highway.

2.50 Horizontal Pipe — Any pipe of fitting which makes an angle of more than 45° with the vertical.

2.51 Indirect Waste Pipe — The pipe that does not connect directly with the drainage system, but conveys liquid wastes by discharging into a plumbing fixture/ interceptor that is directly connected to the drainage system.

2.52 Inlet Fittings — An arrangement of connecting the internal waste branch pipe from wash basin, sinks and shower drains to the main deep seal trap with the help of hopper extension.

2.53 Inlet Hopper — A receptacle fitting for receiving refuse from each floor and dropping it into the chute.

2.54 Insanitary — Condition that is contrary to sanitary principles or is injurious to health**.**

2.55 Inspection Chamber — A water-tight chamber constructed in any house-drainage system which takes wastes from gully traps and disposes to manhole with access for inspection and maintenance.

2.56 Interceptor — A device designed and installed so as to separate and retain deleterious, hazardous or undesirable matter from normal wastes and permit normal sewage or liquid wastes to discharge into the disposal terminal by gravity.

2.57 Interceptor Manhole or Interceptor Chamber — A manhole incorporating an intercepting trap and providing means of access thereto.

2.58 Invert — The lowest point of the internal surface of a pipe or channel at any cross-section.

2.59 Junction Pipe — A pipe incorporating one or more branches.

2.60 Lagging — Thermal insulation or pipes.

2.61 Licensed (or Registered) Plumber — A person licensed (or registered) under the provisions of this Code.

2.62 Main Soil Pipe (MSP) — A pipe connecting one or more branch soil pipes to the drain.

2.63 Main Soil and Waste Pipe (MSWP) — A pipe connecting one or more branch soil and waste pipes to the drain.

2.64 Main Vent Pipe (MVP) — A pipe which receives a number of branch vent pipes.

2.65 Main Waste Pipe (MWP) — A pipe connecting one or more branch waste pipes to the drain.

2.66 Manhole — An opening by which a man may enter or leave a drain, a sewer or other closed structure for inspection, cleaning and other maintenance operations, fitted with suitable cover.

2.67 Manhole Chamber — A Chamber constructed on a drain or sewer so as to provide access thereto for inspection, testing or clearance of obstruction.

2.68 Offset — A pipe fitting used to connect two pipes whose axes are parallel but not in line.

2.69 Pipe System — The system to be adopted will depend on the type and planning of the building in which it is to be installed and will be one of the following:

a) *Single stack system* (*see* Fig. 1) — The piping system in which there is no trap ventilation and the stack itself acts as vent through roof. In this system care shall be taken for proper sizing of the pipes and the trap arm distance, specially the horizontal distance of sanitary fixtures from the drainage stack and vertical distance between connection of branches from fixtures to drainage stack.

b) *One pipe — Partially ventilated system* (*see* Fig. 2) — The piping system in which soil and waste pipes are connected to a single vertical stack [as explained in **2.69** (a)] with additional vent pipe for ventilation of traps of water closets. It is also sometimes known as single stack — partially ventilated system.

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c) *One pipe — Fully ventilated systme* (*see* Fig. 3) — The piping system in which the waste pipes from the sinks, baths and wash basins, and the soil pipe from water closet are connected to a single vertical stack. The traps of the water closets, waste appliances, etc, are individually ventilated and connected with a separate stack to preserve the water seal. It is also sometimes known as single stack — fully ventilated system.

d) *Two pipe system*

1) *Two pipe system with common vent pipe* (*see* Fig. 4A) — The piping system in which all soil appliances such as water closets, urinals, bidet and bedpan sinks are connected to soil stack and all other plumbing fixtures such as baths, sinks, and basins are connected to waste stack through deep seal trap. In addition, a common vent stack is provided for ventilation of soil and waste stacks.

2) *Two pipe system with independent vent pipes* (*see* Fig. 4B) — The piping system in which all soil appliances such as water closets, urinals , bidet and bedpan sinks are connected to soil stack, and all other plumbing fixtures such as baths, sinks, and basins are connected to waste stack through deep seal trap. In addition, there are independent a vent stacks provided for respective ventilation of soil and waste stacks.

2.70 Plumbing

a) The pipes, fixtures and other apparatus inside a building for bringing in the water supply and removing the liquid and water borne wastes.

b) The installation of the foregoing pipes, fixtures and other apparatus.

2.71 Plumbing System — The plumbing system shall include the water supply and distribution pipes; plumbing fittings and traps; soil, waste, vent pipes and anti-siphonage pipes; building drains and building sewers including their respective connections, devices and appurtenances within the property lines of the premises; and water-treating or water-using equipment.

2.72 Premises — Premises shall include passages, buildings and lands of any tenure, whether open or enclosed, whether built on or not, and whether public or private in respect of which a water rate or charge is payable to the Authority or for which an application is made for supply of water and disposal of waste to the public sewer.

2.73 Puff Ventilation — The ventilation provided for waste traps in two-pipe system, in order to preserve the water seal.

2.74 Saddle — A purpose made fitting, so shaped as to fit over a hole cut in a sewer or drain used to form connections.

2.75 Sanitary Appliances — The appliances for the collection and discharge of soil or waste matter.

2.76 Sewer — A pipe or conduit, generally closed, but normally not flowing full for carrying sewage and/or other waste liquids.

2.77 Slop Hopper (Slop Sink) — A hopper shaped sink, with a flushing run and outlet similar to those of a WC pan, for the reception and discharge of human excreta.

2.78 Soakaway — A pit, dug into permeable ground lined to form a covered perforated chamber or filled with hard-core, to which liquid is led, and from which it may soak away into the ground.

2.79 Soffit (Crown) — The highest point of the internal surface of a sewer or culvert at any cross-section.

2.80 Soil Appliances — A sanitary appliance for the collection and discharge of excretory matter.

2.81 Soil Pipe — A pipe that conveys the discharge of water closets or fixtures having similar functions, with or without the discharges from other fixtures.

2.82 Soil Waste — The discharge from water closets, urinals, slop hopper, stable yard or cowshed gullies and similar appliances.

2.83 Stack Vent — The extension of a soil or waste stack above the highest horizontal drain connected to the stack.

2.84 Sub Soil Water — Water occurring naturally in the subsoil.

2.85 Sub Soil Water Drain

a) A drain intended to collect and carry away subsoil water.

b) A drain intended to disperse into the subsoil from a septic tank.

2.86 Sullage — *See* **2.99**.

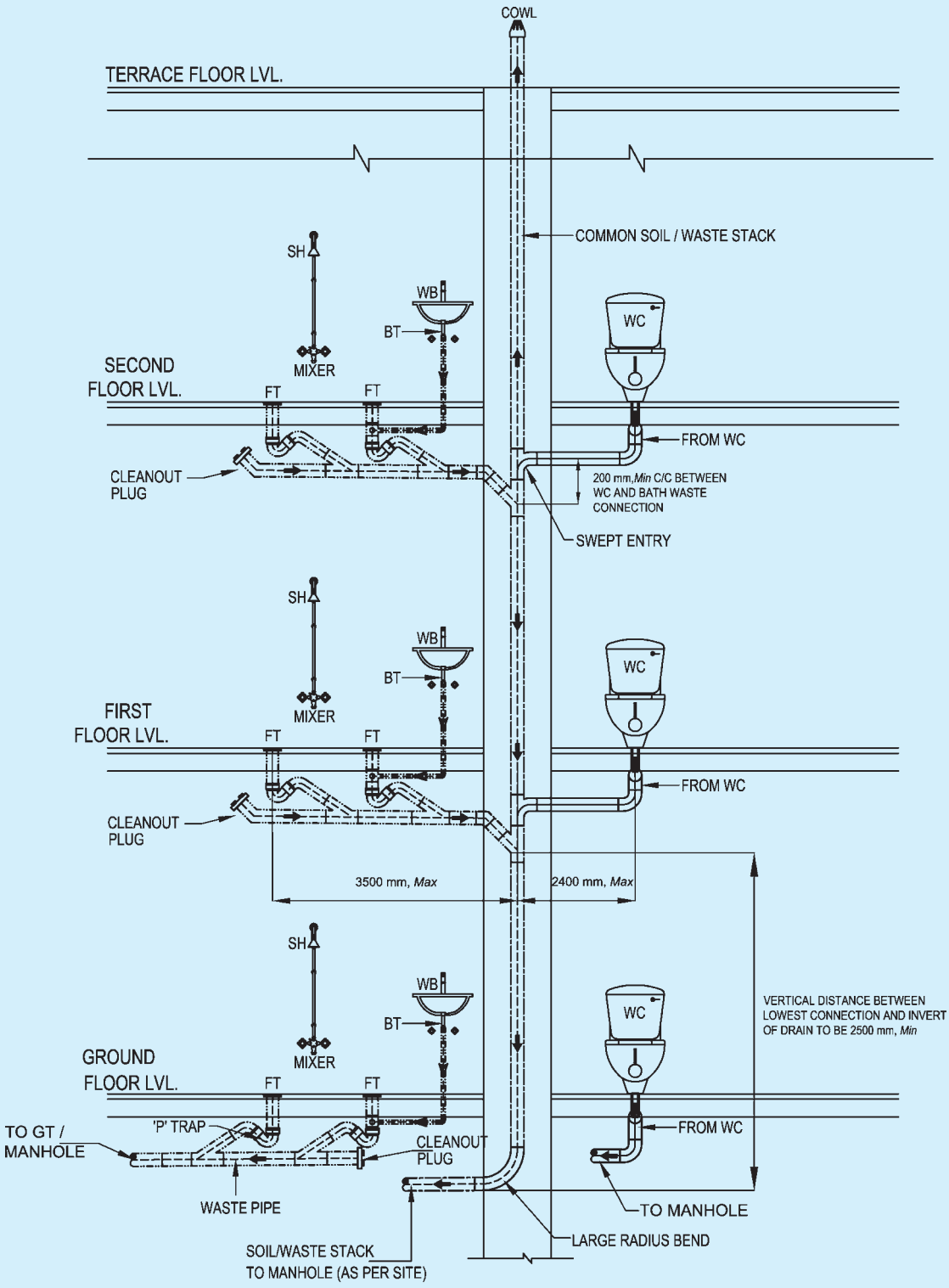
2.87 Supply Pipe — So much of any service pipe as is not a communication pipe.

2.88 Supports — Hangers and anchors or devices for supporting and securing pipe and fittings to walls, ceilings, floors or structural members.

2.89 Surface Water — Natural water from the ground surface, paved areas and roofs.

2.90 Surface Water Drain — A drain conveying surface water including storm water.

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LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

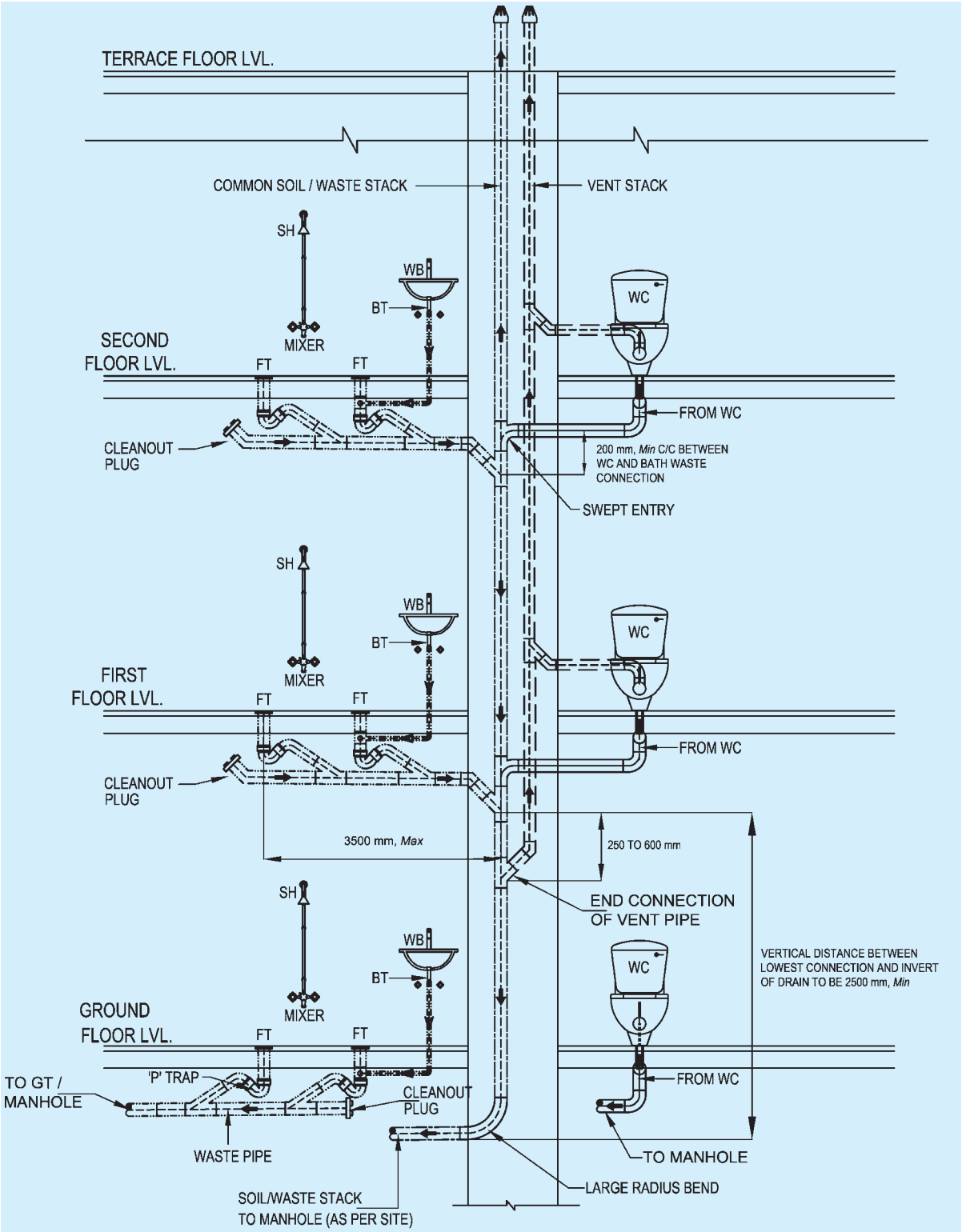
NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste piping shall also be planned in a similar manner as for other waste appliances.

FIG. 1 SINGLE STACK SYSTEM

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LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

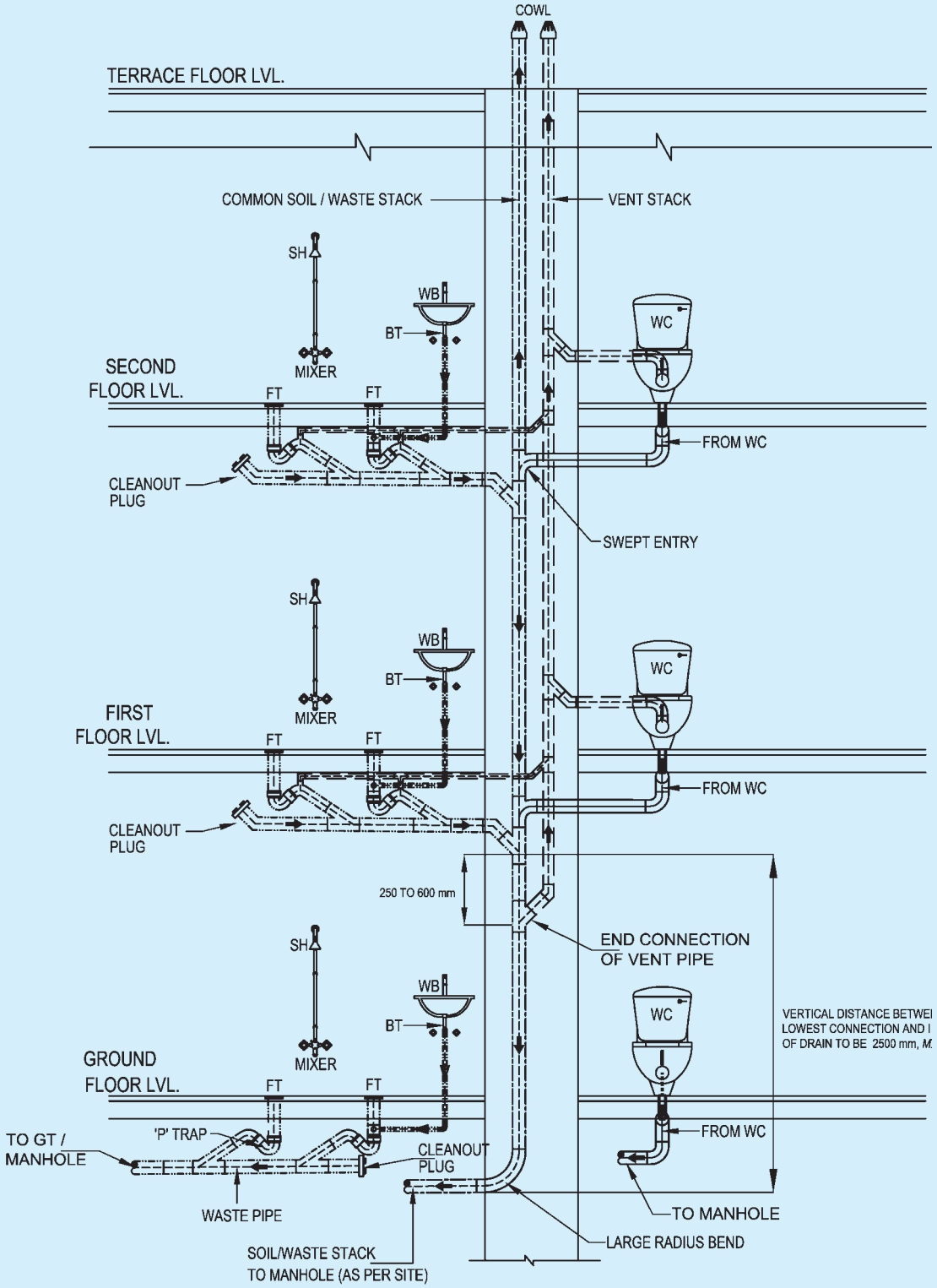
NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste/vent piping shall also be planned in a similar manner as for other waste appliances.

FIG. 2 ONE PIPE — PARTIALLY VENTILATED SYSTEM

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LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

NOTES

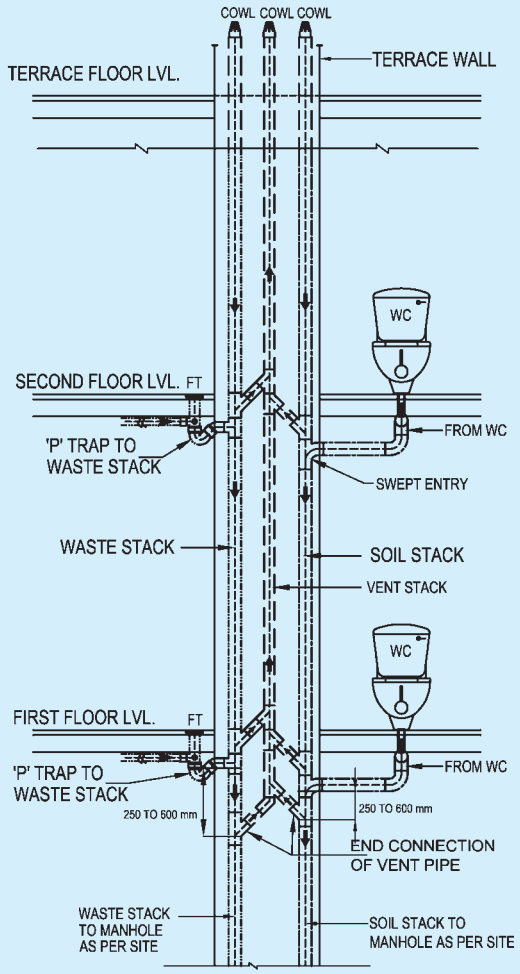
1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste/vent piping shall also be planned in a similar manner as for other waste appliances.

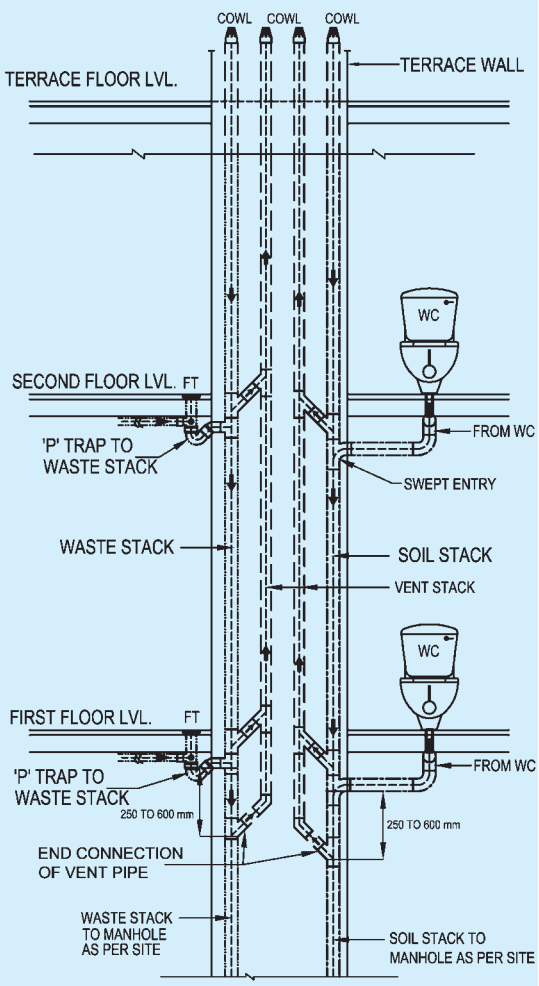
3 The vent pipe shall be installed either in suspended ceiling or in the wall above the toilet floor, depending on space availability and structural arrangements.

FIG. 3 ONE PIPE — FULLY VENTILATED SYSTEM

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4A TWO PIPE SYSTEM WITH COMMON VENT PIPE



4B TWO PIPE SYSTEM WITH INDEPENDENT VENT PIPES

LEGEND

SH	SHOWER
WC	WATER CLOSET
WB	WASH BASIN
FT	FLOOR TRAP
BT	BOTTLE TRAP
GT	GULLY TRAP

NOTES

1 Presentation of type of fixtures/drains, and pipe route/layout is typical in nature.

2 Kitchen waste/vent piping shall also be planned in a similar manner as for other waste appliances.

FIG. 4 TWO PIPE SYSTEM

2.91 Systems of Drainage

a) *Combined system* — A system in which foul water (sewage) (black and grey water) and surface water are conveyed by the same sewers and drains.

b) *Separate system* — A system in which foul water (sewage) (black and grey water) and surface water are conveyed by the separate sewers and drains.

c) *Partially separate system* — A modification of the separate system in which part of the surface water is conveyed by the foul (sanitary) sewers and drains.

2.92 Trade Effluent — Any liquid either with or without particles of matter in suspension which is wholly or in part produced in the course of any trade or industry, at trade premise. It includes farm wastes but does not include domestic sewage.

2.93 Trap — A fittings or device so designed and constructed as to provide, when properly vented, a

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liquid seal which will prevent the back passage of air without materially affecting the flow of sewage or waste water through it.

2.94 Vertical Pipe — Any pipe or fitting which is installed in a vertical position or which makes an angle or not more than 45° with the vertical.

2.95 Vent Stack/Vent Pipe — A vertical vent-pipe installed primarily for the purpose of proving circulation of air to and from any part of the drainage system. It also protects trap seals from excessive pressure fluctuation.

2.96 Vent System — A pipe or pipes installed to provide a flow of air to or from a drainage system or to provide a circulation of air with in such system to protect traps seals from siphonage and back-pressure.

2.97 Waste Appliance — A sanitary appliance for the collection and discharge of water after use for ablutionary, culinary and other domestic purpose.

2.98 Waste Pipe — In plumbing, any pipe that receives the discharge of any fixtures, except water closets or similar fixtures and conveys the same to the house drain or soil or waste stack. When such pipe does not connect directly with a house drain or soil stack, it is called an indirect waste pipe.

2.99 Waste Water (Sullage) — The discharge from wash basins, sinks and similar appliances, which does not contain human or animal excreta.

2.100 Water Closet — A water flushed plumbing fixture designed to receive human excrement directly from the user of the fixture. The term is used sometimes to designate the room or compartment in which the fixture is placed.

2.101 Water Seal — The water in a trap, which acts as a barrier to the passage of air through the trap.

3 GENERAL

3.1 Basic Principles

The basic principles of water supply, drainage and sanitation are given below, and the design of drainage and sanitation should in general be guided by the applicable principles.

3.1.1 *Potable Water*

All premises intended for human habitation, occupancy, or use shall be provided with supply of potable water. This water supply shall not be connected with unsafe water resources, nor shall it be subject to the hazards of backflow.

3.1.2 *Water Provision*

Plumbing fixtures, devices and appurtenances shall be provided with water in sufficient volume and at pressures adequate to enable them to function properly and without undue noise under normal conditions of use.

There should be at least a residual head of 0.018 N/mm^2 at the consumer's tap. There may be certain fixtures or appliances in the installation that may require a higher pressure, such as 0.05 N/mm^2 or even higher (such as 0.1 N/mm^2 in case of flush valves), in which case the system shall be designed using pumps, tanks or both to achieve the required minimum pressure.

NOTE — The residual head shall be taken at the highest/farthest outlets in the building.

3.1.3 *Water Efficiency*

Plumbing system shall be designed, installed and adjusted to use the optimum quantity of water consistent with proper performance and cleaning.

3.1.4 *Safety Devices*

Plumbing system shall be designed and installed with safety devices to safeguard against dangers from contamination, explosion, overheating, etc.

3.1.5 *Minimum Amenities*

Each dwelling unit on premises (abutting on a sewer or with a private sewage disposal system) shall have at least one water closet, one kitchen wash place or a sink, and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in **13** and **B-9** of Part 3 'Development Control Rules and General Building Requirements' of the Code shall also be complied with.

3.1.6 *Drainage System*

The drainage system shall be designed, installed and maintained to guard against fouling, deposit of solids and clogging and with adequate cleanouts so arranged that the pipes may be readily cleaned.

3.1.7 *Materials and Workmanship*

The plumbing system shall have durable material, free from defective workmanship and so designed and installed as to give satisfactory service for its reasonable expected life. The accessories of the plumbing system should be of such specifications as to meet the functional requirements of the installation, so as to also avoid any inconsistency leading to leakage and resultant seepage.

3.1.8 *Fixture Traps and Vent Pipes*

Each fixture directly connected to the drainage system shall be equipped with a liquid seal trap. Trap seals shall be maintained to prevent sewer gas, other

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potentially dangerous or noxious fumes, or vermin from entering the building. Further, the drainage system shall be designed to provide an adequate circulation of air in all pipes with no danger of siphonage, aspiration, or forcing of trap seals under conditions of ordinary use by providing vent pipes throughout the system.

3.1.9 *Foul Air Exhaust*

Each vent terminal shall extend to the outer air and be so installed as to minimize the possibilities of clogging and the return of foul air to the building, as it conveys potentially noxious or explosive gases to the outside atmosphere. All vent pipes shall be provided with a cowl.

3.1.10 *Testing*

The plumbing system shall be subjected to required tests to effectively disclose all leaks and defects in the work or the material.

3.1.11 *Exclusion from Plumbing System*

No substance that will clog or accentuate clogging of pipes, produce explosive mixtures, destroy the pipes or their joints, or interfere unduly with the sewage-disposal process shall be allowed to enter the drainage system.

3.1.12 *Light and Ventilation*

Wherever water closet or similar fixture is located in a room or compartment, it should be properly lighted and ventilated.

3.1.13 *Individual Sewage Disposal Systems*

If water closets or other plumbing fixtures are installed in buildings where connection to public sewer is not possible, suitable provision shall be made for acceptable treatment and disposal.

3.1.14 *Maintenance*

Plumbing systems shall be maintained in a safe and serviceable condition.

3.1.15 *Approach for Use and Cleaning*

All plumbing fixtures shall be so installed with regard to spacing as to be approachable for their intended use and for cleaning. All doors, windows and any other device needing access within the toilet shall be so located that they have proper approach.

3.1.16 *Accessibility for Persons with Disabilities*

All doors, windows and fixtures, including WC, urinals, grab bars, wash basin, mirror and all other accessories for use by persons with disabilities shall be so installed/ located that they have proper access with appropriate width, height, space, centerlines, and ease of operation (*see* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code).

3.1.17 *Structural Safety*

Plumbing system shall be installed with due regard to preservation of the structural members and prevention of damage to walls and other surfaces.

3.1.18 *Protection of Ground and Surface Water*

Sewage or other waste shall not be discharged into surface or sub-surface water without acceptable form of treatment.

3.2 Drainage and Sanitation

3.2.1 *Preparation and Submission of Plan*

No person shall install or carry out any water-borne sanitary installation or drainage installation or any works in connection with anything existing or new buildings or any other premises without obtaining the prior sanction of the Authority.

The owner shall make an application in the prescribed form (*see* Annex A) to the Authority to carry out such a work.

3.2.2 *Site Plan*

A site plan of the premises on which the building is to be situated or any such work is to be carried out shall be prepared drawn to a scale not smaller than 1 in 500 (*see* Part 2 'Administration' of the Code). The site plan of the building premises shall show,

a) the adjoining plots and streets with their names;
b) the position of the municipal sewer and the direction of flow in it;
c) the invert level of the municipal sewer, the road level, and the connection level of the proposed drain connecting the building in relation to the sewer,
d) the angle at which the drain from the building joints the sewer; and
e) the alignment, sizes and gradients of all drains and also of surface drains, if any.

A separate site plan is not necessary if the necessary particulars to be shown in such a site plan are already shown in the drainage plan.

3.2.3 *Drainage Plan*

The application (*see* **3.3.1**) shall be accompanied by a drainage plan drawn to a scale of not smaller than 1 in 100 and furnished along with the building plan (*see* Part 2 'Administration' of the Code). The plans shall show the following:

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a) Every floor of the building in which the pipes or drains are to be used;
b) The position, forms, level and arrangement of the various parts of such building, including the roof thereof;
c) All new drains as proposed with their sizes and gradients;
d) Invert levels of the proposed drains with corresponding ground levels;
e) The position of every manhole, gully, soil and waste pipe, vent pipe, rainwater pipe, water closet, urinal, latrine, bath, lavatory, sink, trap or other appliances in the premises proposed to be connected to any drain and the following colours are recommended for indicating sewers, waste water pipes, rainwater pipes an existing work:

Description of Work	*Colour*
Sewers	Red
Waste water pipes and rainwater pipes	Blue
Existing work	Black

f) The position of refuse chute, inlet hopper and collection chamber.

3.2.3.1 In the case of an alteration or addition to an existing building, this clause shall be deemed to be satisfied if the plans as furnished convey sufficient information for the proposals to be readily identified with previous sanctioned plans and provided the locations of tanks and other fittings are consistent with the structural safety of the building.

3.2.3.2 The plans for the building drainage shall in every case be accompanied by specifications for the various items of work involved. This information shall be supplied in the prescribed form given in Annex B.

3.2.4 In respect of open drains, cross-sectional details shall be prepared to a scale not smaller than 1 in 50 showing the ground and invert levels and any arrangement already existing or proposed for the inclusion of any or exclusion of all storm water from the sewers.

3.2.5 *Completion Certificate*

At the completion of the plumbing installation work, the licensed/registered plumber shall give a completion certificate in the prescribed form, which is given in Annex C.

3.3 Licensing/Registration of Plumbers

3.3.1 *Execution of Work*

The work which is required to be carried out under the provisions of this section, shall be executed only by a licensed/registered plumber under the control of the Authority and shall be responsible to carry out all lawful directions given by the Authority. No individual shall engage in the business of plumbing unless so licensed/ registered under the provisions of this Section.

3.3.1.1 No individual, firm, partnership or corporation shall engage in the business of installing, repairing or altering plumbing unless the plumbing work performed in the course of such business is under the direct supervision of a licensed/registered plumber from approved Authority.

3.3.2 *Examination and Certification*

The Authority shall establish standards and procedure for the qualification, examination and licensing/ registration of plumbers and shall issue licences to such persons who meet the qualifications thereof and successfully pass the examination.

3.3.3 For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences, reference may be made to good practice [9-2(2)]. The Authority may also utilize the services of the certified plumbers who are certified for the required skill level under the appropriate scheme of the Government.

4 DRAINAGE AND SANITATION

4.1 Types of Sanitary Appliances

4.1.1 *Soil Appliances*

4.1.1.1 *Water closet*

It shall essentially consist of a closet consisting of a bowl to receive excretory matter, trap and a flushing apparatus. It is recommended to provide ablution tap adjacent to the water closet, preferably on right hand side wall. The various types/style of water closets may be:

a) Squatting Indian type water closet,
b) Washdown type water closet,
c) Siphonic washdown type water closet, and
d) Universal or Anglo-Indian water closet.

4.1.1.2 *Bidet*

Bidet is an ablution appliance for cleansing excretory organs with water for personnel hygiene. It may be pedestal type or wall hung with a shallow bowl. Hot and cold water supplied through a mixer is discharged from a spray installed over the rim of the appliance. The bidet outlet should essentially connect to soil pipe in a system.

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4.1.1.3 *Urinal*

It is a soil appliance for urination and is connected to soil pipe after a suitable trap. Urinal should have adequate provision of flushing apparatus. The various types/style of urinal may be:

a) Bowl type urinal: flat back or angle back.

b) Slab (single) type urinal.

c) Stall (single) type urinal.

d) Squatting plate type urinal.

e) Syphon jet urinal with integral trap.

f) Water less (non-water) urinal

4.1.1.4 *Slop sink*

Slop sink is a large sink, generally of square shape. the appliance is used in hospitals and is installed in the dirty utility room, sluice room and similar locations for disposal of excreta and other foul waste and for washing bed pans and urine bottles/pans. It is provided with a flushing mechanism. It is also provided in Janitor's closet where it is used for cleaning the housekeeping mops, etc.

4.1.1.5 *Bed pan sink*

Bed pan sink, also known as bedpan washer and disinfector, is a part of medical equipment inventory which is used to clean manually or automatically, the hospital bedpans, urine bottles and other containers used for collecting body fluids. It is provided in dirty utility room, sluice room, similar locations for disposal of excreta and other foul waste and for washing bed pans, urine bottles/pans. It is a soil appliance and is connected to soil pipe after a suitable trap. In manual models, it has a flushing arrangement.

Provision for installing a bedpan washer and disinfector should be made in all intensive care units in hospitals.

4.1.2 *Waste Appliances*

4.1.2.1 *Wash basin*

It is of one-piece construction having a combined overflow and preferably should have soap holding recess or recesses that should properly drain into the bowl. Each basin shall have circular waste hole through which the liquid content of the basin shall drain.

4.1.2.2 *Wash-trough*

It is a linear trough for simultaneous use by number of persons.

4.1.2.3 *Sink*

It is used in kitchen and laboratory for the purpose of cleaning utensils/ apparatus and also serve the purpose of providing water for general usage. The sink may be made with or without overflow arrangement. The sink shall be of one-piece construction including combined over flow, where provided. The sink shall have a circular waste hole into which the interiors of the sink shall drain.

4.1.2.4 *Bath tub*

Bath tub may be of enameled steel, cast iron, gel-coated, glass fibre reinforced plastic or may be cast *in-situ*. It shall be stable, comfortable, easy to get in and out, water tight, with anti-skid base, and easy to install and maintain. The bath tub shall be fitted with overflow and waste pipe of nominal diameter of not less than 32 mm and 40 mm, respectively.

4.1.2.5 *Drinking fountain*

It is a bowl fitted with a push button tap and a water bubbler or a tap with a swan neck outlet fitting. It has a waste fitting, a trap and is connected to the waste pipe.

4.1.3 The requirements of various soil appliances and waste appliances shall be in accordance with accepted standards [9-2(3)].

4.2 Drainage and Sanitation Requirements

4.2.1 *General*

There should be at least one water tap and arrangement for drainage in the vicinity of each water closet or group of water closet in all the buildings.

4.2.2 Each dwelling unit on premises (abutting on a sewer or with a private sewage disposal system) shall have at least one water closet, one kitchen wash place or a sink, and one bathing place or shower to meet the basic requirements of sanitation and personal hygiene.

In case of a group housing, the requirements relating to toilet or sanitary room and kitchen as given in **13** and **B-9** of Part 3 'Development Control Rules and General Building Requirements' of the Code shall also be complied with.

4.2.3 All other structures for human occupancy or use on premises (abutting on a sewer or with a private sewage disposal system) shall have adequate sanitary facilities, but in no case less than one water closet and one other fixture for cleaning purposes.

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Table 1 Office Building
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
	Executive Rooms and Conference Halls in Office Buildings				
i)	Toilet suite comprising one WC, one wash basin (with optional shower stall if building is used round the clock at user's option)	Unit could be common for male/female or separate depending on the number of user of each facility		For individual officer rooms	
	Pantry optional as per user requirement				
	Main Office Toilets for Staff and Visitors				
ii)	Water closets	*See* Note		1 per 25	1 per 15
iii)	Ablution tap with each water closet	← 1 in each water closet →			
iv)	Urinals	*See* Note	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100 From 101 to 200, add @ 3% For over 200, add @ 2.5%	—
v)	Wash basins	*See* Note		1 per 25	1 per 25
vi)	Drinking water fountain	*See* Note		1 per 100	1 per 100
vii)	Cleaner's sink	← 1 per floor →			

NOTE — Staff and public toilet utilities are generally common in office buildings. Where public toilets are to be provided independently, similar requirements as that of staff toilet may be provided.

4.2.4 *For Residences*

4.2.4.1 Dwelling with individual convenience shall have at least the following fitments:

a) One bath room provided with a tap and a floor trap;
b) One water closet with flushing apparatus with an ablution tap; and
c) One tap with a floor trap or a sink in kitchen or wash place.

4.2.4.1.1 Where only one water closet is provided in a dwelling, it is desirable to have the bath and water closet separately accommodated.

4.2.4.2 Dwellings without individual conveniences shall have the following fitments:

a) One water tap with floor trap in each tenement,
b) One water closet with flushing apparatus and one ablution tap bath for every two tenements, and
c) One bath with water tap and floor trap for every two tenements.

4.2.5 *For Buildings Other than Residences*

4.2.5.1 The requirements for fitments for drainage and sanitation in the case of buildings other than residences shall be in accordance with Table 1 to Table 15.

The accessibility requirements for provision of these facilities for persons with disabilities shall be in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

The following shall be, in addition, taken into consideration:

a) The figures shown are based upon one (1) fixture being the minimum required for the number of persons indicated or part thereof.
b) Building categories not included in the tables shall be considered separately by the Authority.
c) Drinking fountains shall not be installed in the toilets.
d) Where there is the danger of exposure to skin contamination with poisonous, infectious or irritating material, wash basin with eye wash jet and an emergency shower (safety shower with eye wash unit) located in an area accessible at all times with the passage/right of way suitable for access to a wheel chair, shall be provided.
e) When applying the provision of these tables for providing the number of fixtures, consideration shall be given to the accessibility of the fixtures. Using purely numerical basis may not result in an

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Table 2 Factories
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Offices/Visitors		Workers	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets (workers and staff)	1 for up to 25 2 for 26 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 15 2 for 16 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100
	For persons 101-200 add	3%	5%	3%	5%
	For persons over 200 add	2.5%	4%	2.50%	4%
ii)	Ablution tap	1 in each water closet	1 in each water closet	1 in each water closet	1 in each water closet
iii)	Urinals	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100 From 101 to 200, add @ 3% For over 200, add @ 2.5%	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100 From 101 to 200, add @ 3% For over 200, add @ 2.5%	—
iv)	Wash basins	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof	1 per 25 or part thereof
	Wash basins in rows or troughs and taps spaced 750 mm c/c				
v)	Drinking water fountain	1 per every 100 or part thereof with minimum one on each floor		1 per every 100 or part thereof with minimum one on each floor	
vi)	Cleaner's sink	1 on each floor	1 on each floor	1 on each floor	1 on each floor
vii)	Showers/bathing rooms	← As per trade requirements →			
viii)	Emergency shower and eye wash fountain	—	—	1 per every shop floor per 500 persons	

NOTES

1 For factories requiring workers to be engaged in dirty and dangerous operations or requiring them to being extremely clean and sanitized conditions additional and separate (if required so) toilet facilities and if required by applicable Industrial and safety laws and the *Factories Act* shall be provided in consultation with the user.

2 Depending on the type of disability of a person and the hazard posed by the type of activities in the factory for a person with disabilities, if a person with disabilities is decided to be engaged for a particular activity, the requirements of accessibility shall be guided by the provisions given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

Table 3 Cinema, Multiplex Cinema, Concert and Convention Halls, Theatres and Stadia
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 100 up to 400 Over 400 add at 1 per 250 or part thereof	3 per 100 up to 200 Over 200 add at 2 per 100 or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
ii)	Ablution tap	1 in each water closet	1 in each water closet	1 in each water closet	1 in each water closet
	1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals				
iii)	Urinals	1 per 25 or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45	—
iv)	Wash basins	1 per 200 or part thereof		1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
v)	Drinking water fountain	← 1 per 100 persons or part thereof →			
vi)	Cleaner's sink	← 1 per floor →			
vii)	Showers/bathing rooms	← As per trade requirements →			

NOTES
1 Some WCs may be Indian style, if desired.
2 Male population may be assumed as two-third and female population as one-third.

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Table 4 Art Galleries, Libraries and Museums
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public		Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 200 up to 400 Over 400 add at 1 per 250 or part thereof	1 per 100 up to 200 Over 200 add at 1 per 150 or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	1 per 50	—	Nil up to 6 1 per 7 to 20 2 per 21 to 45	—
iv)	Wash basins	1 for every 200 or part thereof. For over 400, add at 1 per 250 persons or part thereof	1 for every 200 or part thereof. For over 200, add at 1 per 150 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
v)	Drinking water fountain	1 per 100 persons or part thereof			
vi)	Cleaner's sink	1 per floor (Minimum)			
vii)	Showers/bathing rooms	As per requirements			

NOTES
1 Some WCs may be Indian style, if desired.
2 Male population may be assumed as two-third and female population as one-third.

Table 5 Hospitals with Indoor Patient Wards
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one wash basin and shower stall	Private room with up to 4 patients		For individual doctor's/officer's rooms	
	For General Wards, Hospital Staff and Visitors				
ii)	Water closets	1 per 5 beds or part thereof	1 per 5 beds or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 15 beds	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45	—
v)	Wash basins	2 for every 30 beds or part thereof. Add 1 per additional 30 beds or part thereof		1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
vi)	Drinking water fountain	1 per ward		1 per 100 persons or part thereof	
vii)	Cleaner's sink	1 per ward		—	
viii)	Bed pan sink	1 per ward		—	
ix)	Kitchen sink	1 per ward		—	

NOTES
1 Some WCs may be of Indian style, if desired.
2 Male population may be assumed as two-third and female population as one-third.
3 Provision for additional and special hospital fittings where required shall be made.
4 Drinking water fountains are not recommended for hospitals for reasons of infection control. This is to be decided by the health authority recommendations.

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Table 6 Hospitals with Outdoor Patient Department
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Patient Toilets		Staff Toilets	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC and one wash basin (with optional shower stall if building used for 24 h)	For up to 4 patients		For individual doctor's/officer's rooms	
ii)	Water closets	1 per 100 persons or part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45	—
v)	Wash basins	2 per 100 persons of part thereof	2 per 100 persons or part thereof	1 for up to 15 2 for 16 to 35	1 for up to 12 2 for 13 to 25
vi)	Drinking water fountain	*See* Note 2		1 per 100 persons or part thereof	

NOTES
1 Some WCs may be Indian style, if desired.
2 Drinking water fountains are not recommended for hospitals for reasons of infection control. This to be decided by the health authority recommendation.
3 The WCs shall be provided keeping in view the location of main OPD waiting hall and sub-waiting halls, floor wise, so as to serve the people effectively. The number of patients shall be calculated floor wise. The OPD population shall include patient attendants @ at least 1 per patient.
4 Male population may be assumed as two-third and female population as one-third.
5 Provision for additional and special hospital fittings where required shall be made.

Table 7 Hospitals, Administrative Buildings
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Toilets	
		Males	Females
(1)	(2)	(3)	(4)
i)	Toilet suite comprising one WC, one urinal and one wash basin (with optional shower stall if building used for 24 h)	For individual doctor's/officer's rooms	
ii)	Water closets	1 per 25 persons or part thereof	1 per 15 persons or part thereof
iii)	Ablution tap	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals	
iv)	Urinals	1 for 6 to 15 2 for 16 to 50	—
v)	Wash basins	1 per 25 persons or part thereof	1 per 25 persons or part thereof
vi)	Drinking water fountain	1 per 100 persons or part thereof (*See* Note 2)	
vii)	Cleaner's sink	1 per floor, *Min*	
viii)	Kitchen sink	1 per floor, *Min*	

NOTES
1 Some WCs may be Indian style, if desired.
2 Drinking water fountains to be provided only when it is a separate block and patients will not use it.

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Table 8 Hospitals Staff Quarters and Nurses Homes

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Quarters		Nurses Homes	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 4 persons or part thereof	1 per 4 persons or part thereof	1 per 4 persons or part thereof 2 for 5 to 35	1 per 4 persons or part thereof 2 for 5 to 25
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Wash basins	1 per 8 persons or part thereof		1 per 8 persons or part thereof	
iv)	Bath (showers)	1 per 4 persons or part thereof		1 per 4 to 6 persons or part thereof	
v)	Drinking water fountain	1 per 100 persons or part thereof, *Min* 1 per floor		1 per 100 persons or part thereof, *Min* 1 per floor	
vi)	Cleaner's sink	1 per Floor		1 per Floor	

NOTES
1 Some WCs may be Indian style, if desired.
2 For independent housing units, fixtures shall be provided as for residences.

Table 9 Hotels

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Rooms		Non Residential Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Toilet suite comprising one WC, wash basin with shower or a bath tub	Individual guest rooms with attached toilets		—	
	Guest Rooms with Common Facilities				
ii)	Water closets	1 per 100 persons up to 400 Over 400 add at 1 per 250 or part thereof	2 per 100 persons up to 200 Over 200 add at 1 per 100 or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100
iii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iv)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	—
v)	Wash basins	1 per WC/Urinal	1 per WC	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57
vi)	Bath (showers)	1 per 10 persons or part thereof		—	—
vii)	Cleaner's sink	1 per 30 rooms, *Min* 1 per floor			
viii)	Kitchen sink	1 per kitchen			

NOTES
1 Some WCs may be Indian style, if desired.
2 Male population may be assumed as two-third and female population as one-third.
3 Provision for additional and special fittings where required shall be made.

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Table 10 Restaurants
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Public Rooms		Non-Residential Staff	
		Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)
i)	Water closets	1 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	2 per 50 seats up to 200 Over 200 add at 1 per 100 or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals			
iii)	Urinals	1 per 50 persons or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	—
iv)	Wash basins	1 per WC	1 per WC	1 per WC	1 per WC
v)	Cleaner's sink	1 per each restaurant			
vi)	Kitchen sink/dish washer	1 per kitchen			

NOTES
1 Some WCs may be Indian style, if desired.
2 Male population may be assumed as two-third and female population as one-third.
3 Provision for additional and special fittings where required shall be made.

Table 11 Schools and Educational Institutions
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Nursery School	Non-Residential		Residential	
			Boys	Girls	Boys	Girls
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	Water closets	1 per 15 pupils or part thereof	1 per 40 pupils or part thereof	1 per 25 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals				
iii)	Urinals	—	1 per 20 pupils or part thereof	—	1 per 25 pupils or part thereof	—
iv)	Wash basins	1 per 15 pupils or part thereof	1 per 60 pupils or part thereof	1 per 40 pupils or part thereof	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
v)	Bath/showers	1 per 40 pupils or part thereof	—	—	1 per 8 pupils or part thereof	1 per 6 pupils or part thereof
vi)	Drinking water fountain or taps	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof	1 per 50 pupils or part thereof
vii)	Cleaner's sink	← 1 per each floor →				

NOTES
1 Some WCs may be Indian style, if desired.
2 For teaching staff, the schedule of fixtures to be provided shall be the same as in case of office building.

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Table 12 Hostels
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Resident		Non-Resident		Visitor/Common Rooms	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	1 per 8 or part thereof	1 per 6 or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 100 up to 400 Over 400 add at 1 per 250	2 per 100 up to 200 Over 200 add at 1 per 100
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	1 per 25 or part thereof	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	—	1 per 50 or part thereof	—
iv)	Wash basins	1 per 8 persons or part thereof	1 per 6 persons or part thereof	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per WC/ Urinal	1 per WC
v)	Bath/showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	—	—	—	—
vi)	Cleaner's sink	←		1 per each floor		→	

NOTE — Some WCs may be Indian style, if desired.

Table 13 Fruit and Vegetable Markets
(*Clause* 4.2.5.1)

Sl No.	Fixtures	Shop Owners		Common Toilets in Market Building		Public Toilet for Floating Population	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	1 per 8 or part thereof		1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 50 (*Min* 2)	1 per 50 (*Min* 2)
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided in receiving/ sale area of each shop and for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	—	—	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	—	1 per 50	—
iv)	Wash basins	1 per 8 or part thereof		1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57	—	—
v)	Bath/showers	1 per 8 persons or part thereof	1 per 6 persons or part thereof	—	—	1 per 50 persons	1 per 50 persons

NOTES
1 Toilet facilities for individual buildings in a market should be taken same as that for office buildings.
2 Common toilets in the market buildings provide facilities for persons working in shops and their regular visitors.
3 Special toilet facilities for a large floating population of out of town buyers/sellers, labour, drivers of vehicles for whom special toilet (public toilets).

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Table 14 Bus Stations, Airports and Railway Stations

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Junction Stations, Intermediate Stations and Bus Stations		Terminal Railway and Bus Stations		Domestic and International Airports	
		Males	Females	Males	Females	Males	Females
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Water closets	3 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	4 for up to 1 000 Add 1 per additional 1 000 or part thereof	5 for up to 1 000 Add 1 per additional 1 000 or part thereof	*Min* 2 For 200 : 5 For 400 : 9 For 600 : 12 For 800 : 16 For 1 000 : 18	*Min* 2 For 200 : 8 For 400 : 15 For 600 : 20 For 800 : 26 For 1 000 : 29
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet	One in each water closet
		1 water tap with draining arrangements shall be provided for every 50 persons or part thereof in the vicinity of water closets and urinals					
iii)	Urinals	4 for up to 1 000 Add 1 per additional 1 000	—	6 for up to 1 000 Add 1 per additional 1 000	—	1 per 40 or part thereof	—
iv)	Wash basins	1 per WC/ Urinal	1 per WC	1 per WC/ Urinal	1 per WC	1 per WC/ Urinal	1 per WC
v)	Bath/showers	2 per 1 000		3 per 1 000		4 per 1 000	
vi)	Drinking water fountain or taps (in common lobby for male/female)	2 per 1 000 or part thereof		3 per 1 000 or part thereof		4 per 1 000 or part thereof	
vii)	Cleaner's sink	1 per toilet compartment with 3 WCs	1 per toilet compartment with 3 WCs	1 per toilet compartment with 3 WCs	1 per toilet compartment with 3 WCs	1 per toilet compartment with 3 WCs	1 per toilet compartment with 3 WCs

NOTES

1 Some WCs may be Indian style, if desired.

2 Male population may be assumed as three-fifth and female population as two-fifth.

3 Separate provision shall be made for staff and workers.

Table 15 Shopping Malls and Retail Buildings

(*Clause* 4.2.5.1)

Sl No.	Fixtures	Staff Toilets in Shopping Building		Public Toilet for Floating Population	
		Males	Females	Males	Females
(1)	(2)	(5)	(6)	(7)	(8)
i)	Water closets	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57 5 for 58 to 77 6 for 78 to 100	1 per 50 (*Min* 2)	1 per 50 (*Min* 2)
ii)	Ablution tap	One in each water closet	One in each water closet	One in each water closet	One in each water closet
iii)	Urinals	Nil up to 6 1 for 7 to 20 2 for 21 to 45 3 for 46 to 70 4 for 71 to 100	—	1 per 50	—
iv)	Wash basins	1 for up to 15 2 for 16 to 35 3 for 36 to 65 4 for 66 to 100	1 for up to 12 2 for 13 to 25 3 for 26 to 40 4 for 41 to 57	1 per 50 (*Min* 2)	1 per 50 (*Min* 2)
v)	Bath/showers	1 per 100 persons	1 per 100 persons	—	—

NOTES

1 Toilet facilities for individual facilities in a shopping building should be taken same as that for office buildings.

2 Staff toilets in the shopping buildings provide facilities for persons working in shops and building, as well as for maintenance staff.

3 The number of persons against the fixture bath/showers represent the maintenance staff requiring such facility.

4 Public toilet facilities are provided for a large floating population for buyers and visitors.

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installation suited to the need of a specific building. For example, schools should be provided with toilet facilities on each floor. Similarly, toilet facilities shall be provided for temporary workmen employed in any establishment according to the needs; and in any case one WC and one wash basin shall be provided.

f) All buildings used for human habitation for dwelling, work, occupation, medical care or any purpose detailed in the various tables, abutting a public sewer or a private sewage disposal system, shall be provided with minimum sanitary facilities as per the schedule in the tables. In case the disposal facilities are not available, they shall be provided as a part of the building design for ensuring high standards of sanitary conditions in accordance with this section.

g) Workplaces where crèches are provided, they shall be provided with one WC for 10 persons or part thereof, one wash basin for 15 persons or part thereof, one kitchen sink with floor trap for preparing food/milk preparations. The sink provided shall be with a drinking water tap.

h) In all types of buildings, individual toilets and pantry should be provided for executives, and for meeting/seminar/conference rooms, etc, as per the user requirement.

j) Where food is consumed indoors, water stations may be provided in place of drinking water fountains.

4.3 Materials, Fittings and Appliances

4.3.1 *Standards for Materials, Fittings and Sanitary Appliances*

All materials, fittings and sanitary appliances shall conform to Part 5 'Building Materials' of the Code.

4.3.2 *Choice of Material for Pipes*

4.3.2.1 *Salt glazed stoneware pipe*

For all sewers and drains in all soils, except where supports are required as in made-up ground, glazed stoneware pipe shall be used as far as possible in preference to other types of pipes. These pipes are particularly suitable where acid effluents or acid subsoil conditions are likely to be encountered. Salt glazed stoneware pipes shall conform to accepted standards [9-2(4)].

4.3.2.2 *Cement concrete pipes*

When properly ventilated, cement concrete pipes with spigot and socket or collar joints present an alternative to glazed stoneware sewers of over 150 mm diameter. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those subsoils that are likely to affect adversely the quality or strength of concrete. Where these pipes are employed for conveying liquid containing sulphates, the pipes used shall be manufactured using sulphate resisting Portland cement. Owing to the longer lengths of pipes available, the joints would be lesser in the case of cements concrete pipes. These pipes may be used for surface water drains in all diameters. Cement concrete pipes shall conform to accepted standards [9-2(5)].

4.3.2.3 *Cast iron pipes*

4.3.2.3.1 These pipes shall be used in the following situation:

a) In bed or unstable ground where soil movement is expected;

b) In made-up or tipped ground;

c) To provide for increased strength where a sewer is laid at insufficient depth, where it is exposed or where it has to be carried on piers or above ground;

d) Under buildings and where pipes are suspended in basements and like situations;

e) In reaches where the velocity is more than 2.4 m/s; and

f) For crossings of watercourses.

NOTE — In difficult foundation condition such a in the case of black cotton soil, the cast iron pipes shall be used only when suitable supporting arrangements are made.

4.3.2.3.2 It shall be noted that cast iron pipes even when given a protective paint are liable to severe external corrosion in certain soils; among such soils are:

a) Soils permeated by peaty waters; and

b) Soils in which the subsoil contains appreciable concentrations of sulphates. Local experiences shall be ascertained before cast iron pipes are used where corrosive soil conditions are suspected. Where so used, suitable measures for the protection of the pipes may be resorted to as an adequate safeguard.

4.3.2.3.3 Cast iron pipes shall conform to accepted standards [9-2(6)].

4.3.2.4 *Asbestos cement pipes*

Asbestos cement pipes are commonly used for house drainage systems and they shall conform to accepted standards [9-2(7)]. They are not recommended for underground situations. However, asbestos cement pressure pipes conforming to accepted standards [9-2(7)] may be used in underground situations also, provided they are not subject to heavy superimposed

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loads. These shall not be used to carry acid effluents or sewage under conditions favourable for the production of hydrogen sulphide and shall not be laid in those subsoils which are likely to affect adversely the quality or strength of asbestos cement pipes. Where so desired, the life of asbestos cement pipes may be increased by lining inside of the pipe with suitable coatings like epoxy/polyester resins, etc.

4.3.2.5 *PVC pipes*

Unplasticized PVC pipes may be used for drainage purposes; however, where hot water discharge is anticipated, the wall thickness shall be minimum 3 mm irrespective of the size and flow load.

PVC and HDPE pipes shall conform to accepted standards [9-2(8)].

NOTE — Where possible, high density polyethylene pipes (HDPE) and PVC pipes may be used for drainage and sanitation purposes, depending upon the suitability.

4.3.2.6 *Corrugated pipes*

These pipes (externally corrugated) are used for sewerage and drainage applications. They are light weight and have long life. The leakage and infiltration at joints are less. The operational cost is low and can easily withstand natural settlements without suffering cracks or leakages. They consume fewer raw material and have less carbon dioxide emission.

4.3.2.7 *Low noise pipes*

Waste water systems encompass the system of drainage and pressure relief pipes within a building and terminate 0.5 m outside the external wall. Waste water systems are based on the primary pressure-relief system in which water and air-flow occurs in the same pipe. The waste water system shall be separated from the roof drainage system.

Noise is a variance in air pressure that spreads like a wave. If quick changes in pressure occur between 20 and 20 000 times a second (frequency 20 Hz and 20 kHz), they are audible to humans. The loudness of noise is determined by the amplitude of the wave, which is measured in decibels (dB).

The main cause of noise in indoor drainage systems (primarily focused on the downpipe) are the choice of the pipe system, the bracket type and the design of drainage system. Optimizing these factors will therefore have the best influence on noise reduction.

4.3.2.8 *Under slung pipes*

In under slung plumbing, the toilet slab is built at the same level as the slabs outside the toilet. Holes/core cuts are punctured through the slab wherever pipes have to pass through, and the plumbing is clamped to the bottom of the slab. It is then concealed above a false ceiling, which is accessible above the false ceiling for routine maintenance. In this type of plumbing, any leaks will drip onto the false ceiling which is easily detectable thus allow quick maintenance without much damage to the structure or occupied premises

4.4 Preliminary Data for Design

4.4.1 *General*

Before the drainage system for a building or group of buildings is designed and constructed, accurate information regarding the site conditions is essential. This information may vary with the individual scheme but shall, in general, be covered by the following:

a) Site plan (*see* **3.2.2**).
b) Drainage plan (*see* **3.2.3**).
c) *Use* — A description of the use for which the building is intended and periods of occupation in order that peak discharges may be estimated;
d) *Nature of waste* — While dealing with sewage from domestic premises, special problems under this head may not arise; however, note shall be taken of any possibility of trade effluents being discharged into the pipes at a future date;
e) *Outlet connection* — The availability of sewers or other outlets;
f) *Cover* — The depth (below ground) of the proposed sewers and drains and the nature and weight of the traffic on the ground above them;
g) *Subsoil condition*
    1) The approximate level of the subsoil water, and any available records of flood levels shall be ascertained, as also the depth of the water table relative to all sewer connections, unless it is known to be considerably below the level of the latter.
    2) In the case of deep manholes, this information will influence largely the type of construction to be adopted. The probable safe bearing capacity of the subsoil at invert level may be ascertained in the case of a deep manhole.
    3) Where work of any magnitude is to be undertaken, trial pits or boreholes shall be put at intervals along the line of the proposed sewer or drain and the data therefrom tabulated, together with any information available from previous works carried out in the vicinity. In general, the information derived from

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trial pits is more reliable than that derived from boreholes. For a long length of sewer or drain, information derived from a few trial pits at carefully chosen points may be supplemented by that obtained from number of intermediate boreholes.

Much useful information is often obtained economically and quickly by the use of a soil auger.

4) The positions of trial pits or boreholes shall be shown on the plans, together with sections showing the strata found and the dates on which water levels are recorded.

h) *Location of other services* — The position, depth and size of all other pipes, mains, cables, or other services, in the vicinity of the proposed work, may be ascertained from the Authority, if necessary;

j) *Reinstatement of surfaces* — Information about the requirements of the highway authority is necessary where any part of the sewer or drain is to be taken under a highway. Those responsible for the sewer or drain shall be also responsible for the maintenance of the surface until permanently reinstated. The written consent of the highway authority to break up the surface and arrangement as to the charges thereof and the method and type of surface reinstatement shall always be obtained before any work is commenced;

k) *Diversion and control of traffic*

1) In cases where sewers cross roads or foot-paths, cooperation shall be maintained with the police and Authorities regarding the control and diversion of vehicular and/ or pedestrian traffic as may be necessary. Access to properties along the road shall always be maintained and adequate notice shall be given to the occupiers of any shops or business premises, particularly if obstruction is likely.

2) During the period of diversion, necessary danger lights, red flags, diversion boards, caution boards, watchmen, etc, shall be provided as required by the Authority.

m) *Way-leaves* (*easements*) — The individual or authority carrying out the work is responsible for negotiating way-leaves where the sewer crosses land in other ownership. The full extend and conditions of such way-leaves shall be made known to the contractor and his employees, and prior notice of commence-ment of excavation shall always be given to the owners concerned, and cooperation with them shall be maintained at all stages, where sewers run across fields or open ground, the exact location of manholes shall be shown on way-leaves or easement plans. The right of access to manhole covers and the right to maintain the sewer shall be specifically included in any way-leave or easement arrangements which may be made with the owner of the land; and

n) *Damage to buildings and structures* — When sewer trenches have to be excavated near buildings or walls a joint inspection with the owners of the property shall be made to establish whether any damage or cracks exist before starting the work, and a properly authenticated survey and record of the condition of buildings likely to be affected shall be made. Tell tales may be placed across outside cracks and dated, and kept under observation. Un-retouched photographs taken by an independent photographer may provide useful evidence.

4.4.2 *Drainage into a Public Sewer*

Where public sewerage is available, the following information is particularly necessary and may be obtained from the Authority:

a) The position of the public sewer or sewers in relation to the proposed buildings.

b) The invert level of the public sewer;

c) The system on which the public sewers are designed (combined, separate or partially separate), the lowest level at which connection may be made to it, and the Authority in which it is vested;

d) The material of construction and condition of the sewer if connection is not to be made by the Authority;

e) The extent to which surcharge in the sewer may influence the drainage scheme;

f) Whether the connection to the public sewer is made, or any part of the drain laid, by the Authority, or whether the owner is responsible for this work; if the latter, whether the Authority imposes any special conditions;

g) Whether an intercepting trap is required by the Authority on the drain near the boundary of the curtilage; and

h) Where manholes are constructed under roads, the approval of the Highway Authority for the type of cover to be fitted shall be obtained.

4.4.3 *Other Methods of Disposal of Sewage*

4.4.3.1 Where discharge into a public sewer is not possible, the drainage of the building/building campus shall be on a separate system. Foul water shall be

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disposed of by adequate treatment approved by the Authority on the site. The effluent from the plant shall be discharged after meeting the norms specified by the statutory authority into a natural watercourse or on the surface of the ground or disposed of subsoil dispersion preferably draining to a suitable outlet channel.

4.4.3.2 In the case of dilution into a natural stream course, the quality of the effluent shall conform and the requirements of the Authority controlling the prevention of pollution of streams.

4.4.3.3 In the case of subsoil dispersion, the requirements of the Authority for water supply shall be observed to avoid any possible pollution of local water supplies or wells.

4.4.3.4 The general subsoil water level and the subsoil conditions shall be ascertained, including the absorptive capacity of the soil.

4.4.3.5 A subsoil dispersion is not desirable near a building or in such positions that the ground below the foundations is likely to be affected.

4.4.3.6 Where no other method of disposal is possible, foul water may be diverted to cesspools and arrangements made with the Authority for satisfactory periodical removal and conveyance to a disposal works.

4.4.3.7 Under the separate system, drainage of the building shall be done through septic tanks of different sizes or by stabilization ponds or by any other treatment methods such as extended aeration activated process, sequential batch process, fluidized bio-reactors, membrane bio-reactor, submerged aerobic fixed film, rotating biological contactor, electrolyte process, etc, as approved by the Authority.

For detailed information on the design and construction of septic tanks and waste stabilization ponds, sewage treatment plants reference may be made to good practice [9-2(9)].

4.4.3.8 *Bio-toilet* (or eco-*toilet*)

It is useful in situations where no suitable water supply or sewer system and sewage treatment plant is available to capture the nutrients in human excreta.

The toilet is made of a structure, generally of prefabricated type, above the ground, a bio-digester tank below the ground and in case of sub-zero temperature regions, a solar panel. Bio-toilet involves complete sludge free disposal of human waste and eliminates need for manual scavenging. It decomposes solid waste to water and bio-gas. It is eco-friendly, hazard free, requiring least maintenance and is capable of functioning efficiently at sub-zero temperatures (*see* Fig. 5)

4.4.4 *Disposal of Surface and Subsoil Waters*

All information which may influence the choice of methods of disposal of surface and/or subsoil waters shall be obtained. In the absence of surface water drainage system, and if practicable and permissible, disposal into a natural water-course or soakaway may be adopted. The location and flood levels of the water course as also the requirements of the Authority controlling the river or the waterway shall be ascertained.

4.5 Planning and Design Considerations

4.5.1 *Aim*

The efficient disposal of foul and surface water from a building is of great importance to public health and is

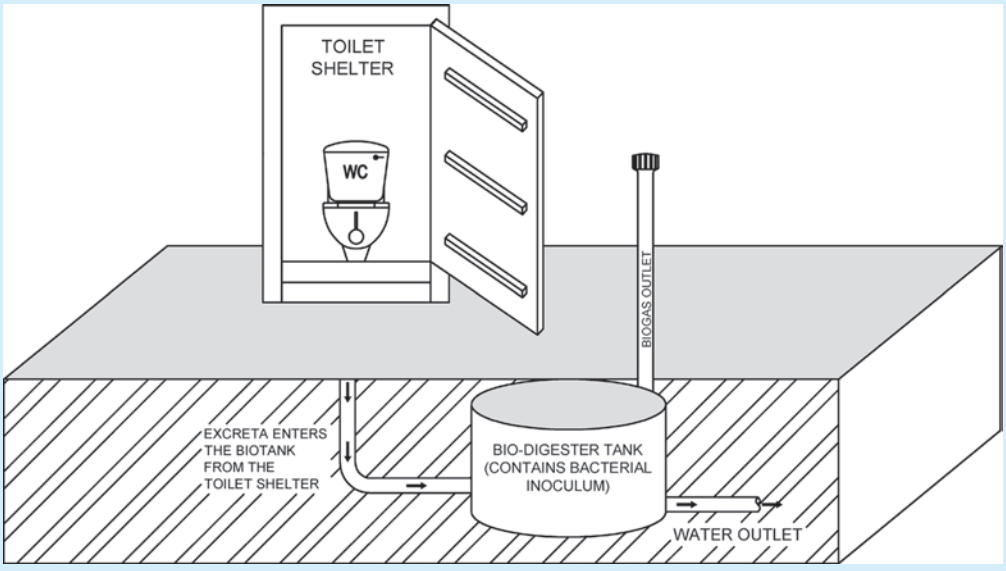


FIG. 5 BIO-TOILET OR ECO-TOILET

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an essential part of the construction of the building. In designing a drainage system for an individual building or a housing colony, the aim shall be to provide a system of self-cleaning conduits for the conveyance of foul, waste, surface or subsurface waters and for the removal of such wastes speedily and efficiently to a sewer or other outlet without risk of nuisance and hazard to health. Also, intent should be to take into consideration that, waste water, storm water and solid waste are potential resources.

4.5.1.1 To achieve this aim, a drainage system shall satisfy the following requirements:

a) Rapid and efficient removal of liquid wastes without leakage;

b) Prevention of access of foul gases to the building and provision for their escape from the system.

c) Adequate and easy access for clearing obstructions;

d) Prevention of undue external or internal corrosion, or erosion of joints and protection of materials of construction; and

e) Avoidance of air locks, siphonage, proneness to obstruction, deposit and damage.

4.5.1.2 The realization of an economical drainage system is added by compact grouping of fitments in both horizontal and vertical directions. This implies that if care is taken and ingenuity brought into play when designing the original building or buildings to be drained, it is possible to group the sanitary fittings and other equipment requiring drainage; both in vertical and horizontal planes, as to simplify the drainage system and make it most economical.

4.5.1.3 Efficient and an economical plumbing system can be achieved by planning the toilets in compact grouping with the layout of the bathrooms and observing the following guidelines:

a) Placing of plumbing fixtures around an easily accessible pipe shaft; in high rise buildings the pipe shafts may have to be within the building envelope and easy provision for access panels and doors should be planned in advance, in such cases so as not to cause inconvenience during maintenance.

b) Adopting repetitive layout of toilets in the horizontal and vertical directions.

c) In planning for malls, the required public and toilet facilities shall be located not more than one storey above or below the space to be served with such facilities, and the path of travel to such facilities shall not exceed 91 m.

In other occupancies, the required public and toilet facilities shall be located not more than one storey above or below the space to be served with such facilities, and the path of travel to such facilities shall not exceed 152 m.

However, in the above buildings, toilet rooms shall not open directly into a room used for preparation of food for service to public.

d) Avoiding any conflict with the reinforced cement concrete structure by avoiding embedding pipes in it, avoiding pipe crossings in beams, columns and major structural elements.

e) Identifying open terraces and areas subject to ingress of rainwater directly or indirectly and providing for location of inlets at each level for down takes for disposal at ground levels.

f) Avoiding crossing of services of individual property through property of other owners.

g) Planning to avoid accumulation of rainwater or any backflow from sewers particularly in planned low elevation areas in a building.

h) *Setting of sanitary fixtures* — A water closet, urinal, lavatory or bidet shall not be set closer than 380 mm from the centre to any side wall partition, vanity or other obstruction, or closer than 760 mm centre-to-centre between adjacent fixtures. There shall not be less than 530 mm clearance in front of the water closet, urinal, lavatory or bidet to any wall, fixture or door. Water closet compartment shall not be less than 760 mm in width and 1 520 mm in depth for floor mounted closets, and not less than 760 mm in width and 1 420 mm in depth for wall hung water closets.

The urinal partitions shall begin at a height not greater than 305 mm from and extend not less than 1 520 mm above the finished floor surface. The walls or partitions shall extend from the wall surface at each side of the urinal not less than 460 mm or to a point not less than 150 mm beyond the outermost front lip of the urinal measured from the finished back wall surface, whichever is greater.

j) Usually, the vertical distance between two horizontal connections to a vertical drain should be more than 200 mm in order to avoid back flow.

4.5.1.4 Typical mounting arrangements for various plumbing fixtures, including drainage systems and ventilation are illustrated in Annex D.

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4.5.2 *Layout*

4.5.2.1 *General*

Rainwater should preferably be dealt separately from sewage and sullage. Sewage and sullage shall be connected to sewers. However, storm water from the courtyard may be connected to the sewer where it is not possible to drain otherwise; after obtaining permission of the Authority.

4.5.2.2 *Additional requirements*

The following requirements are suggested to be considered in the design of drainage system:

a) The layout shall be as simple and direct as practicable.

b) The pipes should be laid in straight lines, as far as possible, in both vertical and horizontal planes.

c) Anything that is likely to cause irregularity of flow, such as abrupt changes of direction, shall be avoided.

d) The pipes should be non-absorbent, durable, smooth in bore and of adequate strength.

e) The pipes should be adequately supported without restricting movement.

f) Drains should be well ventilated, to prevent the accumulation of foul gases and fluctuation of air pressure within the pipe, which could lead to unsealing (siphoning) of gully or water closet traps.

g) All the parts of the drainage system should be accessible for feasibility of inspection and practical maintenance.

h) No bends and junctions whatsoever shall be permitted in sewers except at manholes and inspection chambers.

j) Sewer drain shall be laid for self-cleaning velocity of 0.75 m/s and generally should not flow more than half-full.

k) Pipes crossing in walls and floors shall be through mild steel sleeves of diameter leaving an annular space of 5 mm around the outer diameter of the pipe crossing the wall.

m) Pipes should not be laid close to building foundation.

n) Pipes should not pass near large trees because of possibility of damage by the roots.

p) Branch connections should be swept in the direction of flow.

q) Sewer pipes should be at least 900 mm below road and at least 600 mm below fields and gardens.

r) Pipes should not pass under a building unless absolutely necessary. Where it is necessary to lay pipes under a building, the following conditions shall be observed:

1) Pipes shall be centrifugally cast (spun) iron pressure pipe as per good practice [9-2(10)];
2) The pipe shall be laid in straight line and at uniform gradient;
3) Means of access in form of manholes/ inspection chamber shall be provided at each end, immediately outside the building;
4) In case the pipe or any part of it is laid above the natural surface of the ground, it shall be laid on concrete supports, the bottom of which goes at least 150 mm below the ground surface.

NOTE — It is desirable that pipe/drains should not be taken through a living room or kitchen and shall preferably be taken under a staircase room or passage.

s) Consideration shall be given to alternative layouts so as to ensure that the most economical and practical solution is adopted. The possibility of alterations shall be avoided by exercising due care and forethought.

4.5.2.3 *Protection against vermin and dirt*

The installation of sanitary fittings shall not introduce crevices which are not possible to inspect and clean readily.

Pipes, if not embedded, shall be run well clear of the wall. Holes through walls to lay pipes shall be made good on both sides to prevent entry of insects. Materials used for embedding pipes shall be rodent-proof. Passage of rodents from room-to-room or from floor-to-floor shall be prevented by suitable sealing. The intermediate lengths of ducts and chases shall be capable of easy inspection. Any unused drains, sewers, etc, shall be demolished or filled in to keep them free from rodents.

All pipe shafts shall be plastered before any pipes are installed in the shaft. It is advisable to lay pipes on the steel supports with adequate gap between plastered wall and support structure. This will provide a smooth surface and prevent location for survival of insects and vermins.

4.5.2.4 *Choice of plumbing system*

4.5.2.4.1 In selecting one or more of the type of piping systems, the building and the layout of toilets/fixtures, relationship with other services, acceptability to the Authority, and any special requirements of users, shall be studied.

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a) *Single stack system* [*see* **2.69** (a)]

1) The single stack system is ideal when the toilet/fixture layouts are repetitive and there is less space for pipes on the wall.
2) In any system so selected there should be not more than two toilet connections per floor.
3) The system requires minimum 100 mm diameter stack for a maximum of 5 floors in a building.
4) In this system, care shall be taken of the horizontal distance of sanitary fixtures from the drainage stack and vertical distance between connections of branches from fixtures to drainage stack.
5) All the safeguards for the use of this system given in **4.5.2.4.2** shall be complied with.

b) *One pipe — partially ventilated system* [*see* **2.69** (b)]

The system and the applicable safeguards under this system are the same as for single stack system. The prime modification is to vent the soil appliance(s).

c) *One pipe — fully ventilated system* [*see* **2.69** (c)]

1) This system is suitable for buildings where the toilet/fixture layouts and the shafts are repetitive. It requires less shaft space, and is economical.
2) Continuous flow of water in the pipe from waste appliances makes it less prone to blockage and makes the system more efficient.
3) The system eliminates the need for a gully trap which requires constant cleaning.
4) This system requires individual vent pipes installed either in suspended ceiling or in the wall above the floor level in the toilet, provided construction details of the building allow provision of vent pipes for individual fixtures and routing of vent pipes to remote shafts where main vent stacks may have been located.
5) The system requires minimum 100 mm diameter stack.
6) The system is ideal when the main pipes run at the ceiling of the lowest floor or in a service floor.

d) *Two pipe system* [*see* **2.69** (d)]

1) This system provides safety and flexibility in layouts for larger toilets and for buildings having higher requirement of performance due to its height and type of occupancy.
2) In large buildings and houses with open ground and gardens, the sullage water from the waste system can be suitably treated and usefully utilized for gardening and agriculture.
3) In larger and multi-storeyed buildings, the sullage is treated within the building for reuse as makeup water for cooling towers for air conditioning system and is also used for flushing water closets provided it has absolutely no connection with any water supply line, tank or system used for domestic and drinking supply.

For detailed information regarding design and installation of soil, waste and vent pipes, reference may be made to good practice [9-2(11)].

4.5.2.4.2 *Safeguards for single stack system*

a) As far as practicable, the fixtures on a floor shall be connected to stack in order of increasing discharge rate in the downward direction.
b) The size of the vent pipe (terminating to the outdoor) shall be same as the size of drainage stack in the case of single stack system.
c) Water closets shall be connected to the stack through a sanitary tee; the maximum horizontal distance from the stack being 2 400 mm.
d) For fixtures other than water closets, the maximum horizontal distance from the stack shall be 3 500 mm.
e) The vertical distance between the waste branch (from floor trap or from the individual appliance) and the soil branch connection, when soil pipe is connected to stack above the waste pipe, shall be not less than 200 mm.
f) Depth of water seal traps from different fixtures shall be as per **4.5.3.6.1.6.**
g) Branches and stacks which receive discharges from WC pans should not be less than 100 mm, except where the outlet from the siphonic water closet is 80 mm, in which case a branch pipe of 80 mm may be used. For outlet of floor traps 75 mm dia pipes may be used.
h) The horizontal branch distance for fixtures from stack, bend(s) at the foot of stack to avoid back pressure as well as vertical distance between the lowest connection and the invert of drain shall be as per good practice [9-2(11)].
j) For tall buildings, ground floor appliances are recommended to be connected directly to manhole/inspection chamber.

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4.5.2.4.2.1 Drainage stack shall be sized in accordance with Table 16. The drainage stack and branch piping shall be the vents for the drainage system. Stack shall be uniformly sized based on the total connected drainage fixture unit load.

Table 16 Single Stack Sizing
(*Clause* 4.5.2.4.2.1)

Sl No.	Stack Size	Maximum Connected Drainage Fixture Units (DFU)		
	mm	Stacks Less than 23 m in Height	Stacks 23 m to Less than 49 m in Height	Stacks 49 m and Greater in Height[1)]
(1)	(2)	(3)	(4)	(5)
i)	75	24	—	—
ii)	100	225	24	—
iii)	125	480	225	24
iv)	150	1 015	480	225
v)	200	2 320	1 015	480
vi)	250	4 500	2 320	1 015
vii)	300	8 100	4 500	2 320
viii)	375	13 600	8 100	4 500

[1)] To be considered for one-pipe partially ventilated system only.

4.5.2.4.2.2 An alternative design approach for designing the single stack system is also used in some of the countries, which may be followed if approved by the authority. Such an approach may utilize the following, and may also require reference to available specialist literature:

a) The size of the vent pipe (terminating to the outdoor) shall be same as the size of drainage stack in the case of single stack system.

b) Using branch discharge pipes, self and external siphonage of the water seal of traps can be avoided.

c) In respect of branch discharge pipes, the entire developed length including fittings up to farthest connection is 4.0 m.

d) A 45º bend shall be used for the horizontal branch pipe with a drop connection after the connection from the appliance.

e) To match the crowns of small and larger pipes, an eccentric reducer is used with straight portion on top.

f) A non-ventilated discharge pipe shall be connected to discharge stack with a sweep junction having an angle of 87º to 88.5º.

g) In respect of vertical discharge stacks, concentric or eccentric reducers may be permitted.

h) In respect of stacks not exceeding 10 m in height, from the upper most connection to change of direction, no branch discharge pipe shall be connected to the stack or horizontal side for a distance of 1.0 m. In respect of second change in direction, no branch discharge pipe shall be connected within a distance of 0.5 m after the change of direction. The pipe stack shall not be connected to sanitary appliances from the lowest floor.

j) In respect of stacks exceeding 10 m in height, from the upper most connection to change of direction, no branch discharge pipe shall be connected to the stack or horizontal side for a distance of 2.0 m. The connection of the ventilated branch to the main stack shall not be within 2.0 m from the change of direction. In respect of second change in direction, no branch discharge pipe shall be connected within a distance of 0.5 m after the change of direction. The pipe stack shall not be connected to sanitary appliances from the lowest floor.

k) The connection of branch discharge pipes to the vertical stack shall be such that back flow will not cross flow into fixtures on the opposite ends.

4.5.3 *Drainage (Soil, Waste and Vent) Pipes*

4.5.3.1 *General considerations*

4.5.3.1.1 Drainage pipes shall be kept clear of all other services. Provisions shall be made during the construction of the building for the entry of the drainage pipes. In most cases this may be done conveniently by installing sleeves or conduit pipes into or under the structure in appropriate positions. This will facilitate the installation and maintenance of the services.

4.5.3.1.2 Horizontal drainage piping should be so routed as not to pass over any equipment or fixture where leakage from the line could possibly cause damage or contamination. Drainage piping shall never pass over switch-gear or other electrical equipment. If it is impossible to avoid these areas and piping shall run in these locations, then a pan or drain tray should be installed below the pipe to collect any leakage or condensation. A drain line should run from this pan to a convenient floor drain or service sink.

4.5.3.1.3 All vertical soil, waste, vent and anti-siphonage pipes shall be covered on top with a copper or heavily galvanized iron wire dome or cast iron terminal guards. All cast iron pipes, which are to be painted periodically, shall be fixed to give a minimum clearance of 50 mm clear from the finished surface of the wall by means of a suitable clamp.

NOTE — Asbestos cement cowls may be used in case asbestos cement pipes are used as soil pipes.

4.5.3.1.4 Drainage pipes shall be carried to a height above the buildings as specified for vent pipe (*see* **4.5.3.4**).

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4.5.3.2 *Soil pipes*

A soil pipe, conveying to a drain, any solid or liquid filth, shall be circular and shall have a minimum diameter of 100 mm.

4.5.3.2.1 Except where it is impracticable, the soil pipe shall be situated outside the building or in suitably designed pipe shafts and shall be continued upwards without diminution of its diameter, and (except where it is unavoidable) without any bend or angle, to such a height and position as to afford by means of its open end a safe outlet for foul air. The position of the open end with its covering shall be such as to comply with the conditions set out in **4.5.3.4** relating to vent pipe. Even if the pipes are laid externally, the soil pipes shall not be permitted on a wall abutting a street unless the Authority is satisfied that it is unavoidable. Where shafts for pipes are provided, the cross-section area of the shaft shall be suitable to allow free and unhampered access to the pipes and fittings proposed to be installed in the shaft. However, in no case cross-section area of the shaft shall be less than a square of 1 m side. All pipe shafts shall be provided with an access door at ground level and facilities for shaft ventilation.

4.5.3.2.2 Soil pipes, whether insider or outside the building, shall not be connected with any rainwater pipe and there shall not be any trap in such soil pipe or between it and any drain with which it is connected.

4.5.3.2.3 The soil pipe shall be provided with heel rest bend which shall rest on sound footing, if terminating at firm ground level. When the stack is terminating at the ceiling of a floor, the bend shall be provided with sufficient structural support to cater for the stack dead weight and the thrust developed from the falling soil/waste. Vertical stack shall be fixed at least 50 mm clear of the finished surface of the wall by means of a suitable clamp of approved type.

4.5.3.3 *Waste pipes*

Every pipe in a building for carrying off the waste or overflow water from every bath, wash basin or sink to a drain shall be of 32 mm to 50 mm diameter, and shall be trapped immediately beneath such wash basins or sink by an efficient siphon trap — P trap with adequate means for inspection and cleaning. Such P traps shall be ventilated into the external air whenever such ventilation is necessary to preserve the seal of the trap. Waste pipes, P traps, etc, shall be constructed of iron, lead, brass, PVC, engineering plastics, stoneware, asbestos cement or other approved material. The overflow pipe from wash basin, sinks, etc, shall be connected with the waste pipe immediately above the trap. Vertical pipes carrying off waste water shall have a minimum diameter of 75 mm.

NOTE — Whenever wash basins and sinks have in-built overflow arrangements, there is no need to provide overflow pipes in such cases.

4.5.3.3.1 Every pipe in a building for carrying off waste water to a drain shall be taken through an external wall of the building by the shortest practicable line, and shall discharge below the grating or surface box of the chamber but above the inlet of a properly trapped gully. The waste pipe shall be continued upwards without any diminution in its diameter and (except when unavoidable) without any bend or angle to such a height and position as to afford by means of the open end of the waste pipe, a safe outlet for foul air, the position of the open end and its covering being such as to comply with the conditions.

4.5.3.3.2 Except where it is impracticable, the common waste pipe shall be situated outside the building and shall be continued upwards without diminution of its diameter (except where it is unavoidable) without any bend or angle being formed to such a height and position as to avoid by means of the open end a safe outlet for foul air, the position of the open end and the covering threat being such as to comply with the conditions set out in **4.5.3.4** relating to vent pipe.

4.5.3.4 *Vent pipes*

Vent pipes should be so installed that water cannot be retained in them. They should be fixed vertically. Whenever possible, horizontal runs should be avoided. Vent pipe shall be carried to such a height and in such a position as to afford by means of the open end of such pipe or vent shaft, a safe outlet for foul air with the least possible nuisance.

4.5.3.4.1 The upper end of the main vent pipe may be continued to the open air above roof level as a separate pipe, or it may join the MSP and/or MWP above the floor level of the highest appliance. Its lower end may be carried down to join the drain, at a point where air relief may always be maintained.

4.5.3.4.2 Branch vent pipes should be connected to the top of the BSP and BWP between 75 mm and 450 mm from the crown of the trap.

4.5.3.4.3 The vent pipe shall always be taken to a point 1 500 mm above the level of the eaves or flat roof or terrace parapet whichever is higher or the top of any window within a horizontal distance of 3 m. The least dimension shall be taken as a minimum and local conditions shall be taken into account. The upper end of every vent pipe shall be protected by means of a cowl.

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4.5.3.4.4 In case the adjoining building is taller, the vent pipe shall be carried higher than the roof of the adjacent building, wherever it is possible.

4.5.3.4.5 The building drain intended for carrying waste water and sewage from a building shall be provided with at least one vent pipe situated as near as practicable to the building from an inspection chamber and as far away as possible from the point at which the drain empties into the sewer or other carrier.

4.5.3.4.6 *Size of vent pipe*

a) The building drain vent pipe shall be of not less than 75 mm diameter. When, however, it is used as MSP or MWP, the upper portion, which does not carry discharges, shall not be of lesser diameter than the remaining portion;

b) The diameter of the main vent pipe in any case should not be less than 50 mm;

c) A branch vent pipe on a waste pipe in both one and two-pipe systems shall be of not less than two-thirds the diameter of the branch waste pipe, subject to a minimum of 25 mm; and

d) A branch vent pipe on a soil pipe in both one and two-pipe systems shall be not less than 32 mm in diameter.

e) Vent pipes to be sized/designed considering the drainage fixture units of individual fixtures/appliances as per good engineering practices (*see* **4.5.3.4.7**).

4.5.3.4.7 *Venting system for high rise buildings*

In the case of fully ventilated system, suitable sized pipe stacks carry soil and waste drainage, wherein each sanitary fixture is individually vented. The practical way of implementation of this system is by venting each water closet and floor drain. A fully ventilated one pipe drainage system is most popular in advanced plumbing installations.

Properly sized vent pipe would ensure maintenance of atmospheric pressure within gravity drainage pipes.

Sizing of vent pipe is based on cumulative drainage fixture units of all fixtures served by the pipe. Sizing also depends on maximum permissible lengths. Maximum lengths are also subject to the limitation that one-third of length shall be horizontal. Horizontal pipes always rise towards termination point, avoiding vertical loops.

The minimum required diameter of stack vents and vent stacks shall be determined from the developed length and the total drainage fixture units (DFU) connected thereto, in accordance with Table 17. However, in no case, the diameter shall be less than half the diameter of the drain served or less than 32 mm.

NOTE — In case, if fully ventilated one-pipe system is not implemented then it shall indicate the case of two-pipe system along with common vent pipe for which the guideline for sizing shall be provided. Also, it shall provide a sketch for two-pipe system along with connection of branch pipes from wash basin to the deep seal trap through inlet fitting as per prevailing conditions as approved by Authority.

4.5.3.5 *Design of drainage pipes*

A stack is the main vertical pipe that carries away discharge from water closets and urinals (soil stack) or other clear waste water from equipment (waste stack) with adequate suitable fittings, which may be a long-turn, tee-wye or short-turn or sanitary tee. Depending on the rate of flow in to the drain stack, the diameter of the stack, the type of stack fittings and the flow down the stack from higher levels (if any), the discharge from the fixture drain may or may not fill the cross-section of the stack at the level of entry. In any event, as soon as the water enters the stack, the force of gravity rapidly accelerates it downward and before it travels very far, it assumes the form of a sheet around the wall of the stack, leaving the centre of the pipe open for the flow of air.

This sheet of water continues to accelerate until the frictional force exerted by the wall of the falling sheet of water equals the gravitational force. If the distance the water travel is sufficient enough and provided that no flow enters the stack at lower levels to interfere the sheet, the sheet remains unchanged in thickness and velocity until it reaches the bottom of the stack. The ultimate vertical velocity the sheet attains is called the 'terminal velocity'. The distance the sheet must fall to attain this terminal velocity is called the 'terminal length'.

Following formulae may be used for calculating the terminal velocity and terminal length:

$$V_t = 3.0\ (Q/d)^{2/5}$$

$$L_t = 0.052\ V_t^2$$

where

V_t = terminal velocity in the stack, m/s;

L_t = terminal length below the point of flow entry, m;

Q = quantity rate of flow, l/s; and

d = diameter of stack, mm.

At the centre of the stack is a core of air that is dragged along with the water by friction. A supply source of air shall be provided to avoid excessive pressures in the stack. The usual means of supplying this air are through the stack vent or vent stack. The entrained air in the stack causes a pressure reducing inside the stack, which is caused by the frictional effect of the falling sheet of water dragging the core of air with it.

4.5.3.5.1 *Estimation of maximum flow of sewer*

a) *Simultaneous discharge flow*

1) The maximum flow in a building drain or a stack depends on the probable maximum number of simultaneous discharging appliances. For the

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calculation of this peak flow certain loading factors have been assigned to appliances in terms of fixture units, considering their probability and frequency of use. These fixture unit values are given in Table 18.

2) For any fixtures not covered under Table 18, Table 19 may be referred to for deciding their fixture unit rating depending on their drain or trap size.

3) From Tables 18 and 19, the total load on any pipe in terms of fixtures units may be calculated knowing the number and type of appliances connected to this pipe.

4) For converting the total load in fixture units to the peak flow in litre per minute, Fig. 6 is to be used.

5) The maximum number of fixture units that are permissible for various recommended pipe size in the drainage system are given in Table 20 and Table 21.

6) Results should be checked to see that the soil, waste and building sewer pipes are not reduced in diameter in the direction of flow. Where appliances are to be added in fixture, these should be taken into account in assessing the pipe sizes by using the fixture units given in Table 18 and Table 19.

Table 17 Size and Developed Length of Stack Vents and Vent Stacks
(*Clause* 4.5.3.4.7)

Sl No.	Diameter of Soil and / or Waste Stack mm	Total Fixture Units Being Vented (DFU)	Maximum Developed Length of Vent for the Diameter of Vent m										
			32 mm	40 mm	50 mm	65 mm	75 mm	100 mm	125 mm	150 mm	200 mm	250 mm	300 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
i)	32	2	9	—	—	—	—	—	—	—	—	—	—
ii)	40	8	15	45	—	—	—	—	—	—	—	—	—
iii)	40	10	9	30	—	—	—	—	—	—	—	—	—
iv)	50	12	—	23	61	—	—	—	—	—	—	—	—
v)	50	20	9	15	45	—	—	—	—	—	—	—	—
vi)	65	42	8	9	30	91	—	—	—	—	—	—	—
vii)	75	10	—	13	45	110	317	—	—	—	—	—	—
viii)	75	21	—	10	34	82	247	—	—	—	—	—	—
ix)	75	53	—	8	29	70	207	—	—	—	—	—	—
x)	75	102	—	—	26	64	189	—	—	—	—	—	—
xi)	100	43	—	8	11	26	76	299	—	—	—	—	—
xii)	100	140	—	—	8	20	61	229	—	—	—	—	—
xiii)	100	320	—	—	7	17	52	195	—	—	—	—	—
xiv)	100	540	—	—	6	15	46	177	—	—	—	—	—
xv)	125	190	—	—	—	8.5	25	98	302	—	—	—	—
xvi)	125	490	—	—	—	6.4	19	76	232	—	—	—	—
xvii)	125	940	—	—	—	5.5	16	64	204	—	—	—	—
xviii)	125	1 400	—	—	—	4.9	15	58	180	—	—	—	—
xix)	150	500	—	—	—	—	10	40	122	305	—	—	—
xx)	150	1 100	—	—	—	—	8	30	94	238	—	—	—
xxi)	150	2 000	—	—	—	—	7	26	79	201	—	—	—
xxii)	150	2 900	—	—	—	—	6	23	73	183	—	—	—
xxiii)	200	1 800	—	—	—	—	—	9	29	73	287	—	—
xxiv)	200	3 400	—	—	—	—	—	7	22	58	222	—	—
xxv)	200	5 600	—	—	—	—	—	6	19	49	186	—	—
xxvi)	200	7 600	—	—	—	—	—	5	17	43	171	—	—
xxvii)	250	4 000	—	—	—	—	—	—	9	24	94	293	—
xxviii)	250	7 200	—	—	—	—	—	—	7	18	73	226	—
xxix)	250	11 000	—	—	—	—	—	—	6	16	61	192	—
xxx)	250	15 000	—	—	—	—	—	—	5	14	55	174	—
xxxi)	300	7 300	—	—	—	—	—	—	—	9	37	116	287
xxxii)	300	13 000	—	—	—	—	—	—	—	7	29	91	219
xxxiii)	300	20 000	—	—	—	—	—	—	—	6	24	76	186
xxxiv)	300	26 000	—	—	—	—	—	—	—	5	22	70	152
xxxv)	375	15 000	—	—	—	—	—	—	—	—	12	40	94
xxxvi)	375	25 000	—	—	—	—	—	—	—	—	9	29	73
xxxvii)	375	38 000	—	—	—	—	—	—	—	—	8	25	61
xxxviii)	375	50 000	—	—	—	—	—	—	—	—	7	23	55

NOTE — The developed length shall be measured from the vent connection to the open air.

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b) *Maximum discharge flow* — The maximum rate of *discharge* flow shall be taken as thrice the average rate; allowance being made in addition for any exceptional peak discharges. A good average rule is to allow for a flow of liquid wastes from buildings at the rate of 3 litre per minute per 10 persons.

4.5.3.5.2 *Gradients*

4.5.3.5.2.1 The discharge of water through a domestic drain is intermittent and limited in quantity and, therefore, small accumulations of solid matter are liable to form in the drains between the building and the public sewer. There is usually a gradual shifting of these deposits as discharges take place. Gradients should be sufficient to prevent these temporary accumulations building up and blocking the drains.

a) *Drainage loads* — Single family dwellings contain plumbing fixtures, such as one or more bathroom groups, each consisting of a toilet, wash basin and bathtub or shower unit, a kitchen sink, dishwasher and washing machine. Large buildings also have other fixtures, slop sinks and drinking water coolers. The important characteristic of these fixtures is that they are not used continuously. Rather, they are used with irregular frequencies that vary greatly during the day. In addition, the various fixtures have quite different discharge characteristics regarding both the average flow rate per use and the duration of a single discharge. Consequently, the probability of all the fixtures in the building operating simultaneously is small.

b) *Stack capacities* — The criterion of flow capacities in drainage stacks is based on the limitation of the water occupied cross-section to a specified fraction of the cross-section of the stack where terminal velocity exists, as suggested by earlier investigations.

Flow capacity can be expressed in terms of the stack diameter and the water cross-section, as follows:

$$Q = 27.8 \times r_s^{5/3} \times D^{8/3}$$

where

Q = capacity, l/s;

r_s = ratio of the cross-sectional area of the sheet of water to the cross-sectional area of the stack; and

D = diameter of the stack, mm.

c) *Design requirement for high rise buildings drainage system* — Drainage pipe stacks are sized for one third of their carrying capacity. Plumbing codes provides values of drainage fixture units for each fixture. Different values for fixture units are based on the nature of occupancy and the place of installation. Sizing of drainage pipes is based on the cumulative values of drainage fixture units connected to the pipe. A vertical pipe shall always have larger carrying capacity when compared to horizontal pipe of same size. Carrying capacity of horizontal pipe is dependent on gradient provided. Carrying capacities of vertical pipes are restricted by their maximum permissible lengths. This restriction does not

Table 18 Drainage Fixture Units (DFU) for Different Fixtures with Minimum Pipe Sizes
(*Clause* 4.5.3.5.1)

Sl No.	Type of Fixture	Application		Minimum Trap Size mm
		Private	Public	
(1)	(2)	(3)	(4)	(6)
i)	Bathroom group (water closet, wash basin, bidet and tub or shower)			
	a) Water closet (flush valve)	8	—	—
	b) Water closet (flush tank)	6	—	—
ii)	Bathtub	3	—	40
iii)	Bar sink	1	2	40
iv)	Ablution faucet/Bidet	1	2	40
v)	Clothes washer	3	3	50
vi)	Dishwasher	2	2	40
vii)	Drinking fountain	—	0.5 (0.75)	32
viii)	Floor drain	1	2	50
ix)	Wash basin	1	1	32
x)	Service or mop basin/sink	1.5	3	50
xi)	Kitchen sink	2	2	40
xii)	Shower	2	2	50
xiii)	Laundry sink	2	2	40
xiv)	Clinical or surgeon's scrub sink	—	6	80
xv)	Urinal (with flush valve)	2	2 (3)	50
xvi)	Urinal (with flush tank)	2	2 (3)	50
xvii)	Urinal with sensor operated	2	2 (3)	50
xviii)	Water closet (flush valve)	4	6 (8)	80
xix)	Water closet (flush tank)	3	4 (6)	80
xx)	Combination fixture (faucet)	1	2	40

NOTES

1 A shower head over a bath tub does not increase the fixture unit value.

2 Size of floor trap shall be determined by the area of surface water to be drained.

3 Wash basins with 32 mm and 40 mm trap have the same load value.

4 Trap size shall be consistent with the fixture outlet size.

5 For fixtures added to bathroom group, the DFU value is added to those additional fixtures to the bathroom group fixture count.

6 No floor traps to be provided inside operating rooms, procedure rooms, AIIR isolation rooms and PE isolation rooms.

7 The values given in parentheses pertain to such public use buildings (congregation halls) where an enhanced requirement is expected to be encountered as compared to the normal maximum use in public use buildings.

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apply to horizontal pipes. Irrespective of drainage fixture units, the minimum size for the fixture shall be adopted. The minimum size of horizontal pipe is critical to ensure self cleansing velocities in sewers.

Table 19 Fixture Unit Values for Fixtures Based on Fixture Drain on Trap Size
(*Clause* 4.5.3.5.1)

Sl No.	Fixture Drain on Trap Size	Fixture Unit Value
(1)	(2)	(3)
i)	32 mm and smaller	1
ii)	40 mm	2
iii)	50 mm	3
iv)	65 mm	4
v)	80 mm	5
vi)	100 mm	6

4.5.3.5.2.2 When flow occurs in drain piping, it should not entirely fill the cross-section of the pipe under flow condition. If the pipe were to flow full, pressure fluctuations would occur which could possibly destroy the seal of the traps within the building. Normally, the sewer shall be designed for discharging the peak flow as given in **4.5.3.5.1**, flowing half-full with a minimum self-cleansing velocity of 0.75 m/s. The approximate gradients which give this velocity for the sizes of pipes likely to be used in building drainage and the corresponding discharges when following half-full are given in Table 22.

4.5.3.5.2.3 In cases where it is practically not possible to conform to the ruling gradients, a flatter gradient may be used, but the minimum velocity in such cases shall on no account be less than 0.61 m/s and adequate flushing should be done.

NOTE — Where gradients are restricted, the practice of using a pipe of larger diameter than that required by the normal flow, in order to justify laying at a flatter gradient does not result in increasing the velocity of flow, further this reduces the depth of flow and thus for this reasons the above mentioned practice should be discouraged.

4.5.3.5.2.4 On the other hand, it is undesirable to employ gradients giving a velocity of flow greater than 2.4 m/s. Where it is unavoidable, cast iron pipes shall be used. The approximate gradients, which give a velocity of 2.4 m/s for pipes of various sizes and the corresponding discharge when flowing half-full are given in Table 22.

4.5.3.5.2.5 The discharge values corresponding to nominal diameter and gradient given in Table 22 are based on Manning's formula (n = 0.015).

NOTE — Subject to the minimum size of 100 m, the sizes of pipes shall be decided in relation to the estimated quantity of flow and the available gradient.

4.5.3.6 *Drain appurtenances*

4.5.3.6.1 *Trap*

All traps shall be protected against siphonage and back pressure ensuring access to atmospheric air for air circulation and preserving the trap seal in all conditions.

4.5.3.6.1.1 A trap may be formed as an integral trap with the appliance during manufacture or may be a separate fitting called an attached trap which may be connected to the waste outlet of the appliance.

4.5.3.6.1.2 Traps should always be of a self-cleansing pattern. A trap, which is not an integral part of an

Table 20 Horizontal Fixture Branches and Stacks[1)]
(*Clause* 4.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Drainage Fixture Units[2)] (DFU) that can be Connected to			
		Branch	Stacks[3)]		
		Total for Horizontal Branch	Total Discharge into One Branch Interval	Total for Stack of Three Branch Intervals or Less	Total for Stack Greater than Three Branch Intervals
	mm				
(1)	(2)	(3)	(4)	(5)	(6)
i)	32	1	2	2	2
ii)	40	3	2	4	8
iii)	50	6	6	10	24
iv)	65	12	9	20	42
v)	75	20	20	48	72
vi)	100	160	90	240	500
vii)	125	360	200	540	1 100
viii)	150	620	350	960	1 900
ix)	200	1 400	600	2 200	3 600
x)	250	2 500	1 000	3 800	5 600
xi)	300	3 900	1 500	6 000	8 400
xii)	375	7 000	*See* Note	*See* Note	*See* Note

1) Does not include branches of the building sewer.
2) Depending upon the probability of simultaneous use of appliances considering the frequency of use and peak discharge rate.
3) Stacks shall be sized based on the total accumulated connected load at each story or branch interval. As the total accumulated connected load decreases, stacks are permitted to be reduced in size. Stack diameters shall not be reduced to less than one-half of the diameter of the larger stack size required.

NOTE — Sizing load based on design criteria.

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appliance, should be directly attached to its outlet and the pipe should be uniform throughout and have a smooth surface.

4.5.3.6.1.3 The trap should have minimum size of outlet/exit, same as that of largest waste inlet pipe.

4.5.3.6.1.4 Traps for use in domestic waste installations and all other traps should be conveniently accessible and provided with cleansing eyes or other means of cleaning.

4.5.3.6.1.5 The minimum internal diameter for sanitary appliances shall be as follows:

Sl No.	*Sanitary Appliance*	*Minimum Internal Diameter of Waste Outlet* mm
i)	Soil appliances:	
	a) Indian and European type water closets	100
	b) Bed pan washers and slop sinks	100
	c) Urinal with integral traps	75
	d) Stall urinals (with not more than 120 mm of channel drainage)	50
	e) Lipped urinal small/large	40
ii)	Waste appliances:	
	a) Drinking fountain	25
	b) Washbasin	32
	c) Bidets	32
	d) Domestic sinks and baths	40
	e) Shower bath trays	40
	f) Domestic bath tubs	50
	g) Hotel and canteen sinks	50
	h) Floor traps (outlet diameter)	75

4.5.3.6.1.6 Depth of water seal traps from different fixtures shall be as follows:

Sl No.	*Item*	*Depth of Seals* mm		
		Two Pipe System	One Pipe System	Single Stack System
i)	Water closets	50	50	50
ii)	Floor traps	50	50	50
iii)	Other fixtures, directly connected to the stack:			
	a) Where attached to branch waste pipes of 75 mm dia or more	40	40	40
	b) Where attached to branch waste pipes of less than 75 mm dia	40	40	75

NOTE — When connection is made through floor trap, no separate seals are required for individual fixtures.

4.5.3.6.2 *Floor drains*

All toilets/bathrooms in a building desirably should be provided with floor drains to facilitate cleaning.

4.5.3.6.2.1 Floor drains shall connect into a trap so constructed that it can be readily cleaned and of a size to serve efficiently the purpose for which it is intended. The trap shall be either accessible from the floor drain or by a separate cleanout within the drain.

4.5.3.6.2.2 Floor drain also receives, waste piping which does not connect to the sanitary system, known as indirect waste. This discharge from an indirect waste should be conveyed into a water supplied, trapped and vented floor drain.

Table 21 Building Drains and Sewers[1)]

(*Clause* 4.5.3.5.1)

Sl No.	Diameter of Pipe	Maximum Number of Drainage Fixture Units (DFU) that can be Connected to any Portion of the Building Drain or the Building Sewer Including Branches of the Building Drain[2)], for Slope			
	mm	1/200	1/100	1/50	1/25
(1)	(2)	(3)	(4)	(5)	(6)
i)	32	—	—	1	1
ii)	40	—	—	3	3
iii)	50	—	—	21	26
iv)	65	—	—	24	31
v)	75	—	36	42	50
vi)	100	—	180	216	250
vii)	125	—	390	480	575
viii)	150	—	700	840	1 000
ix)	200	1 400	1 600	1 920	2 300
x)	250	2 500	2 900	3 300	4 200
xi)	300	3 900	4 600	5 600	6 700
xii)	375	7 000	8 300	10 000	12 000

[1)] Includes branches of the building sewer.

[2)] The minimum size of any building drain serving a water closet shall be 75 mm.

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Table 22 Different Diameter Pipes Giving Velocity and Corresponding Discharge at Minimum and Maximum Gradient

(*Clauses* 4.5.3.5.2.2, 4.5.3.5.2.4 *and* 4.5.3.5.2.5)

Sl No.	Diameter	Minimum Gradient (Velocity : 0.75 m/s)	Discharge at the Minimum Gradient	Maximum Gradient (Velocity : 2.4 m/s)	Discharge at the Maximum Gradient
	mm		m^3/min		m^3/min
(1)	(2)	(3)	(4)	(5)	(6)
i)	100	1 in 57	0.18	1 in 5.6	0.59
ii)	150	1 in 100	0.42	1 in 9.7	1.32
iii)	200	1 in 145	0.73	1 in 14	2.40
iv)	230	1 in 175	0.93	1 in 17	2.98
v)	250	1 in 195	1.10	1 in 19	3.60
vi)	300	1 in 250	1.70	1 in 24.5	5.30

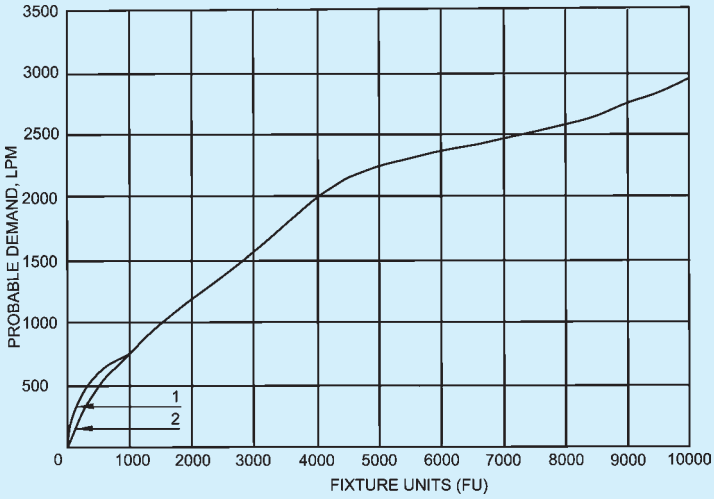
4.5.3.6.2.3 Floor drain should be provided in mechanical equipment rooms, where pumps, boilers, water chillers, heat exchangers and other air conditioning equipment are periodically drained for maintenance and repair. Boiler requires drain at safety relief valve discharge.

4.5.3.6.2.4 Strategically floor drains are required to be located in buildings with wet fire protection sprinkler systems to drain water in case of activation of sprinkler heads.

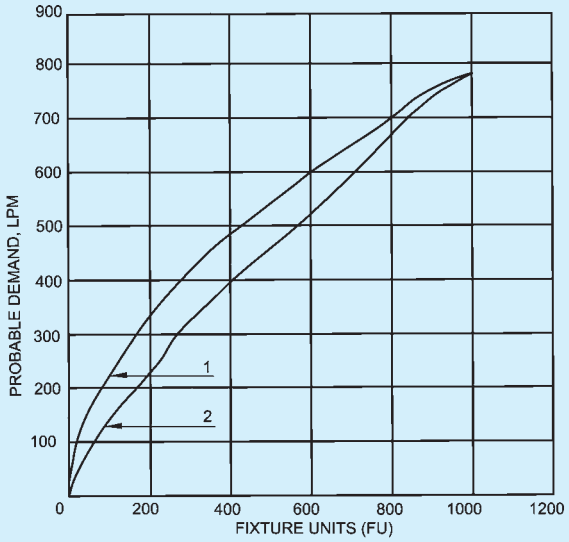
4.5.3.6.2.5 The minimum diameter for floor drains outlets before connecting to floor trap is 75 mm.

4.5.3.6.3 *Cleanouts*

The cleanout provides access to horizontal and vertical lines and stacks to facilitate inspection and means to remove obstructions common to all piping systems,



6A GRAPH FOR PROBABLE DEMAND UP TO 10 000FU



6B GRAPH FOR PROBABLE DEMAND UP TO 1 000FU

CURVE 1 — SYSTEM WITH FLUSH VALVES

CURVE 2 — SYSTEM WITH FLUSH TANKS

FIG. 6 GRAPH FOR PROBABLE DEMAND

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such as solid objects, greasy wastes, hair and the like.

4.5.3.6.3.1 Cleanouts in general should be gas and water tight, provide quick and easy plug removal, allow ample space for rodding tools, have means of adjustments to finished floor level, be attractive and be designed to support whatever load is directed over them.

4.5.3.6.3.2 Waste lines are normally laid beneath the floor slab at a sufficient distance to provide adequate back-fill over the joints. Cleanouts are then brought up to floor level grade by pipe extension pieces.

4.5.3.6.3.3 The size of the cleanout within a building should be the same size as the piping up to 100 mm. For larger size piping 100 mm cleanouts are adequate for their intended purpose.

4.5.3.6.3.4 Cleanouts are suggested to be provided at the following locations:

a) Inside the building at a point of exit. Use a wye branch or a trap.
b) At every change of direction greater than 45°.
c) At the base of all stacks.
d) At the horizontal header, receiving vertical stacks and serving the purpose of offset header.

4.5.3.6.3.5 *Supports for drainage and sewerage pipes*

The supports for the above pipes and fittings shall be in accordance with manufacturer's recommendations and shall comply with the applicable standards.

4.5.4 *Indirect Wastes*

4.5.4.1 *General*

Waste, overflow and drain pipes from the following types of equipment shall not be connected into any drainage system directly to prevent backflow from the drainage system into the equipment/installation:

a) Plumbing and kitchen appliances:
    1) Underground or overhead water tanks
    2) Drinking water fountains
    3) Dishwashing sinks and culinary sinks used for soaking and preparation of food
    4) Cooling counters for food and beverages
    5) Kitchen equipment for keeping food warm
    6) Pressure drainage connections from equipment
b) Air conditioning, heating and other mechanical equipment:
    1) Air handling equipment
    2) Cooling tower and other equipment
    3) Condensate lines from equipment
    4) Storage tanks
    5) Condensate lines
    6) Boiler blow down lines
    7) Steam trap drain lines
c) Laboratories and other areas:
    1) Water stills
    2) Waste from laboratory in specified sinks
    3) Sterlizers and similar equipment
    4) Water purification equipment

4.5.4.2 *Indirect waste receptors*

All plumbing fixtures or other receptors receiving the discharge of indirect waste pipes shall be of such shape and capacity as to prevent splashing or flooding and shall be located where they are readily accessible for inspection and cleaning.

4.5.4.3 *Pressure drainage connections*

Indirect waste connections shall be provided for drains, overflows or relief vents from the water supply system, and no piping or equipment carrying wastes or producing wastes or other discharges under pressure shall be directly connected to any part of the drainage system.

The above shall not apply to any approved sump pump or to any approved plumbing fixture discharging pressurized waste or device when the Authority has been satisfied that the drainage system has the capacity to carry the waste from the pressurized discharge.

An indirect waste is required for any type of fixture or equipment that may come in contact with the food. The purpose is to isolate the fixture or equipment from drainage system waste.

Indirect waste piping shall be a minimum of 25 mm in size, but not smaller than drain of the equipment or fixture. There is no limitation on the length of indirect waste piping.

4.5.5 *Special Wastes*

4.5.5.1 *General*

Wastes having characteristics which may be detrimental to the pipes in which it is disposed as well as to the persons handling it. Such wastes used in a building need to be specially identified and a suitable and safe method of its disposal installed to ensure that the piping system is not corroded nor the health and safety of the occupants is affected in any way.

Whenever the occupant or the user of any wastes is unaware of the dangers of the consequences of disposing the waste, he shall be made aware of the dangers of his action along with providing suitable warning and instruction for correct disposal be provided to him.

Piping system for all special wastes should be separate and independent for each type of waste and should not be connected to the building drainage system. Other applicable provisions for installation of soil and waste pipe system shall be however be followed.

4.5.5.2 *Laboratory wastes*

A study of the possible chemical and corrosive and toxic properties of wastes handled and disposed of in a laboratory need to be ascertained in advance. The relevant statutory rules and regulation regarding the method of disposal of strong and objectionable wastes shall be followed.

All sinks, receptacles, traps, pipes, fittings and joints shall be of materials resistant to the liquids disposed of

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in the system.

In laboratories for educational, research and medical institutions, handling mildly corrosive and toxic wastes, they may be neutralized in chambers using appropriate neutralizing agents. The chamber shall be provided with chambers at inlet and outlet for collecting samples of the incoming and outgoing waste for monitoring its characteristics.

4.5.5.3 *Infected wastes*

Infected liquid wastes are generated in hospitals from patient excreta, operation theatres, laboratories testing samples of stools, urine, blood, flesh, etc, which shall not be disposed of into the drainage system. Such waste shall be collected separately and pre-treated, and sterilized, if required, before disposal into the building drainage system.

Soiled linen from infectious patients needs to be collected from the respective areas of the hospital in separate linen bins and pre-washed in dirty utility room in a sluice tub and sterilized in the laundry (sluice machine) before its regular washing in the hospital laundry. Liquid wastes from the washing operations shall be neutralized to prevent any cross contamination before discharge in the building's drainage system.

4.5.5.4 *Research laboratory wastes*

Research laboratories conducting research in all areas of science and technology, for example, chemical industry, pharmacy, metallurgy, bio-sciences, agriculture, atomic energy, medicine, etc, shall follow the established procedures laid down by statutory bodies to handle, treat and dispose wastes which are highly toxic, corrosive, infectious, inflammable, explosive and having bacterial cultures, complex organic and inorganic chemicals. Such wastes shall not be disposed of in a building drainage system or the city sewerage system unless they are pre-treated and meet the disposal criteria in accordance with the relevant rules/regulations.

It requires a liquid waste decontamination system which consists of at least one reactor or sterilizer plus a holding tank. An ideal system would consist of two or more sterilizers to provide redundancy with two or more tanks. There should be a sampling tank between this system and building drainage. The final reacted waste water should flow to ETP and not to STP.

4.5.6 *Grease Traps*

Oil and grease is found in wastes generated from kitchens in hotels, industrial canteens, restaurant, butcheries, some laboratories and manufacturing units having a high content of oil and greases in their final waste.

Waste exceeding temperature of 60°C should not be allowed in the grease trap. When so encountered, it may be allowed to cool in a holding chamber before entering the grease trap.

Oil and greases tend to solidify as they cool within the drainage system. The solidified matter clogs the drains and the other matter in the waste stick to it due to the adhesion properties of the grease. Oil and greases are lighter than water and tend to float on the top of the waste water.

Grease traps shall be installed in building having the above types of wastes. In principle the grease laden water is allowed to retain in a grease trap which enables any solids to be settled or separated for manual disposal. The retention time allows the incoming waste to cool and allow the grease to solidify. The clear waste is then allowed to discharge into the building's drainage system.

4.5.7 *Oil Interceptors*

Oils and lubricants are found in wastes from vehicle service stations, workshops manufacturing units whose waste may contain high content of oils. Oils for example, petroleum, kerosene and diesel used as fuel, cooking, lubricant oils and similar liquids are lighter than water and thus float on water in a pipe line or in a chamber when stored. Such oils have a low ignition point and are prone to catch fire if exposed to any flame or a spark and may cause explosion inside or outside the drainage system. The flames from such a fire spread rapidly if not confined or prevented at the possible source. Lighter oils and lubricants are removed from the system by passing them through an oil interceptor/ petrol gully. They are chambers in various compartments which allow the solids to settle and allow the oils to float to the top. The oil is then decanted in separate containers for disposal in an approved manner. The oil free waste collected from the bottom of the chamber is disposed of in the building drainage system.

4.5.8 *Radioactive Waste*

Scientific research institutions, hospital and many types of manufacturing processes use radioactive material in the form of radio-isotopes and other radioactive sources for their activities. Manufacture, sale, use and disposal of radioactive material is regulated by the statutory rules and regulation. Proposal for usage and disposal of radioactive materials shall be done in consultation with and prior permission of the Authority by the users of the materials. No radioactive material shall be disposed of in any building drainage system without the authorization of the Authority.

NOTE — All procedures followed and precautions taken shall be in accordance with AERB regulations, including regarding employing delay and decay tanks. Where applicable, the toilets may be designated as 'hot toilets' and should be clearly indicated. All drainage plumbing needs to be isolated and connected to delay and decay tanks (usually required for PET CT scan room, SPECT CT scan room and iodine therapy ward, and may be also required for cyclotron liquid waste).

4.5.9 *Special Situations of Waste Water Disposal*

Buildings may generate uncontaminated waste water from various sources continuously, intermittently or in large volumes for a short time for example, emptying any water tanks or pools, testing fire and water lines for flow conditions, etc. Connections from all such

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sources shall be made to the building drainage system indirectly through a trap. It should be ensured in advance that the building drain or a sump with a pump has the capacity to receive to rate of flow. In case the capacity is less the rate of discharge from the appliances should be regulated to meet the capacity of the disposal. Under no circumstances shall any waste water described above shall be disposed of in any storm water drains.

4.5.10 *Manholes*

4.5.10.1 *General*

A manhole or inspection chamber shall be capable of sustaining the loads which may be imposed on it, exclude subsoil water and be water tight. The size of the chamber should be sufficient to permit ready access to the drain or sewer for inspection, cleaning and rodding and should have a removable cover of adequate strength, constructed of suitable and durable material. Where the depth of the chamber so requires, access rungs, step irons, ladders or other means should be provided to ensure safe access to the level of the drain or sewer. If the chamber contains an open channel, benching should be provided having a smooth finish and formed so as to allow the foul matter to flow towards the pipe and also ensure a safe foothold.

No manhole or inspection chamber shall be permitted inside a building or in any passage therein. The minimum depth of the manhole shall not be less than 800 mm to facilitate gully trap connection. Further, ventilating covers shall not be used for domestic drains. At every change of alignment, gradient or diameter of a drain, there shall be a manhole or inspection chamber. Bends and junctions in the drains shall be grouped together in manholes as far as possible.

Alternative materials of manholes using RCC rings and PVC in sewer lines are being used in some sites. These may be considered subject to ensuring their proper design, keeping in view the lateral and vertical loads at the place of installation.

The holes over the surfaces of covers/gratings of various manholes, gullys and other chambers/drains shall comply with the requirements given in **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

4.5.10.2 *Spacing of manholes*

The spacing of manholes for a given pipe size should be as follows:

Sl No.	*Pipe Diameter* mm	*Spacing of Manhole* m
i)	Up to 300	45
ii)	301 to 500	75
iii)	501 to 900	90
iv)	Beyond 900	Spacing shall depend upon local condition and shall be gotten approved by the Authority

Where the diameter of a drain is increased, the crown of the pipes shall be fixed at the same level and the necessary slope given in the invert of the manhole chamber. In exceptional cases and where unavoidable, the crown of the branch sewer may be fixed at a lower level, but in such cases the peak flow level of the two sewers shall be kept the same.

4.5.10.3 *Size of manhole*

The manhole or chamber shall be of such size as will allow necessary examination or clearance of drains. The size of shall be adjusted to take into account any increase in the number of entries into the chamber.

4.5.10.3.1 Manholes may be rectangular, arch or circular type. The minimum internal size of manholes, chambers (between faces of masonry) shall be as follows:

a) *Rectangular manholes*:

1)	For depths less than 0.90 m	900 mm × 800 mm
2)	For depths from 0.90 m and up to 2.5 m	1 200 mm × 900 mm

NOTE — For depths upto 0.60 m, 600 mm × 600 mm manhole may be used.

b) *Arch type manholes*:

	For depths of 2.5 m and above	1 400 mm × 900 mm

NOTE — The width of manhole chamber shall be suitably increased more than 900 mm on bends, junctions or pipes with diameter greater than 450 mm so that benching width in either side of channel is minimum 200 mm.

c) *Circular manholes*:

1)	For depths above 0.90 m and up to 1.65 m	900 mm diameter
2)	For depths above 1.65 m and up to 2.30 m	1 200 mm diameter
3)	For depths above 2.30 m and up to 9.00 m	1 500 mm diameter
4)	For depths above 9.00 m and up to 14.00 m	1 800 mm diameter

NOTES

1 In adopting the above sizes of chambers, it should be ensured that these sizes accord with full or half bricks with standard thickness of mortar joints so as to avoid wasteful cutting of bricks.

2 The sizes of the chambers/manhole may be adjusted to suit the availability of local building materials, economics of construction and to meet local authority approval.

3 The access shaft shall be corbelled inwards on three sides at the top to reduce its size to that of the cover frame to be fitted or alternatively the access shaft shall be covered over by a reinforced concrete slab of suitable dimensions with an opening for manhole cover and frame.

4 The minimum sewer pipe diameter is 200 mm based on good practice [9-2(12)].

4.5.10.4 *Construction*

4.5.10.4.1 *Excavation*

The manhole shall be excavated true to dimensions and

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levels as shown on the plan. The excavation of deep manholes shall be accompanied with safety measures like timbering, staging, etc. In areas where necessary, appropriate measures for dewatering should be made.

4.5.10.4.2 *Bed concrete*

The manhole shall be built on a bed of concrete 1:4:8 (1 cement : 4 coarse sand : 8 graded stone aggregate 40 mm nominal size). The thickness of bed concrete shall be at least 150 mm for manholes up to 0.9 m in depth, at least 200 mm for manholes from 0.90 m up to 2.5 m in depth and at least 300 mm for manholes of greater depth, unless the structural design demands higher thickness.

This thickness may be verified considering the weight of wall, cover, the wheel loads, impact of traffic which are transmitted through cover and the shaft walls and for water pressure, if any. In case of weak soil, special foundation as suitable shall be provided

4.5.10.4.3 *Brickwork*

The thickness of walls shall be designed depending upon its shape and taking onto account all loads coming over it, including earth pressure and water pressure.

Generally, the brickwork shall be with first class bricks in cement mortar 1: 5 (1 cement : 5 coarse sand). All brickwork in manhole chambers and shafts shall be carefully built in English Bond, the jointing faces of each brick being well 'buttered' with cement mortar before laying, so as to ensure a full joint. The construction of walls in brickwork shall be done in accordance with good practice [9-2(13)].

For various depths the recommended thickness of wall may be as follows:

Depth of the chamber thickness of wall

a) Up to 2.25 m : 200 mm (one brick length)
b) From 2.25 m up to 3.0 m : 300 mm (one and half brick length)
c) From 3.00 m up to 5.0 m : 400 mm (two brick length)
d) From 5.00 m up to 9.0 m : 500 mm (two and half brick length)
e) Above 9.00 m : 600 mm (three brick length)

The actual thickness in any case shall be calculated on the basis of engineering design. Typical sections of the manholes are illustrated in Figs. 7, 8 and 9.

NOTES

1 Rich mix of cement mortar, not weaker than 1:3, should be used in brick masonry, where subsoil water conditions are encountered.

2 For arched type of manholes, the brick masonry in arches and arching over pipes shall be in cement mortar 1:3.

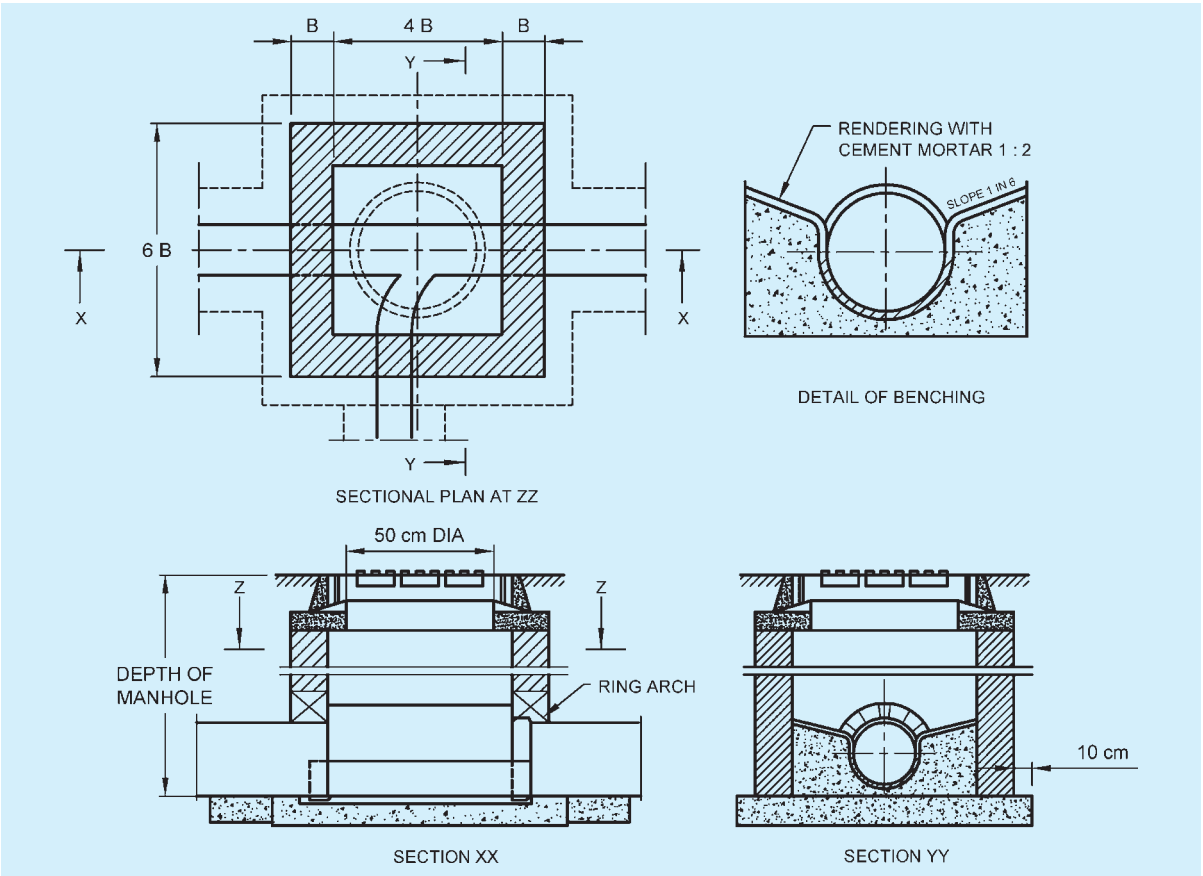
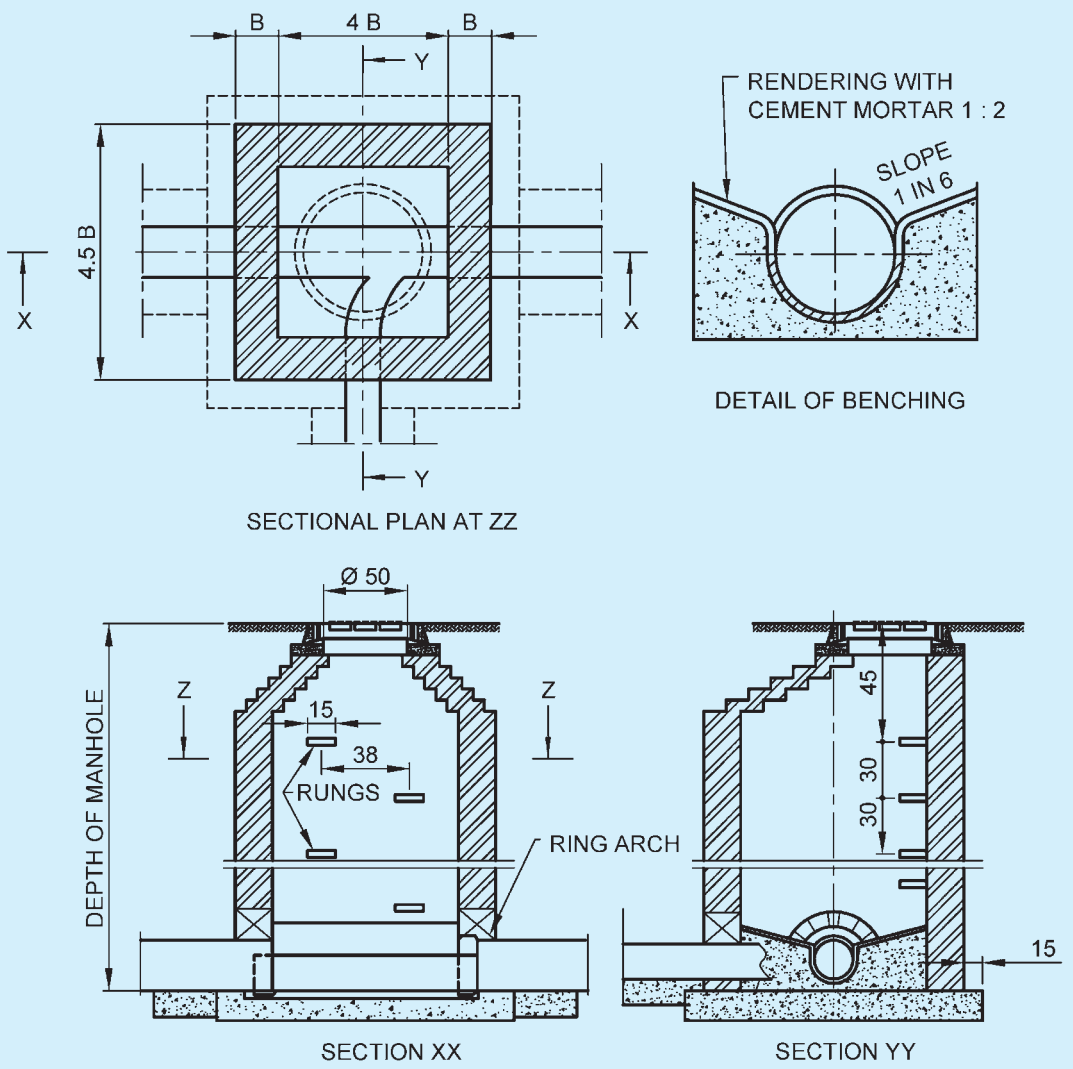


FIG. 7 DETAIL OF MANHOLE (DEPTH LESS THAN 0.90 m)

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All dimensions in centimetres.

FIG. 8 DETAIL OF MANHOLE (DEPTH FROM 0.9 m AND UP TO 2.5 m)

4.5.10.4.4 *Plastering*

The wall shall be plastered (15 mm, minimum) both inside and outside within cement mortar 1:3 and finished smooth with a coat of neat cement. Where subsoil water conditions exit, a richer mix may be used and it shall further be waterproofed with addition of approved waterproofing compound in a quantity as per manufacturer specifications.

All manholes shall be so constructed as to be water-tight under test.

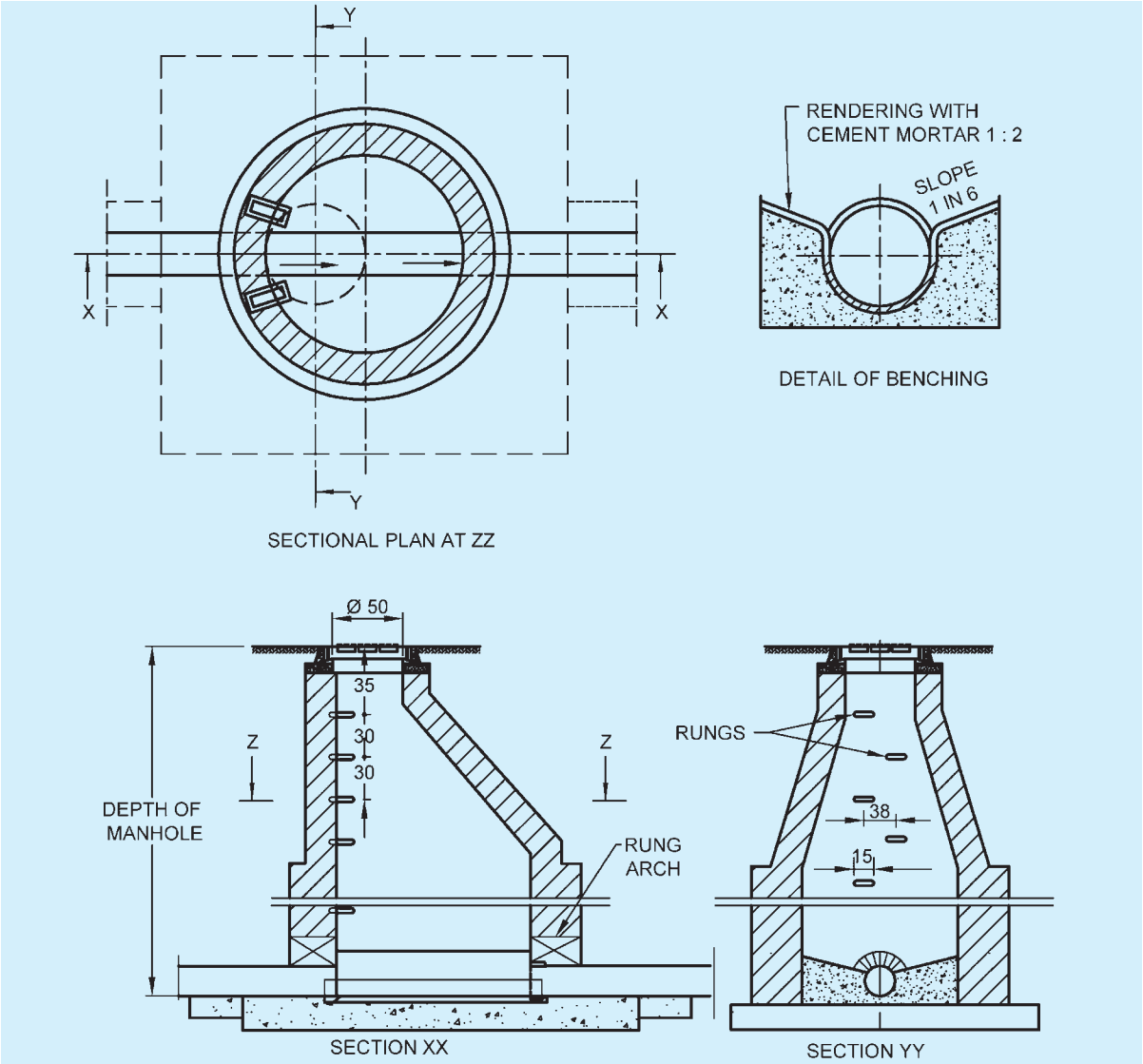
All angles shall be rounded to 75 mm radius and all rendered internal surface shall have hard impervious finish obtained using a steel trowel.

4.5.10.4.5 *Channels and benching*

These shall be semi-circular in the bottom half and of diameter equal to that of the sewer. Above the horizontal diameter, the sides shall be extended vertically 50 mm above the crown of sewer pipe and the top edge shall be suitably rounded off. The branch channels shall also be similarly constructed with respect to the benching, but at their junction with the main channel an appropriate fall, if required suitably rounded off in the direction of flow in the main channel shall be given.

The channel/drain and benching at the bottom of the chamber shall be done in cement concrete 1:2:4 and subsequently plastered with cement mortar of 1:2 proportion or weaker cement mortar with a suitable waterproofing compound and finished smooth, to the grade (where required). The benching at the sides shall be carried up in such a manner as to provide no lodgment for any splashing in case of accidental flooding of the chamber.

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All dimensions in centimetres.

FIG. 9 DETAIL OF MANHOLE (DEPTH 2.5 m AND ABOVE)

Channels shall be rendered smooth and benchings shall have slopes towards the channel.

4.5.10.4.6 *Rungs*

Rungs shall be provided in all manholes over 0.8 m in depth and shall be of cast iron, or PVC encapsulated or composite non-corrosive materials, and of suitable dimensions, conforming to accepted standards [9-2(14)]. These rungs may be set staggered in two vertical rungs which may be 300 mm apart horizontally as well as vertically and shall project a minimum of 100 mm beyond the finished surface if the manhole wall. The top rung shall be 450 mm below the manhole cover and the lowest not more than 300 mm above the benching.

4.5.10.4.7 *Manhole covers and frames*

The size of manhole covers shall be such that there shall be a clear opening of at least 500 mm in diameter for manholes exceeding 0.90 m in depth. The manhole covers and frames used shall conform to accepted standards [9-2(15)].

The frame of manhole shall be firmly embedded to concrete alignment and level in plain concrete on the top of masonry.

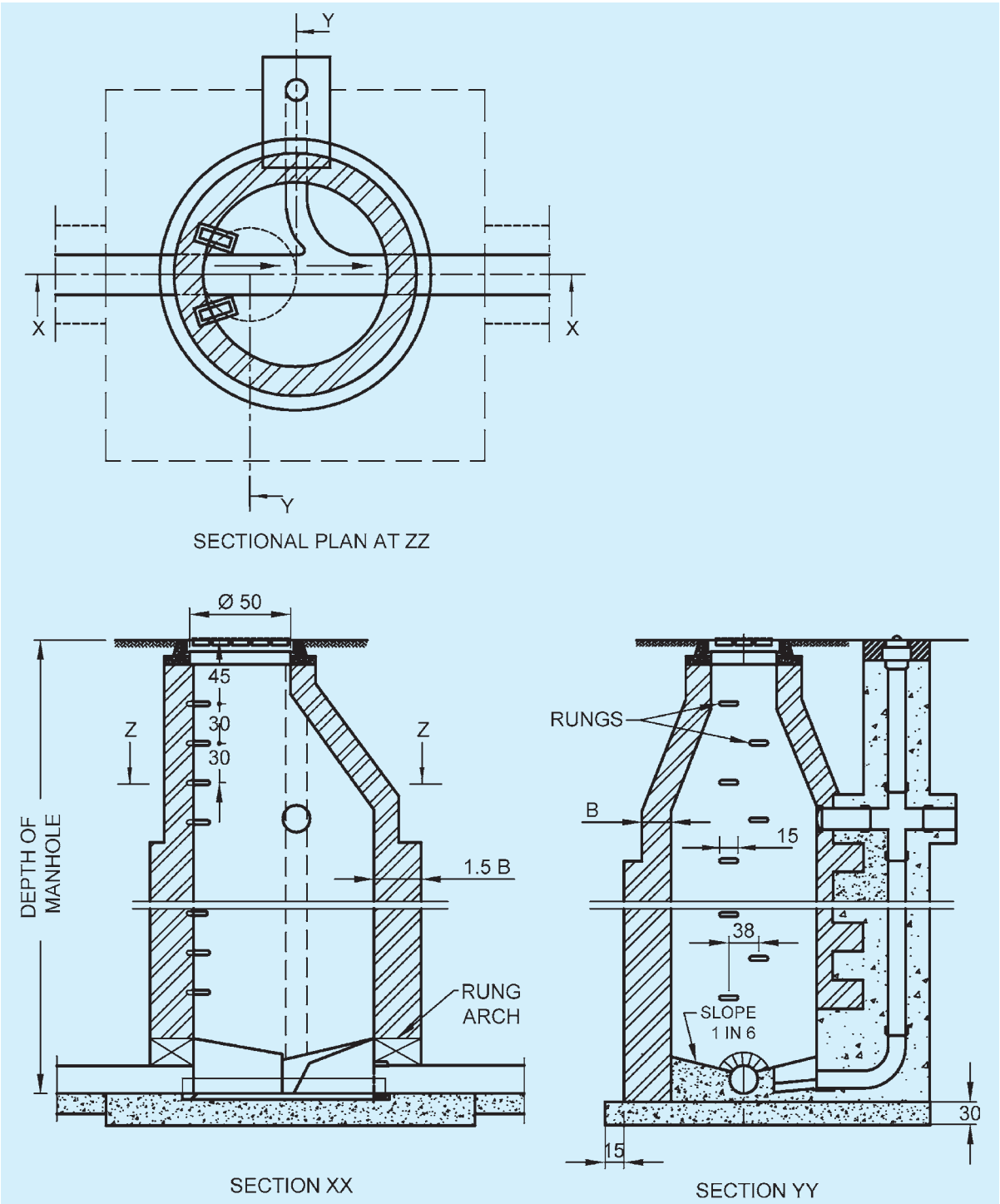
4.5.10.5 *Drop manhole*

Where it is uneconomic or impracticable to arrange the connection within 600 mm height above the invert of the manholes, the connection shall be made by constructing a vertical shaft outside the manhole

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chamber, as shown in Fig. 10. If the difference in level between the incoming drain and the sewer does not exceed 600 mm, and there is sufficient room in the manhole, the connecting pipe may be directly brought through the manhole wall and the fall accommodated by constructing a ramp in the benching of the manhole.

For detailed information regarding manholes in sewerage system, reference may be made to good practice [9-2(16)].



All dimensions in centimetres.

NOTE — Wall thickness have been indicated in brick length to provide for use of modular bricks or traditional bricks. In the figure, B = one brick length, 1.5 B = one an a half brick length, etc.

FIG. 10 DROP MANHOLE

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4.5.10.6 *Manhole covers and recommended locations*

Manhole covers were traditionally and presently manufactured from concrete, steel fibre reinforced concrete, cast iron and ductile iron or PVC materials and these materials are used based on the load carrying capacity and for the following type of applications:

a) Inspection chambers for sewerage;
b) Underground electrical cabling;
c) Telecom cabling;
d) Water, gas and petroleum installations; and
e) Beautification of gardens and landscapes.

Recommended locations conforming to load capacity shall be as per accepted standard [9-2(15)].

4.5.11 *Storm Water Drainage*

4.5.11.1 *General*

The object of storm water drainage is to collect and carry, the rainwater collected within the premises of the building, for suitable disposal.

4.5.11.2 *Design factors*

Estimate of the quantity that reaches the storm water drain (runoff) depends on the following factors:

a) Type of soil and its absorption capacity determined by its soil group.
b) Ground slope and the time in which the area is drained.
c) Intensity of the rainfall for a design period.
d) Duration of the rain/storm.

The runoff reaching the sewer may be given by the expression:

$$Q = 10\ C.i.A$$

where

Q = runoff, m^3/h;
C = coefficient of runoff;
i = intensity of rainfall, mm/h; and
A = area of the drainage district, hectares.

Coefficient of runoff for various surfaces may be taken as:

Type of Surface	*Coefficient of Runoff*
Concrete roof area	0.9
Paved podium areas and asphalted roads	0.8
Unpaved ground	0.3
Lawns and parks	0.15

4.5.11.2.1 *Imperviousness*

The soil conditions and the ground slope determine the impermeability factor. Impermeability factor is the proportion of the total rainfall received on the surface which will be discharging into a storm water drain after allowing for initial abstraction (in local pond and lakes), ground absorption by evaporation, vegetation and other losses. The net flow reaching the storm water drain is called runoff.

The percentage of imperviousness of the drainage area may be obtained from available data for a particular area. In the absence of such data, the following figures may serve as a guide:

Type of Area	*Imperviousness Factor* Percent
Commercial and industrial areas	70 - 90
Residential areas (high density)	60 - 75
Residential areas (low density)	35 - 60
Parks and underdeveloped areas	10 - 20

4.5.11.2.2 *Terrain modelling*

Areas planned for urbanization from agricultural land, forest or low grade land for example, low lying areas prone to flooding, marshy or abandoned quarries, etc, need detailed and careful consideration with respect to its drainage. A detailed contour survey shall be carried out not only with respect to the site but also the surrounding areas to verify the quantity/area contributing runoff, presence of any low lying and natural water body acting as holding pond or any natural drain passing through the area and beyond whose filling up or diversion may cause water logging problem on the site or to the surrounding areas.

The planning of the area should ensure that,

a) all areas become self draining by gravity with respect to the high flood level of the area or the drainage channels passing, whichever is higher;
b) as far as possible, natural drainage pattern with respect to the whole area be maintained except when low lying areas need to be filled up for grading purposes;
c) the drainage in the area shall be planned in accordance with the natural slopes; and
d) levels of the main highway or road connecting to the property shall be determined to ensure proper drainage and protection of the site.

The formation levels of the entire area shall be prepared to determine proposed formation levels by preparing a terrain model which will show the proposed site contours, ground and road levels and connections to all services including storm water disposal system.

4.5.11.2.3 *Rainfall intensity*

The intensity of rainfall is the amount of rain falling in

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unit time and is expressed in centimetre or millimetre per hour. For design purposes, the mean rainfall intensity is collected for 25 years.

4.5.11.2.4 *Design frequency*

Storm water drainage system for an urbanized area is planned on the basis of the design frequency of the storm which shall be determined by the designer. Frequency is the period in which the selected design intensity recurs in a given period of time in years.

NOTE — The rainfall intensity varies with the period, which includes good, bad and average years of rainfall. Meteorological department has long term data regarding the rainfall and have graphs for different periods and the designers are advised to consult the department before designing any scheme.

4.5.11.2.5 *Time of concentration*

Time of concentration is the time required for the rainwater to flow to reach the farthest point of the drainage system or the outfall under consideration. Time of concentration is equal to the inlet time plus the time required for the flow to reach the main or branch drain. The inlet time is the time dependent on the distance of the farthest point in the drainage area to the inlet of the manhole and the surface slopes, etc, and will vary between 5 min and 30 min.

In highly developed sections for example with impervious surfaces it may be as low as 3 min or lower (with good slopes) as in building terraces and paved areas. Correspondingly the design intensity for the drainage for such areas will be much higher. Rainwater pipes have to be designed for an intensity for a very low time of concentration.

4.5.11.2.6 *Natural infiltration*

In planning any area with buildings, layout with paved and non-permeable surfaces, care should be taken to allow maximum discharge of the rainwater to flow directly or indirectly to permeate into the ground for enabling the ground water to be recharged. Some of the techniques which allow infiltration that may be considered are:

a) Use of brick paved open jointed storm water drains.
b) Providing bore holes in the storm water drains.
c) Using paving tiles with open joints which enable water to percolates as it flows on it.

4.5.11.3 *Combined system*

A combined system of drainage is one which carries the sewerage as well as the runoff from the storm water drainage. Relevant applicable statutory rules/ regulations may not allow such system in new areas and the sewerage and the storm water drainage have to be separate and independent of each other. Such systems are however existing in many old cities and the storm water may have to be discharged into the combined drainage system.

Where levels do not permit for connection to a public storm water drain, storm water from courtyards of buildings may be connected to the public sewer, provided it is designed to or has the capacity to convey combined discharge. In such cases, the surface water shall be admitted to the soil sewer through trapped gullies in order to prevent the escape of foul air.

4.5.11.4 *Discharging into a watercourse*

It may often be convenient to discharge surface water to a nearby stream or a watercourse. The invert level of the outfall shall be about the same as the normal water level in the watercourse or ideally should be above the highest flood level of the watercourse. The out-fall shall be protected against floating debris by a screen.

4.5.11.5 *Discharge to a public storm water drain*

Where it is necessary to connect the discharge rainwater into a public storm water drain, such drains shall be designed for the intensity of rain based on local conditions, but in no case shall they be designed for intensity of rainfall of less than 50 mm/h. Rainwater from each building plot shall be connected to the storm water drainage through a separate pipe or an open public drain directly. No trap shall be installed before the connection.

4.5.11.6 *Rainwater pipes for roof drainage*

4.5.11.6.1 The roofs of a building shall be so constructed or framed as to permit effectual drainage of the rainwater therefrom by means of a sufficient number of rainwater pipes of adequate size so arranged, jointed and fixed as to ensure that the rainwater is carried away from the building without causing dampness in any part of the walls or foundations of the building or those of an adjacent building.

4.5.11.6.2 The rainwater pipes shall be fixed to the outside of the external walls of the building or in recesses or chases cut or formed in such external wall or in such other manner as may be approved by the Authority.

4.5.11.6.3 Rainwater pipes conveying rainwater shall discharge directly or by means of a channel into or over an inlet to a surface drain or shall discharge freely in a compound, drained to surface drain but in no case shall it discharge directly into any closed drain.

4.5.11.6.4 Whenever it is not possible to discharge a rainwater pipe into or over an inlet to a surface drain or in a compound or in a street drain within 30 m from the boundary of the premises, such rainwater pipe shall

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discharge into a gully trap which shall be connected with the street drain for storm water and such a gully-trap shall have a screen and a silt catcher incorporated in its design.

4.5.11.6.5 If such streets drain is not available within 30 m of the boundary of the premises, a rainwater pipe may discharge directly into the kerb drain and shall be taken through a pipe outlet across the foot path, if any, without obstructing the path.

4.5.11.6.6 A rainwater pipe shall not discharge into or connect with any soil pipe or its vent pipe or any waste pipe or its vent pipe nor shall it discharge into a sewer unless specifically permitted to do so by the Authority, in which case such discharge into a sewer shall be intercepted by means of a gully trap.

4.5.11.6.7 Rainwater pipes shall be constructed of cast iron, PVC, asbestos cement, galvanized sheet or other equally suitable material and shall be securely fixed.

4.5.11.6.8 The factors that decide the quantity of rainwater entering are:

a) Intensity of rainfall, and
b) Time of concentration selected for rainwater pipe.

A bell mouth inlet at the roof surface is found to give better drainage effect, provided proper slopes are given to the roof surface. The spacing of rainwater pipes depends on the locations available for the down takes and the area which each pipe serves. The spacing will also be determined by the amount of slopes that can be given to the roof. The recommended slopes for the flat roofs with smooth finish would be 1:150 to 1:133, with rough stone/tiles 1:100 and for gravel set in cement or losely packed concrete finish 1:75 to 1:66. The effective strainer area should preferably be 1.5 to 2 times the area of pipe to which it connects to considerably enhance the capacity of rainwater pipes.

The rainwater pipes of cast iron (coefficient of roughness 0.013) shall normally be sized on the basis of roof areas according to Table 23. The vertical down take rainwater pipes, having a bell mouth inlet on the roof surface with effective cross-sectional area of grating 1.5 to 2 times the rainwater pipe area, may be designed by considering the outlet pipe as weir.

The roof area (RA) for drainage may be worked out by using:

$$RA = 0.084 \times d^{5/2}/I$$

where

RA = roof area, m^2;
d = pipe diameter, mm; and
I = intensity of rainfall, mm/h.

4.5.11.6.9 The storm water may be led off in a suitable open drain to a watercourse. The open drain, if not a *Pucca* masonry throughout, shall be so at least where there is either a change in direction or gradient.

4.5.12 *Rainwater Harvesting*

4.5.12.1 *General*

To supplement the ever growing shortage of protected, pure and safe water supply for human consumption, rainwater is an ideal source which can be conserved and used in a useful manner by the people. The amount of rainfall available varies from region to region. Each area has to develop its own method and system to conserve, store and use it to suit its requirement and local conditions. There are several methods by which rainwater can be stored, used and conserved. Each system depends on the amount of precipitation, the period in which the rainfall occurs in a year and the physical infrastructure, for example space available to store the water, etc.

There are several techniques available for catching and storing the rainwater. Most of the techniques are applicable for large open areas, farms, sloping grounds,

Table 23 Sizing of Rainwater Pipes for Roof Drainage in mm/h
(*Clause* 4.5.11.6.8)

Sl No.	Dia of Pipe mm	Roof Area, in m^2 for Average Rate of Rainfall in mm/h					
		50	75	100	125	150	200
(1)	(2)	(3)	(3)	(3)	(3)	(3)	(3)
i)	50	29.70	19.80	14.85	11.88	9.90	7.42
ii)	65	57.23	38.15	28.61	22.89	19.08	14.31
iii)	75	81.84	54.56	40.92	32.74	27.28	20.46
iv)	100	168.00	112.00	84.00	67.20	56.00	42.00
v)	125	293.48	195.66	146.74	117.39	97.83	73.37
vi)	150	462.95	308.64	231.48	185.18	154.32	115.74

NOTE — For rainwater pipes of other materials, the roof areas shall be multiplied by (0.013/coefficient of roughness of surface of that material). For example, for rainwater pipes of PVC (coefficient of roughness = 0.009), the above values of roof area shall be multiplied by 0.013/0.009 = 1.44.

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etc, with a low population base. Two major systems that are ideal for urban and semi-urban developed areas are:

a) Artificial ground water recharge, and
b) Roof top rainwater harvesting.

NOTE — Type and number of recharge pits and roof top rainwater harvesting capacity shall be provided as per the local/ state bye-laws.

4.5.12.2 *Artificial ground water recharge*

With increase in the impermeable surfaces in modern built up areas, there is gross reduction in the original catchment area. This prevents the natural percolation that would have recharged the area in the normal course if the ground was in its natural condition, for example a farm, open ground, forest, etc. This results in a large quantity of water, normally percolating into the ground, running off to the natural drains and into the rivers, causing increased runoff and flooding of downstream areas.

It is therefore essential to catch the runoff and use it for augmentation of ground water reservoir by modifying the natural movement of surface water by recharging it by artificial means, for example construction of recharge structures (*see* Fig. 11). The main objectives achieved may be:

a) Enhancement of sustainable yield in areas where over development and depletion of the aquifers.
b) Conservation and storage of excess surface water in the aquifers.
c) Improve the quality of the existing ground water through dilution.
d) Remove bacteriological and suspended impurities during the surface water transition within the subsoil.
e) Maintain the natural balance of the ground water and its usage as the rainwater is a renewable supply source. A well managed and controlled tapping of the aquifers will provide constant, dependable and safe water supply.

In planning and designing the ground water recharge structures, following should be taken into consideration:

1) Annual rainfall (for estimating approximately rainwater recharge per year).
2) Peak intensity and duration of each storm.
3) Type of soil and subsoil conditions and their permeability factor.
4) Ground slopes and run off which cannot be caught.
5) Location of recharge structures and its overflow outfall.
6) Rainwater measuring devices for finding the flow of water in the system.

For artificial recharge to ground water code for guidelines for artificial recharge to ground water [9-2(17)] may be referred.

NOTE — Rainwater harvesting with underground recharging will depend from region to region as per the climatic, topography, soil conditions and data about intensity of rainfall and retention time for calculating the capacity of recharge wells to be obtained from reference documents from the Authority.

4.5.12.3 *Roof top rainwater harvesting*

4.5.12.3.1 *Harvesting in regular rainfall areas*

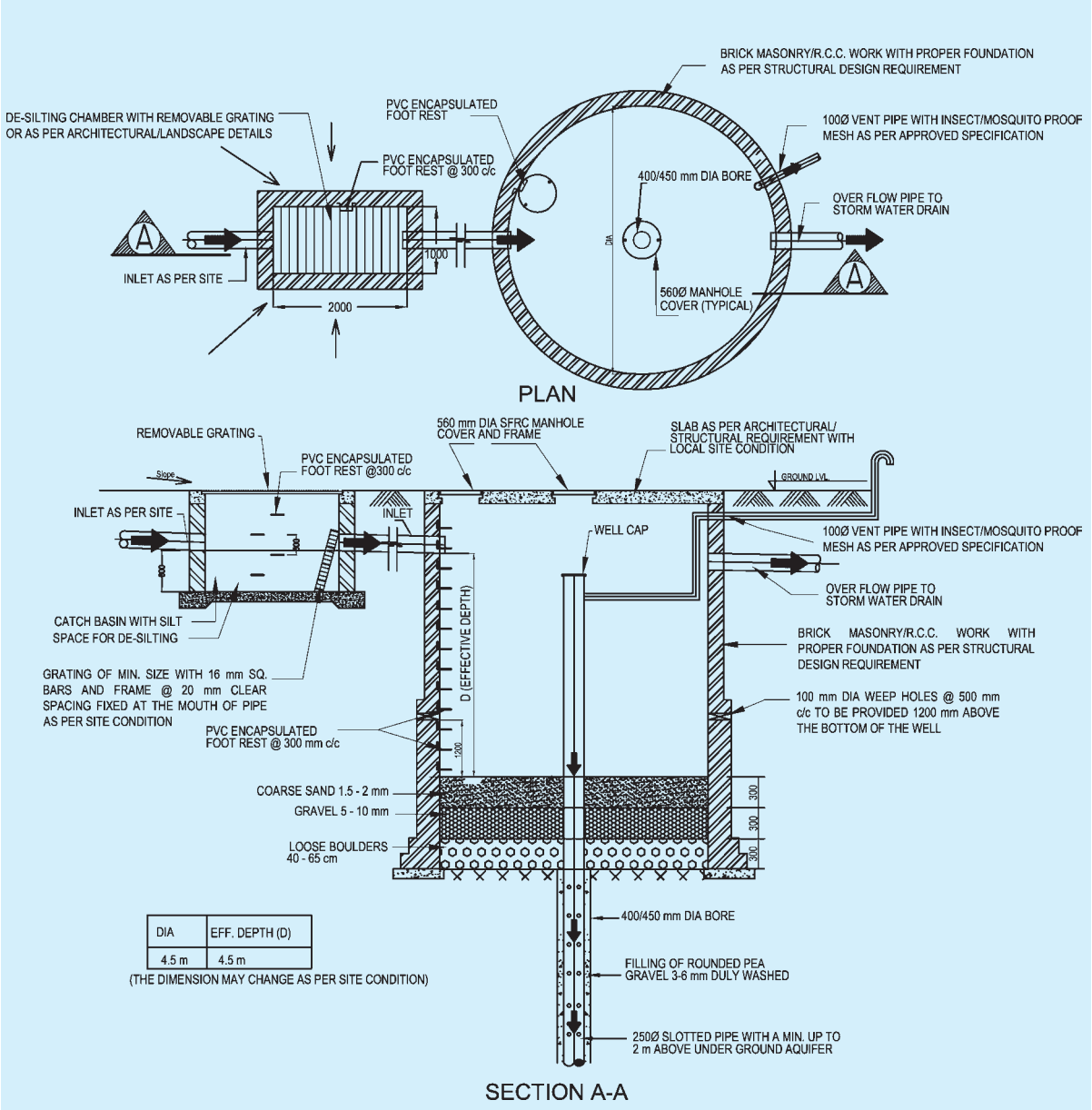
In areas having rainfall over a large period in a year, for example in hilly areas, coastal regions, etc constant and regular rainfall can be usefully harvested and stored in suitable water tanks. Water shall be collected through roof gutters and down take pipes. Provision should be made to divert the 1st rainfall after a dry spell so that ant dust, soot and leaves, etc, are drained away before the water is collected into the water tank. The capacity of the water tank should be enough for storing water required for consumption between two dry spells. The water tank shall be located in a well protected area and shall not be exposed to any hazards of water contamination from any other sources. The water shall be chlorinated using chlorine tablets or solution to maintain a residual chlorine of approximately 1 mg/l. The tank shall have an overflow leading to natural water courses or to any additional tanks (*see* Table 24).

4.5.12.3.2 *Harvesting in limited rainfall areas*

In areas with the rainfall limited during the monsoon period (usually from 15-90 days), roof top rainwater can be stored and used for non-potable purposes, after proper treatment, in the premises itself as mentioned above; excess water, if any, is best used for recharging the ground water. For individual properties and plots the roof top rainwater can be diverted to underground or above ground water storage tank(s), pretreated, stored and used for non-potable purposes. Excess water, if any, may be discharged to existing open or abandoned tube wells. In a well-planned building complex, a system should be laid out so that the runoff is collected in underground or above ground water storage tank(s), pretreated, stored, and used for non-potable purposes. Excess water, if any, shall be discharged in bore-wells as per designs specified by the Central Ground Water Board, Government of India.

For roof top rainwater harvesting, reference may be made to good practice [9-2(18)].

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DIA	EFF. DEPTH (D)
4.5 m	4.5 m

(THE DIMENSION MAY CHANGE AS PER SITE CONDITION)

All dimensions in millimetres unless specified.

NOTE — Depending on site soil condition and keeping the above plumbing details and dimensions in view, the detailed structural/ shop drawing to be prepared, before executing the work.

FIG. 11 ARTIFICIAL GROUND WATER RECHARGE STRUCTURE

4.5.12.4 *Care to be taken in rainwater harvesting*

Water conservation technique discussed above shall be constructed with due care taking following precautions:

a) No sewage or waste water should be admitted into the system.

b) No waste water from areas likely to have oil, grease or other pollutants should be connected to the system.

c) Each structure/well shall have an inlet chamber with a silt trap to prevent any silt from finding its way into the subsoil water.

d) The wells should be terminated at least 5 m above the natural static subsoil water at its highest level so that the incoming flow passes through the natural ground condition and prevent contamination hazards.

e) No recharge structure or a well shall be used for drawing water for any purpose.

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4.5.12.5 *Siphonic drainage system*

It is an installation generally used for special situations such as roofs with large spans for structures like hangars, airport terminals, stadia and industrial sheds, where the number of down pipes has to be limited. These are designed for full flow of pipes and the roof outlets are different from conventional ones.

Siphonic roof drainage systems are engineered on the concept of a full bore (a fill rate of 100 percent). This implies that rainwater flows at high speed through small diameter pipe work, at normally zero gradient.

This siphonic effect is created by the (kinetic) energy derived from the hydraulic head, caused by the difference in height between the roof outlet and the discharge point in a building. Specialist roof outlets prevent air being sucked into the system.

The engineering principle of siphonic roof drainage design is based on the Bernoulli's energy equation for a steady flow of an incompressible fluid with constant density. In order to balance the equation, and to guarantee the required siphonic effect according to the rainfall intensity, the ideal pipe dimensions per flow path need to be determined.

In case of syphon system, the outlets of drainage system prevent vortex formation, thereby preventing air from entering the pipeline ensuring the entire system is running at full flow (*see* Fig. 12). It uses design that complies with Bernoulli's principle where equal energy is created under positive and negative pressure.

4.5.12.6 *Rainwater harvesting for plotted/group housing developments*

The rainwater harvesting methods adopted for plotted and group housing are through collection of rooftop rainwater and surface runoff harvesting.

A network of storm water drains in the entire residential area is used for harvesting rooftop rainwater and surface runoff. Appropriate number of recharge wells measuring 1 m × 1 m × 2 m may be constructed in the storm water drain for facilitating groundwater recharge. The quality of runoff, which passes through the borewell installed inside the recharge well, is ensured through a filter bed of pebbles (*see* Fig. 11).

4.5.12.7 *Other methods of rainwater harvesting*

a) *Creation of artificial reservoirs/lakes for utilization of available storm water* — This shall be based on estimation of amount of runoff volume based on rainfall data (for a period of 10 years) considering the percolation and evaporation losses and efforts to be made to collect all available runoff for proper utilization.

b) *Water balancing methods* — This refers to optimum utilization of available water from different sources, namely ground water, recycled waste water, storm water and municipal supply and its adoption would ensure that there is no wastage of water.

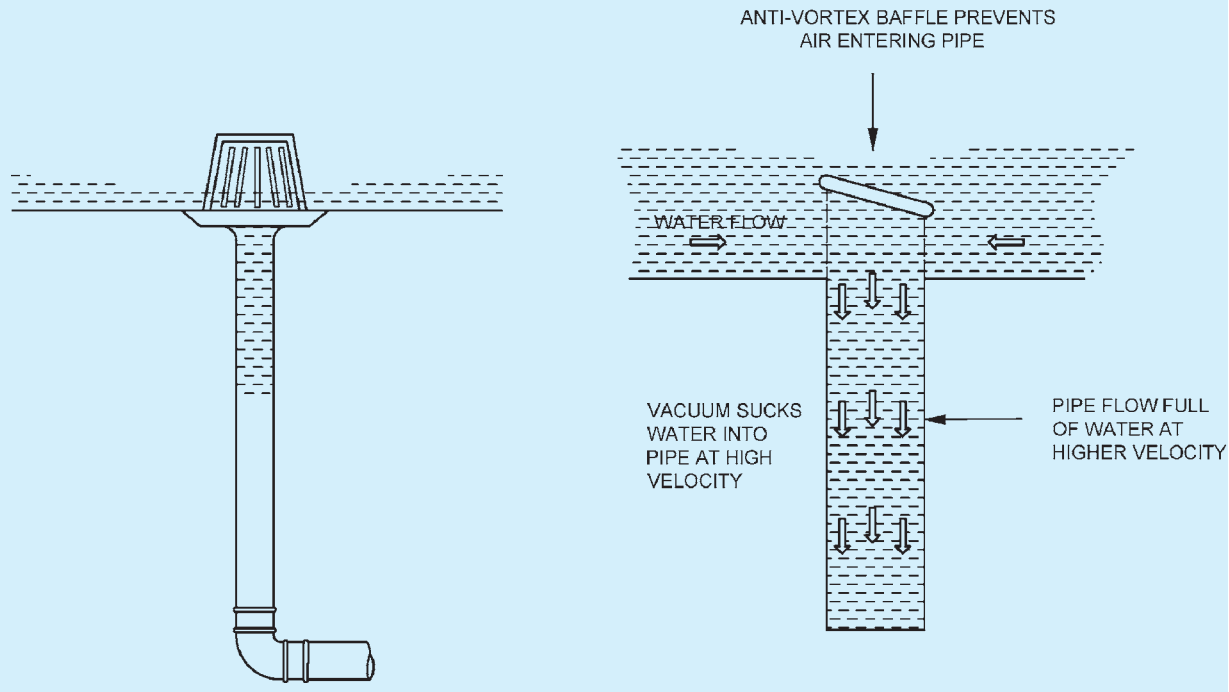


FIG. 12 SIPHONIC DRAINAGE SYSTEM

Table 24 Rainwater Available from Roof Top Harvesting

(*Clause* 4.5.12.3.1)

Rain fall mm →	100	200	300	400	500	600	700	800	900	1 000	1 100	1 200	1 300	1 400	1 500	1 600	1 700	1 800	1 900	2 000
Roof Top Area m^2 ↓	Harvested Water from Roof Tops, m^3 (80 percent of gross precipitation)																			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
20	2	3	5	6	8	10	11	13	14	16	18	19	21	22	24	26	27	29	30	32
30	2	5	7	10	12	14	17	19	22	24	26	29	31	34	36	38	41	43	46	48
40	3	6	10	13	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
50	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
60	5	10	14	19	24	29	34	38	43	48	53	58	62	67	72	77	82	86	91	96
70	6	11	17	22	28	34	39	45	50	56	62	67	73	78	84	90	95	101	106	112
80	6	13	19	26	32	38	45	51	58	64	70	77	83	90	96	102	109	115	122	128
90	7	14	22	29	36	43	50	58	65	72	79	86	94	101	108	115	122	130	137	144
100	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120	128	136	144	152	160
110	9	18	26	35	44	53	62	70	79	88	97	106	114	123	132	141	150	158	167	176
120	10	19	29	38	48	58	67	77	86	96	106	115	125	134	144	154	163	173	182	192
130	10	21	31	42	52	62	73	83	94	104	114	125	135	146	156	166	177	187	198	208
140	11	22	34	45	56	67	78	90	101	112	123	134	146	157	168	179	190	202	213	224
150	12	24	36	48	60	72	84	96	108	120	132	144	156	168	180	192	204	216	228	240
200	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256	272	288	304	320
250	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
300	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480
400	32	64	96	128	160	192	224	256	288	320	352	384	416	448	480	512	544	576	608	640
500	40	80	120	160	200	240	280	320	360	400	440	480	520	560	600	640	680	720	760	800
1 000	80	160	240	320	400	480	560	640	720	800	880	960	1 040	1 120	1 200	1 280	1 360	1 440	1 520	1 600
2 000	160	320	480	640	800	960	1 120	1 280	1 440	1 600	1 760	1 920	2 080	2 240	2 400	2 560	2 720	2 880	3 040	3 200
3 000	240	480	720	960	1 200	1 440	1 680	1 920	2 160	2 400	2 640	2 880	3 120	3 360	3 600	3 840	4 080	4 320	4 560	4 800

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4.5.13 *Subsoil Water Drainage*

4.5.13.1 *General*

Subsoil water is that portion of the rainfall which is absorbed into the ground.

The drainage of subsoil water may be necessary for the following reasons:

a) To increase the stability of the surface;

b) To avoid surface flooding;

c) To alleviate or to avoid causing dampness in the building, especially in the cellars;

d) To reduce the humidity in the immediate vicinity of the building; and

e) To increase the workability of the soil.

4.5.13.2 *Depth of water table*

The standing level of the subsoil water will vary with the season, the amount of rainfall and the proximity and level of drainage channels. Information regarding this level may be obtained by means of boreholes or trial pits, preferably the latter. It is desirable though not always practicable to ascertain the level of the standing water over a considerable period so as to enable the seasonal variations to be recorded and in particular the high water level. The direction of flow of the subsoil water may usually be judged by the general inclination of the land surface and the main lines of the subsoil drains shall follow the natural falls, wherever possible.

4.5.13.3 *Precautions*

Subsoil drains shall be so sited as not to endanger the stability of the buildings or earthwork. In some portions of the drain, it may be necessary to use non-porous jointed pipes.

4.5.13.3.1 No field pipe shall be laid in such a manner or in such a position as to communicate directly with any drain constructed or adopted to be used for conveying sewage, except where absolutely unavoidable and in such case a suitable efficient trap shall be provided between subsoil drain and such sewer.

4.5.13.4 *Systems of subsoil drainage*

Clay or concrete porous field drain pipes may be used and shall be laid in one of the following ways (*see also* Fig. 13):

a) *Natural* — The pipes are laid to follow the natural depressions or valleys of the site; branches discharge into the main as tributaries do into a river.

b) *Herringbone* — The system consists of a number of drains into which discharges from both sides smaller subsidiary branch drains parallel to each other, but an angle to the mains forming a series of herringbone pattern. Normally these branch drains should not exceed 30 m in length.

c) *Grid* — A main or mains drain is laid to the boundaries if the site into which subsidiary branches discharge from one side only.

d) *Fan-shaper* — The drains are laid converging to a single outlet at one point on the boundary of a site, without the use of main or collecting drains.

e) *Moat or cut-off system* — This system consists of drains laid on one or more sides of a building to intercept the flow of subsoil water and carry it away, thereby protecting the foundations of a building.

The choice of one or more of these systems will naturally depend on the local conditions of the site. For building sites, the mains shall be not less than 75 mm in diameter and the branches not less than 65 mm in diameter but normal practice tends towards the use of 100 mm and 75 mm, respectively. The pipes shall generally be laid at 60 to 90 cm depth, or to such a depth to which it is desirable to lower the water-table and the gradients are determined rather by the fall of the land than by considerations of self-cleansing velocity. The connection of the subsidiary drain to the main drain is best made by means of a clayware or concrete junction pipe. The outlet of a subsoil system may discharge into a soakaway or through a catch pit into the nearest ditch or watercourse. Where these are not available, the subsoil drains may be connected, with the approval of the Authority, through an intercepting trap to the surface water drainage system.

NOTE — Care shall be taken that there is no backflow from sub-surface drains during heavy rains.

4.5.13.5 *Deep well/borewell recharging*

Recharge well is one which pushes back surface water into ground water system. The recharge well may be of 1 m in diameter and 6 m deep lined with concrete rings having perforations.

Direct recharge is recommended when the well has gone dry and is yielding negligible amount of water. Indirect recharge is adopted for functioning borewells.

4.5.14 *Waste Disposal Systems in High Altitudes and/or Sub-Zero Temperature Regions*

4.5.14.1 In general, all the care to be exercised regarding water supply systems shall also be applicable in the case of waste disposal systems. The biological and chemical reduction of organic material proceeds slowly under low temperature conditions, consequently affecting the waste disposal systems. The waste disposal methods given in **4.5.14.2**, **4.5.14.3** and **4.5.14.4** shall be used only where it is not practical to install water carriage system.

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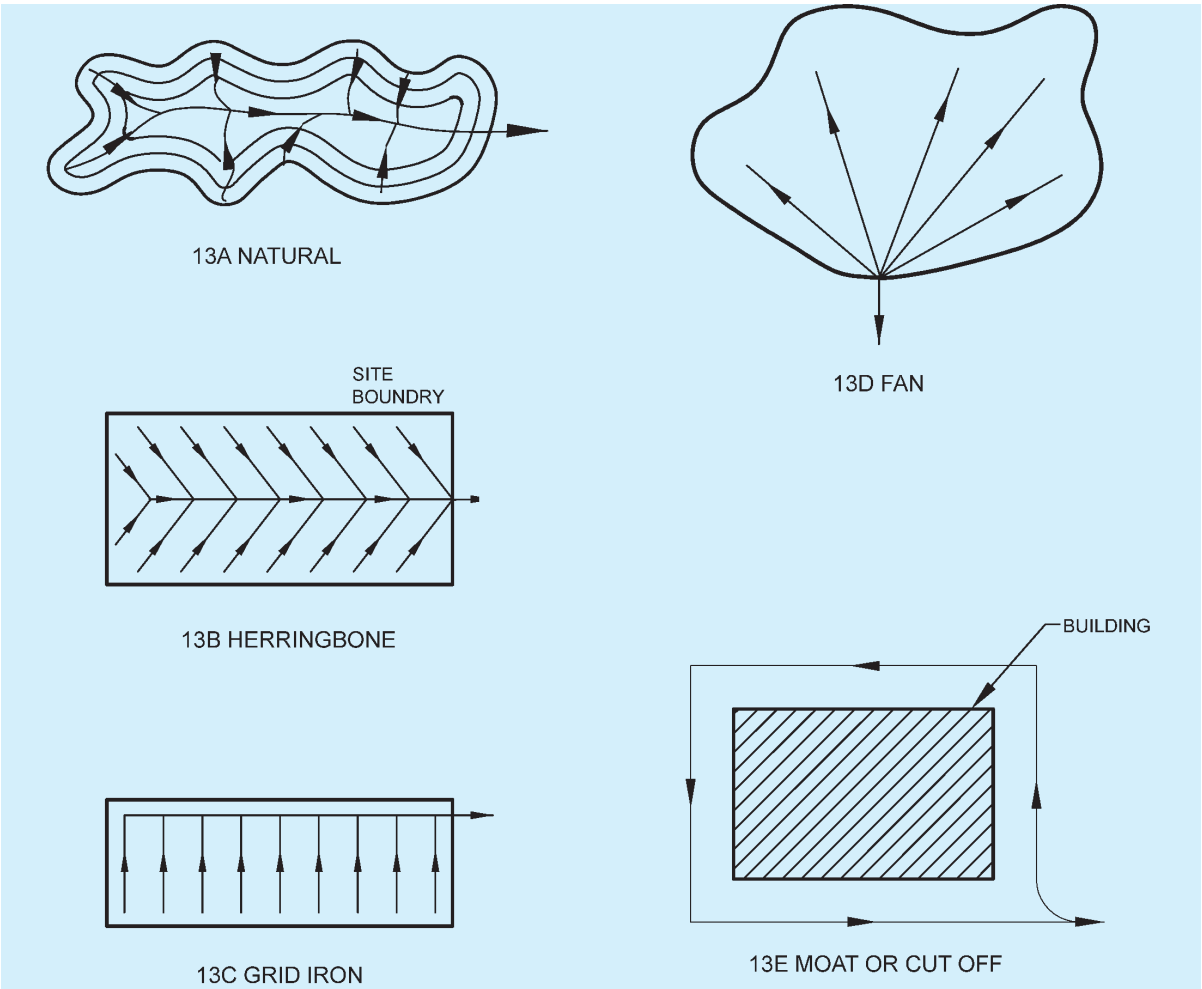


FIG. 13 DETAILS OF SUBSOIL DRAINAGE SYSTEM

4.5.14.2 *Box and can system*

Where box and can systems are employed, adequate arrangements shall be made for the cleaning and disinfection of the can after it is emptied of its contents. The excrement from the can shall be disposed of by burial in isolated spots far from habitation or by incineration, where feasible. The can shall be fitted with a tight fitting lid for use when it is carried for emptying.

4.5.14.3 *Trench or pit latrines*

Trench or pit latrines shall be used only where soil and subsoil conditions favour their use. Whenever they are used, they shall not be closer than 18 m from any source of drinking water, such as well, to eliminate the possibility of bacterial pollution of water.

4.5.14.4 *Chemical toilets*

For the successful functioning of chemical toilets, they shall preferably be installed in heated rooms or enclosures.

NOTE — Chemical toilet essentially consists of small cylindrical tanks with a water-closer seat for the use of 8 to 10 persons. A ventilation pipe is fitted to the seat. A strong solution of caustic soda is used as a disinfectant. It kills bacteria, liquefies the solids and thus checks the decomposition of organic matter. The tank is provided with a drain plug for which liquid runs to a soak pit at the time of disposal.

4.5.14.5 *Water-borne sanitation systems*

Water-borne sanitation systems shall be used, where practicable. Sanitation systems for the collection of sewage should be constructed in such a manner that maximum heat is retained by insulation, if necessary.

4.5.14.5.1 *Sewerage laying*

Under normal circumstances, sewers shall be laid below the frost line. Manholes shall be made of air-tight construction so as to prevent the cold air from gaining access inside and freezing the contents. The trenches for sewers shall be loosely filled with earth after laying sewers, since loose soil is a better insulator than compacted soil. Consequently, sewers laid under traffic ways and other places where soil compaction may be

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expected are required to be given adequate insulation. Where feasible, sewers shall be so located that the trench line is not in shadow, when the sun is shining. Concrete, cast iron and stoneware pipes conduct heat relatively rapidly and as such should be adequately insulated.

4.5.14.5.2 *Septic tanks*

Septic tanks can function only when it can be ensured that the contents inside these do not freeze at low temperature. For this purpose, the septic tanks shall be located well below the frost line. The location of manhole openings shall be marked by staves. Fencing around the septic tanks shall be provided for discouraging traffic over them. As the rate of biological activity is reduced by 50 percent for every 10°C fall in temperature, the capacity of septic tanks shall be increased by 100 percent for operation at 10°C over that for operation at 20°C.

The construction of septic tanks is preferred in rural and fringe areas of suburban and isolated buildings where underground system may neither be feasible nor economical. Septic tanks are only recommended for small communities and institutions whose contributory population does not exceed 300.

For other details, *see* good practice [9-2(9)].

4.5.14.5.3 *Seepage pits*

Seepage pits can function only when the soil and subsoil conditions are favourable. Frozen soil extending to a great depth would preclude the use of such disposal devices in view of the lower water absorption capacity. The discharge of effluent should be made below the frost line.

4.5.14.5.4 *Sewage treatment plants*

Suitable design modifications for sedimentation, chemical and biological processes shall be applied to sewage treatment plants for satisfactory functioning (*see also* **4.13**).

NOTE — Lavatories and bathrooms shall be kept heated to avoid freezing of water inside traps and flushing cisterns.

4.6 Construction Relating to Conveyance of Sanitary Wastes

4.6.1 *Excavation*

4.6.1.1 *General*

The safety precautions as given in Part 7 'Construction Management, Practices and Safety' of the Code shall be ensured.

4.6.1.2 Turf, topsoil or other surface material shall be set aside, turf being carefully rolled and stacked for use in reinstatement. All suitable broken surface material and hard-core shall be set on one side for use in subsequent reinstatement.

4.6.1.3 Excavated material shall be stacked sufficiently away from the edge of the trench and the size of the spoil bank shall not be allowed to become such as to endanger the stability of the excavation. Spoil may be carried away and used for filling the trench behind the work.

4.6.1.4 Excavation shall proceed to within about 75 mm of the finished formation level. This final 75 mm is to be trimmed and removed as a separate operation immediately prior to the laying of the pipes or their foundations.

4.6.1.5 Unless specified otherwise by the Authority, the width at bottom of trenches for pipes of different diameters laid at different depths shall be as given below:

a) For all diameters, up to an average depth of 1 200 mm,
   Width of trench, in mm = Diameter of pipe + 300 mm;
b) For all diameters for depths above 1 200 mm,
   Width of trench, in mm = Diameter of pipe + 400 mm; and
c) Notwithstanding (a) and (b), the total width of trench at the top should not be less than 750 mm for depths exceeding 900 mm.

4.6.1.6 Excavation in roads shall be so arranged, in agreement with the proper authority, as to cause the minimum obstruction to traffic. The methods to be adopted shall depend on local circumstances.

4.6.1.7 All pipes, ducts, cables, mains or other services exposed in the trench shall be effectively supported by timber and/or chain or rope-slings.

4.6.1.8 All drainage sumps shall be sunk clear of the work outside the trench or at the sides of manholes. After the completion of the work, any pipes or drains leading to such sumps or temporary subsoil drains under permanent work shall be filled in properly with sand and consolidated.

4.6.2 *Laying of Pipes*

Laying of pipes shall be done in accordance with good practice [9-2(19)].

4.6.3 *Jointing*

All soil pipes, waste pipes, vent pipes and other such pipes above ground shall be gas-tight. All sewers and drains laid below the ground shall be water-tight. Jointing shall be done in accordance with good practice [9-2(19)].

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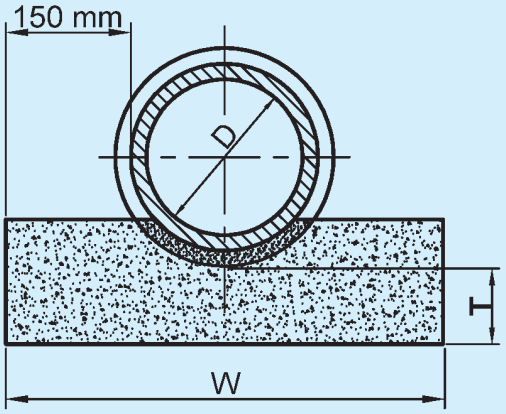
4.6.4 *Support or Protection for Pipes*

4.6.4.1 *General*

It may be necessary to support or surround pipe sewers or drains by means of concrete in certain circumstances. Some of the suggested methods are given in **4.6.4.2** to **4.6.4.4**.

4.6.4.2 *Bedding*

Bedding (*see* Fig. 14) shall be rectangular in section and shall extend laterally at least 150 mm beyond and on both sides of the projection of the barrel of the pipe. The thickness of the concrete below the barrel of the pipe shall be not less than 100 mm for pipes under 150 mm diameter and 150 mm for pipes 150 mm and over in diameter. Where bedding is used alone, the concrete shall be brought up at least to the invert level of the pipe to form a cradle and to avoid line contact between the pipe and the bed.



$W = D + 300$ mm

where

D = external diameter of the pipe.

$$T = \begin{cases} \text{100 mm for pipes under 150 mm nominal dia.} \\ \text{150 mm for pipes of 150 mm nominal dia and over.} \end{cases}$$

FIG. 14 BEDDING

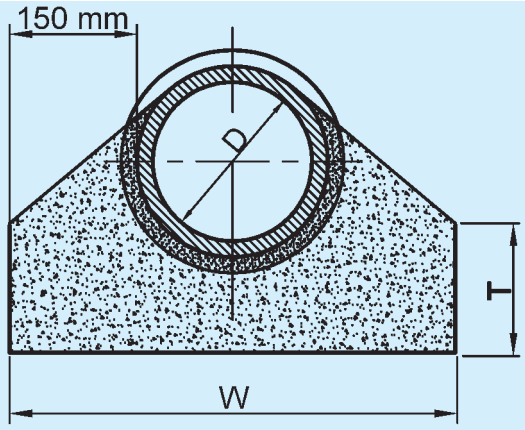
4.6.4.3 *Haunching*

Concrete haunching (*see* Fig. 15) shall consist of,

a) a concrete bed as described for bedding (*see* **4.6.4.2**);

b) the full width of the bed carried up to the level of the horizontal diameter of the pipe; and

c) splays from this level carried up on both sides of the pipe, from the full width of the bed to meet the pipe barrel tangentially.



$W = D + 300$ mm

where

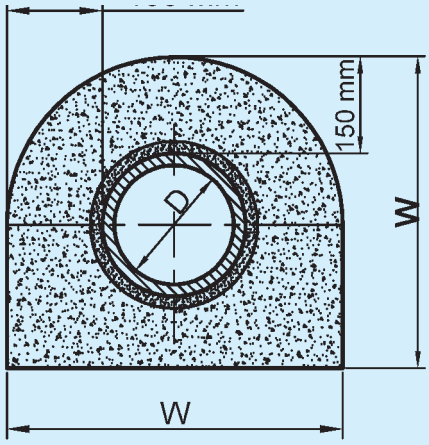
D = external diameter of the pipe.

$$T = \begin{cases} \text{100 mm for pipes under 150 mm nominal dia.} \\ \text{150 mm for pipes of 150 mm nominal dia and over.} \end{cases}$$

FIG. 15 HAUNCHING

4.6.4.4 *Surround or encasing*

The surround or encasing (*see* Fig. 16) shall be similar to haunching up to the horizontal diameter of the pipe and the top portion over this shall be finished in a semicircular form to give a uniform encasing for the top half of the pipe.



$W = D + 300$ mm

where

D = external diameter of the pipe.

FIG. 16 SURROUND OR ENCASING

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4.6.5 *Connection to Existing Sewers*

The connection to an existing sewer shall, as far as possible, be done at the manholes. Where it is unavoidable to make connection in between two manholes, the work of breaking into the existing sewer and forming the connection shall be carried out by the Authority or under its supervision.

4.6.5.1 Breaking into the sewer shall be effected by the cautious enlargement of a small hole and every precaution shall be taken to prevent any material from entering the sewer. No connection shall be formed in such a way as to constitute a projection into the sewer or to cause any diminution in its effective size.

4.6.6 *Back Filling*

4.6.6.1 Filling of the trench shall not be commenced until the length of pipes therein has been tested and passed (*see* **4.10.2**).

4.6.6.2 All timber which may be withdrawn with safety shall be removed as filling proceeds.

4.6.6.3 Where the pipes are unprotected by concrete haunching, the first operation in filling shall be carefully done to hand-pack and tamp selected fine material around the lower half of the pipes so as to buttress them to the sides of the trench.

4.6.6.4 The filling shall then be continued to 150 mm over the top of the pipe using selected fine hand-packed material, watered and rammed on both sides of the pipe with a wooden rammer. On no account shall material be tipped into the trench until the first 150 mm of filling has been completed. The process of filling and tamping shall proceed evenly so as to maintain an equal pressure on both sides of the pipeline.

4.6.6.5 Filling shall be continued in layers not exceeding 150 mm in thickness, each layer being watered and well rammed.

4.6.6.6 In roads, surface materials previously excavated shall be replaced as the top layer of the filling, consolidated and maintained satisfactorily till the permanent reinstatement of the surface is made by the Authority.

4.6.6.7 In gardens, the top soil and turf, if any, shall be carefully replaced.

4.7 Construction Relating to Conveyance of Rain or Storm Water

4.7.1 *Roof Gutters*

Roof gutters shall be of any material of suitable thickness. All junctions and joints shall be water-tight.

4.7.2 *RainWater Pipes*

Rainwater pipes shall conform to the accepted standards [9-2(20)].

4.7.3 *Subsoil Drain Pipes*

4.7.3.1 *Field drain pipes*

Suitable pipes for this purpose are plain cylindrical glazed water pipes, or concrete porous pipes, though the latter may prove unsuitable where subsoil water carries sulphates or is acidic owing to the presence of peat. Trenches for these pipes need be just wide enough at the bottom to permit laying the pipes, which shall be laid with open joints to proper lines and gradients.

It is advisable to cover the pipes with clinker free from fine ash, brick ballast or other suitable rubble, or a layer of inverted turf, brush-wood or straw before refilling the trench, in order to prevent the infiltration of silt through the open joints. Where the subsoil drain is also to serve the purpose of collecting surface water, the rubble shall be carried up to a suitable level and when required for a lawn or playing field, the remainder of the trench shall be filled with pervious top soil. When refilling the trenches, care shall be taken to prevent displacement of pipes in line of levels. When they pass near trees or through hedges, socket pipes with cement or bitumen joints shall be used to prevent penetration by roots.

4.7.3.2 *French drain*

A shallow trench is excavated, the bottom neatly trimmed to the gradient and the trench filled with broken stone, gravel or clinker, coarse at the bottom and finer towards the top.

4.8 Selection and Installation of Sanitary Appliances

Selection, installation and maintenance of sanitary appliances shall be done in accordance with good practice [9-2(21)].

4.9 Refuse Chute System

The refuse chute system provided shall be in accordance with Part 9 'Plumbing Services, Section 3 Solid Waste Management' of the Code.

4.10 Inspection and Testing

4.10.1 *Inspection*

4.10.1.1 All sanitary appliances and fitments shall be carefully examined for defects before they are installed and also on the completion of the work.

4.10.1.2 Pipes are liable to get damaged in transit and, not withstanding tests that may have been made before despatch, each pipe shall be carefully examined on arrival on the site. Preferably, each pipe shall be rung with a hammer or mallet and those that do not ring true and clear shall be rejected. Sound pipes shall be carefully stored to prevent damage. Any defective pipes shall be segregated, marked in a conspicuous manner and their use in the works prevented.

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4.10.1.3 Cast iron pipes shall be carefully examined for damage to the protective coating. Minor damage shall be made good by painting over with hot tar or preferably bitumen. But if major defects in coating exist, the pipes shall not be used unless recoated. Each pipe shall be carefully re-examined for soundness before laying.

4.10.1.4 Close inspection shall be maintained at every stage in the work, particularly as to the adequacy of timber supports used in excavation and the care and thoroughness exercised in filling.

4.10.1.4.1 Careful note shall be kept of the condition of any sewer, manhole or other existing work which may be uncovered and any defects evident shall be pointed out immediately to the Authority.

4.10.1.4.2 No work shall be covered over or surrounded with concrete until it has been inspected and approved by the Authority.

4.10.2 *Testing*

4.10.2.1 Comprehensive tests of all appliances shall be made by simulating conditions of use. Overflow shall be examined for obstructions.

4.10.2.2 *Smoke test*

All soil pipes, waste pipes, and vent pipes and all other pipes when above ground shall be approved gas-tight by a smoke test conducted under a pressure of 25 mm of water and maintained for 15 min after all trap seals have been filled with water. The smoke is produced by burning only waste or tar paper or similar material in the combustion chamber of a smoke machine. Chemical smokes are not satisfactory.

4.10.2.3 *Water test*

4.10.2.3.1 *For pipes other than cast iron*

Glazed and concrete pipes shall be subjected to a test pressure of at least 1.5 m head of water at the highest point of the section under test. The tolerance figure of 2 litre/cm of diameter/km may be allowed during a period of 10 min. The test shall be carried out by suitably plugging the low end of the drain and the ends of connections, if any, and filling the system with water. A knuckle bend shall be temporarily jointed in at the top end and a sufficient length of the vertical pipe jointed to it so as to provide the required test head, or the top end may be plugged with a connection to a hose ending in a funnel which could be raised or lowered till the required head is obtained and fixed suitably for observation.

Subsidence of the test water may be due to one or more of the following causes:

a) Absorption by pipes and joints;

b) Sweating of pipes or joints;

c) Leakage at joints or from defective pipes; and

d) Trapped air.

Allowance shall be made for (a) by adding water until absorption has ceased after which the test proper should commence. Any leakage will be visible and the defective part of the work should be cut out and made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good. A slight amount of sweating which is uniform may be overlooked, but excessive sweating from a particular pipe or joint shall be watched for and taken as indicating a defect to be made good.

NOTE — This test will not be applicable to sanitary pipe work above ground level.

4.10.2.3.2 *For cast iron pipes*

Cast iron sewers and drains shall be tested as for glazed and concrete pipes. The drain plug shall be suitably strutted to prevent their being forced out of the pipe during the test.

4.10.2.4 *Tests for straightness and obstruction*

The following tests shall be carried out:

a) By inserting at the high end of the sewer or drain a smooth ball of a diameter 13 mm less than the pipe bore. In the absence of obstruction, such as yarn or mortar projecting through the joints, the ball should roll down the invert of the pipe, and emerge at the lower end; and

b) By means of a mirror at one end of the line and lamp at the other. If the pipeline is straight, the full circle of light may be observed. If the pipe line is not straight, this will be apparent. The mirror will also indicate obstruction in the barrel.

4.10.2.5 *Test records*

Complete records shall be kept of all tests carried out on sewers and drains both during construction and after being put into service.

4.11 Maintenance

4.11.1 *General*

Domestic drainage system shall be inspected at regular intervals. The system shall be thoroughly cleaned out at the same time and any defects discovered shall be made good.

4.11.2 *Cleaning of Drainage System*

4.11.2.1 Sewer maintenance crews, when entering a deep manhole or sewer where dangerous gas or oxygen deficiencies may be present, shall follow the following procedures:

a) Allow no smoking or open flames and guard against parks.

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b) Erect warning signs.

c) Use only safety gas-proof, electric lighting equipment.

d) Test the atmosphere for noxious gases and oxygen deficiencies (presence of hydrogen sulphide is detected using lead acetate paper and that of oxygen by safety lamps).

e) If the atmosphere is normal, workmen may enter with a safety belt attached and with two men available at the top. For extended jobs, the gas tests shall be repeated at frequent intervals, depending on circumstances.

f) If oxygen deficiency or noxious gas is found, the structure shall be ventilated with pure air by keeping open at least one manhole cover each on upstream and downstream side for quick exit of toxic gases or by artificial means. The gas tests shall be repeated and the atmosphere cleared before entering. Adequate ventilation shall be maintained during this work and the tests repeated frequently.

g) If the gas or oxygen deficiency is present and it is not practicable to ventilate adequately before workers enter, a hose mask shall be worn and extreme care taken to avoid all sources of ignition. Workers shall be taught how to use the hose equipment. In these cases, they shall always use permissible safety lights (not ordinary flash lights), rubber boots or non-sparking shoes and non-sparking tools;

h) Workmen descending a manhole shaft to inspect or clean sewers shall try each ladder step or rung carefully before putting the full weight on it to guard against insecure fastening due to corrosion of the rung at the manhole wall. When work is going on in deep sewers, at least two men shall be available for lifting workers from the manhole in the event of serious injury; and

j) Portable air blowers, for ventilating manhole, are recommended for all tank, pit or manhole work where there is a question as to the presence of noxious gas, vapours or oxygen deficiency. The motors for these shall be of weather proof and flame-proof types; compression ignition diesel type (without sparking plug) may be used. When used, these shall be placed not less than 2 m away from the opening and on the leeward side protected form wind, so that they will not serve as a source of ignition for any inflammable gas which might be present. Provision should be made for ventilation and it should be of the forced type which can be provided by a blower located at ground level with suitable flexible ducting to displace out air from the manhole.

4.11.2.2 The following operations shall be carried out during periodical cleaning of a drainage system:

a) The covers of inspection chambers and manholes shall be removed and the side benching and channels scrubbed;

b) The interceptive trap, if fitted, shall be adequately cleaned and flushed with clean water. Care shall be taken to see that the stopper in the rodding arm is securely replaced;

c) All lengths of main and branch drains shall be rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, the drains shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools and the system thereafter shall be flushed with clean water;

d) The covers of access plates to all gullies shall be removed and the traps plunged and flushed out thoroughly with clean water. Care shall be taken not to flush the gully deposit into the system;

e) Any defects revealed as a result of inspection or test shall be made good;

f) The covers or inspection chambers and gullies shall be replaced, bedding them in suitable grease or other materials; and

g) Painting of ladders/rings in deep manholes and external painting of manhole covers shall be done with approved paints.

4.11.3 All surface water drains shall be periodically rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, they shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools.

4.11.4 All subsoil drains shall be periodically examined for obstruction at the open joints due to the roots of plants or other growths.

4.12 Pumping of Sewage

4.12.1 In the design of sewerage system, it is necessary to collect the sewage of a low lying area at some convenient point from which it shall be lifted by pumps. At the treatment plant also, lifting of sewage may be necessary to provide head for the flow by gravity of sewage.

4.12.2 *Sewage Pump Stations, Sizing of Sumps and Pumps*

They are required as onsite pump stations to cater to drainage from toilets and kitchen. The stations would

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be located in basement floors and leading the sewage to onsite treatment plants. Submersible centrifugal pumps are used for pumping the sewage. The sump capacity depends on effective holding capacity considering the flow from drainage fixtures. Usually, retention period of 15 min is adopted. The size of sump depends on the availability of space. Minimum size of discharge pipe may be 80 mm with a velocity of 1 m/s and pumps are sized for 100 percent design flow.

NOTE — For other details reference to good practice [9-2(12)] shall be made.

4.13 Sewage Treatment Systems

4.13.1 Sewage treatment is the process of removing contaminants from waste water, primarily from household sewage. It includes physical, chemical and biological processes to remove these contaminants and produce environmentally safe treated waste water (or treated effluent).

The by-product of sewage treatment is usually a semisolid waste or slurry, called sewage sludge, that has to undergo further treatment before being suitable for disposal or further application (*see* Fig. 17).

4.13.2 The main objective of treating waste water is to stabilize decomposable organic matter present in the sewage so as to produce treated effluent and sludge, which can be disposed of in the environment without causing health hazards or nuisance.

The microbial population in treatment process can be cultured using the following systems:

a) *Suspended growth system* — In this system, microorganisms remain in suspension and their concentration is related to mixed liquor suspended solids (MLSS).

b) *Attached growth system* — In this system, microorganisms are developed over mobile or immobile solid covered in biomass (slime).

c) *Combined growth system* — In this system, both systems are used to attain the shock loads.

Suspended growth system is generally proposed due to its merits and excellent performance.

4.13.3 *Technologies*

Following technologies for sewage treatment shall be considered based on the requirement:

a) *Extended aeration with activated sludge process (EAASP)* — Activated sludge process is the biological process by which non-settleable substances occurring in dissolved and colloidal forms are converted into settleable sludge which is removed from the liquid carrier (water).

This process is well suitable for completely populated community and does not require skilled labour for handling the plant. It is time tested and requires more number of units to achieve biological oxygen demand (BOD) less than 10 ppm, like coagulants required for better quality.

b) *Sequential batch reactor* (*SBR*) — It is an activated sludge process designed to operate under non-steady state conditions. An SBR operates in a true batch mode with aeration and sludge settlement both occurring in the same tank. There is a degree of flexibility associated with working in a time rather than in a space sequence.

Plant for this process requires less space due to batch process, well suitable for modular growth. It can handle smallest flows and the desired quality can be achieved without coagulants. It requires good quality of decanters, and skilled labour as the process is timer-based automation.

c) *Membrane bio-reactor* (*MBR*) — It is a continuous process of activated sludge treatment, but solids separation is done through pressurised system or through media. As there is physical barrier for solid separation, quality of treatment is good.

It is suitable for any type of growth pattern and can handle smaller flows. It requires less space, and skilled labours to handle.

d) *Rotating bio-bed reactor* (*RBBR*) — It is combined growth process. Bacteria are allowed to grow on media, which is exposed to atmospheric air. It is also known as rotating biological contactor (RBC).

It is suitable for smaller capacities and does not require skilled labour to handle. The quality of treatment is good.

e) *Fluidized bio-bed reactor* (*FBBR*) — In this process, cells are immobilized in small particles which move with the fluid. The small particles create a large surface area for cells to stick and enable a high rate of transfer of oxygen and nutrients to the cells. It is also known as moving bed bio reactor (MBBR). It is suitable for all type of communities, does not require skilled labour and requires less space. It can be installed for all capacities and the quality of treatment is good.

f) *Submerged aerobic fixed film reactor (SAFF)* — It is a combined growth process in

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which bio-media is fixed and bacteria are allowed to grow on media, which has air supply from below.

It does not require skilled labour. Supporting structure for media should be anti-corrosive to enable media fixing.

g) *Trickling filters* — It is an attached growth process where media is used to grow bacteria by trickling sewage over the media. It is an old concept and is not now widely used.

h) *Oxidation ponds/lagoons* — Oxidation ponds, also called lagoons or stabilization ponds are large shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae.

4.14 Treatment of Waste Water and Usage of Recycled Water

See **4.2.4** of Part 9 'Plumbing Services, Section 1 Water Supply' of the Code.

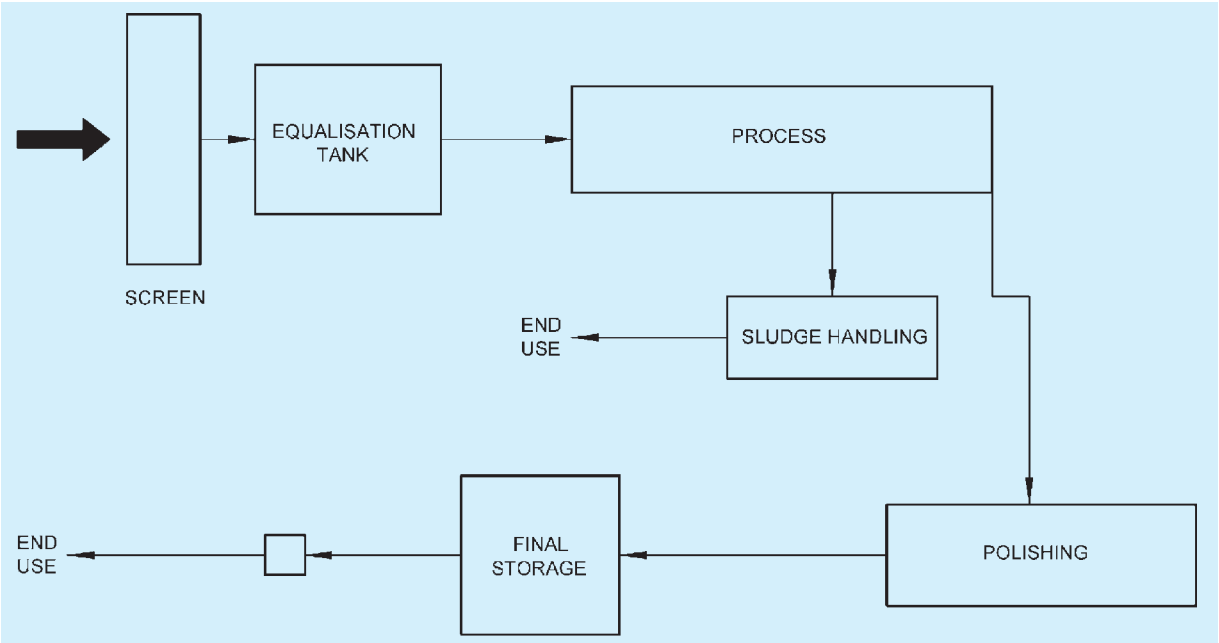


FIG. 17 TYPICAL SCHEME FOR SEWAGE TREATMENT

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ANNEX A

(*Clause* 3.2.1)

APPLICATION FOR DRAINAGE OF PREMISES

I/We hereby make application to the *…… …… for permission to drain the premises……Ward No……..Street No…… Road/Street known as…… ……

The sanitary arrangement and drains of the said premises are shown in the accompanying plans and a description of the specification of the work/material used is also appended (*see* Annex B).

I/We undertake to carry out the work in accordance with Part 9 'Plumbing services, Section 2 Drainage and sanitation' of the National Building Code of India.

……...	……
Signature of the licensed/registered plumber	Signature of the owner
Name and address of the	Name and address……
……	…….
……	…….
Date……..	Date……

NOTE — The application should be signed by the owner of the premises and shall be countersigned by the licensed/registered plumber.

* Insert the name of the Authority.

ANNEX B

(*Clause* 3.2.3.2)

FORM FOR DETAILED DESCRIPTION OF WORK AND SPECIFICATION OF MATERIALS

1) Separation of rainwater and foul water .....
2) Rainwater drains, curbs and points of discharge .....
3) Rainwater gutters, pipes or spouts where discharging .....
4) Open-full-water drains, materials, sizes, curbs and other means places, verandahs, latrines
5) Silt-catcher and grating, size and position .....
6) Drains .....
   a) Main sewage drains: Fall ……..
      Size ……..
   b) Branch drains : Fall ……..
      Size ……
   c) Materials……
   d) Method of jointing……

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ANNEX B — (*Continued*)

7) Bedding of pipes:
   a) Method of bedding .....
   b) Thickness and width of beds of concrete .....
   c) Thickness of concrete round pipes .....
8) Protection of drain laid under wall .....
9) Traps, description and intercepter:
   a) Lavatory waste pipes .....
   b) Bath waste pipes .....
   c) Sink .....
   d) Gully-traps .....
   e) Water closet traps .....
   f) Grease traps .....
   g) Slop sink .....
   h) Urinal .....
   j) Others .....
10) Manholes and inspection chambers:
   a) Thickness of walls .....
   b) Description of bricks .....
   c) Description of rendering .....
   d) Description of invert channels .....
   e) Depth of chambers .....
   f) Size and description of cover and manner of fixing .....
11) Ventilation of drain:
   a) Position — Height above nearest ground level .....
   b) Outlet shaft position of terminal at top .....
12) Soil pipe, waste pipe and vent pipe connections:
   a) Lead and iron pipes .....
   b) Lead pipe of trap with cast iron pipe .....
   c) Stoneware pipe or trap with lead pipe .....
   d) Lead soil pipe or trap with stoneware pipe or trap .....
   e) Cast iron pipe with stoneware drain .....
   f) Stoneware trap with cast iron soil pipe .....
13) Ventilation of water closet trap sink, lavatory and other traps material and supports.
14) Water closets (apartments):
   a)
      1) At or above ground level .....
      2) Approached from .....
      3) Floor material .....
      4) Floor fall towards door .....
      5) Size of window opening in wall made to open .....
      6) Position of same .....
      7) Means of constant ventilation .....
      8) Position of same .....

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b) Water closet apparatus:

1) Description of pan, basin, etc .....
2) Kind .....
3) Flushing cistern .....
4) Material of flushing pipe .....
5) Internal diameter .....
6) Union with basin .....

15) Sanitary fittings, water storage tank, etc:

a) Number and description of sanitary fittings in room and rooms in which they are to be installed .
b) Capacity and position of water storage tanks .....
c) Size and number of draw off taps and whether taken off storage tanks or direct from main supply
d) Details of draw off taps, that is, whether they are of plain screw down pattern or 'waste not' and description of any other sanitary work to be carried out not included under above headings .....

16) Depth of sewer below surface of street……...

17) Level of invert of house drain at point of junction:

a) With sewer .....
b) Level of invert of sewer at point of junction with house drain .....
c) Distance of nearest manhole on sewer from the point at which the drain leaves the premises .....

18) Schedule of pipes:

Description of Pipe/Drain	*Materials*	*Diameter*	*Weight*	*Method of Jointing*
Subsoil drains				
Main sewage drains				
Branch sewage drains				
Soil pipes				
Vent pipes other than soil pipes				
Waste pipes				
Rainwater pipes				
Anti-syphon pipes				

Signature of the licensed/registered plumber .....

Name and address of the licensed/registered plumber .....

.....

.....

.....

Date .....

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ANNEX C

(*Clause* 3.2.5)

FORM FOR LICENSED/REGISTERED PLUMBER'S COMPLETION CERTIFICATE

Certified that I/we have completed the plumbing work of drainage and sanitation system for the premises as detailed below. This may be inspected, approved and connection given.

Ward No .....

Street .....

Locality .....

Block No .....

House No .....

Details of work .....

.....

.....

The work was sanctioned by the Authority*

vide

…….	…….
Signature of the owner	Signature of the licensed/registered plumber
Name and address……	Name and address ……
…….	……..

Date……

The Authority's Report

Certified that the plumbing work of drainage and sanitation system for the premises, have been laid, applied, executed in accordance with Part 9 'Plumbing services, Section 2 Drainage and sanitation' of the National Building Code of India.

Drainage Connection to the main sewer will be made on…….....

Date…… The Authority…….....

* Insert the name of the Authority.

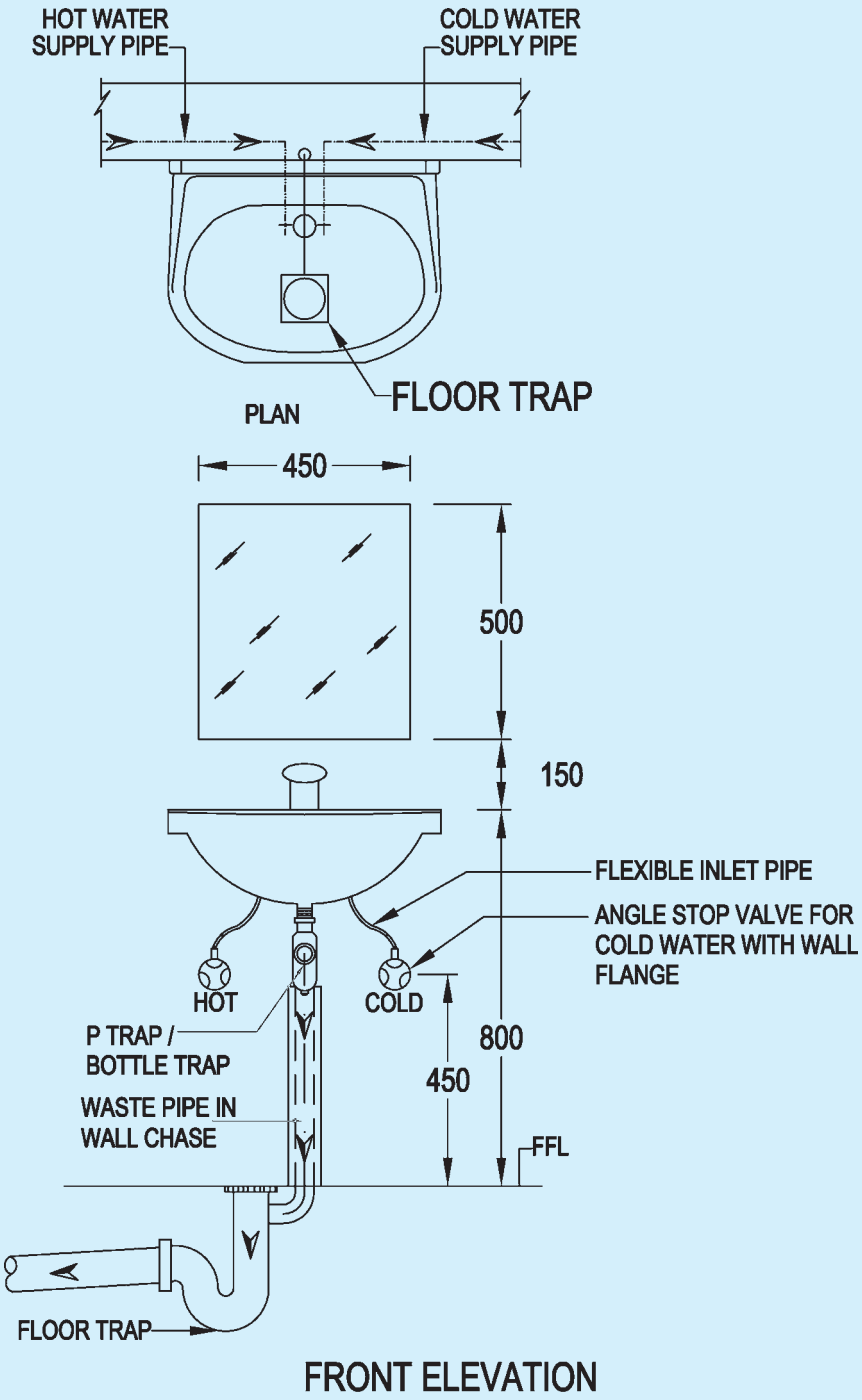
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ANNEX D

(*Clause* 4.5.1.4)

TYPICAL MOUNTING ARRANGEMENTS FOR VARIOUS PLUMBING FIXTURES, INCLUDING DRAINAGE SYSTEMS AND VENTILATION

D-1 ARRANGEMENT FOR RECTANGULAR WASH BASIN

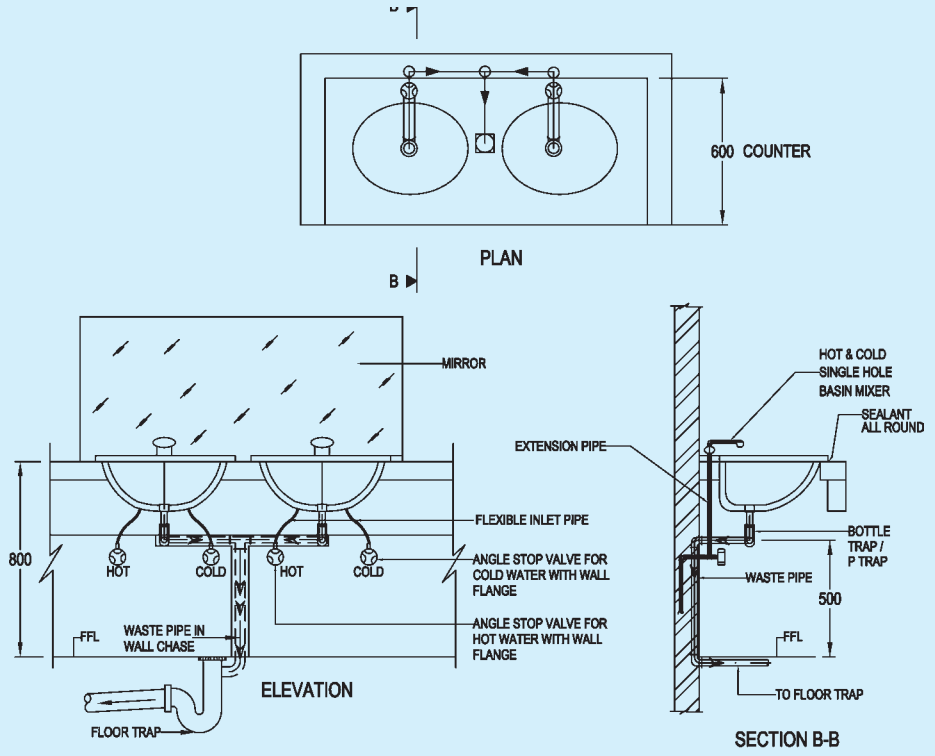


All dimensions in millimetres.

FIG. 18 RECTANGULAR WASH BASIN

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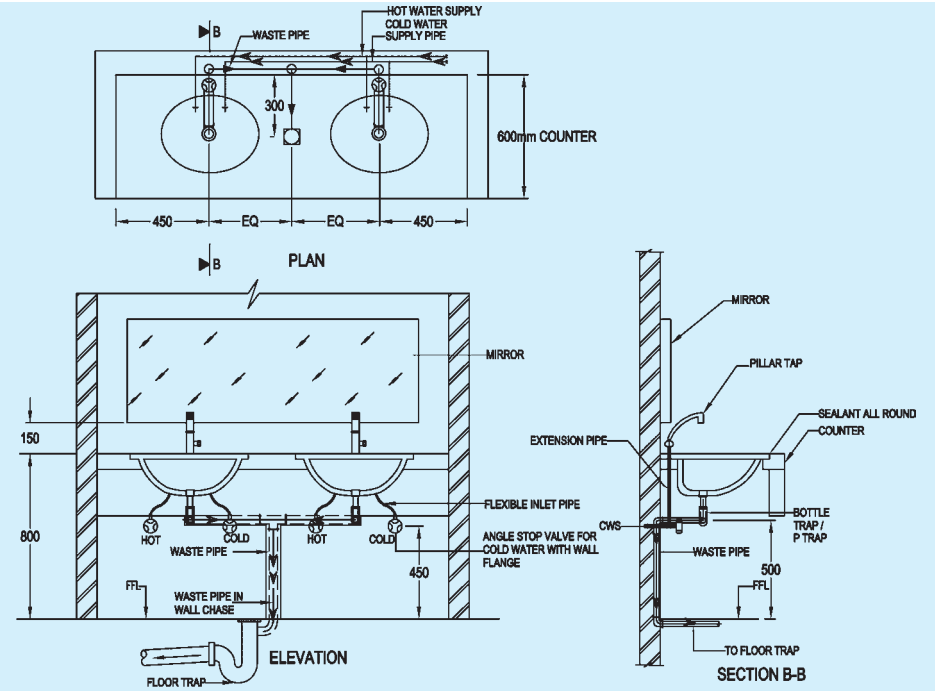
D-2 ARRANGEMENT FOR OVAL WASHBASIN (ABOVE COUNTER)



All dimensions in millimetres.

FIG. 19 OVAL WASH BASIN (ABOVE COUNTER)

D-3 ARRANGEMENT FOR OVAL WASHBASIN (BELOW COUNTER)

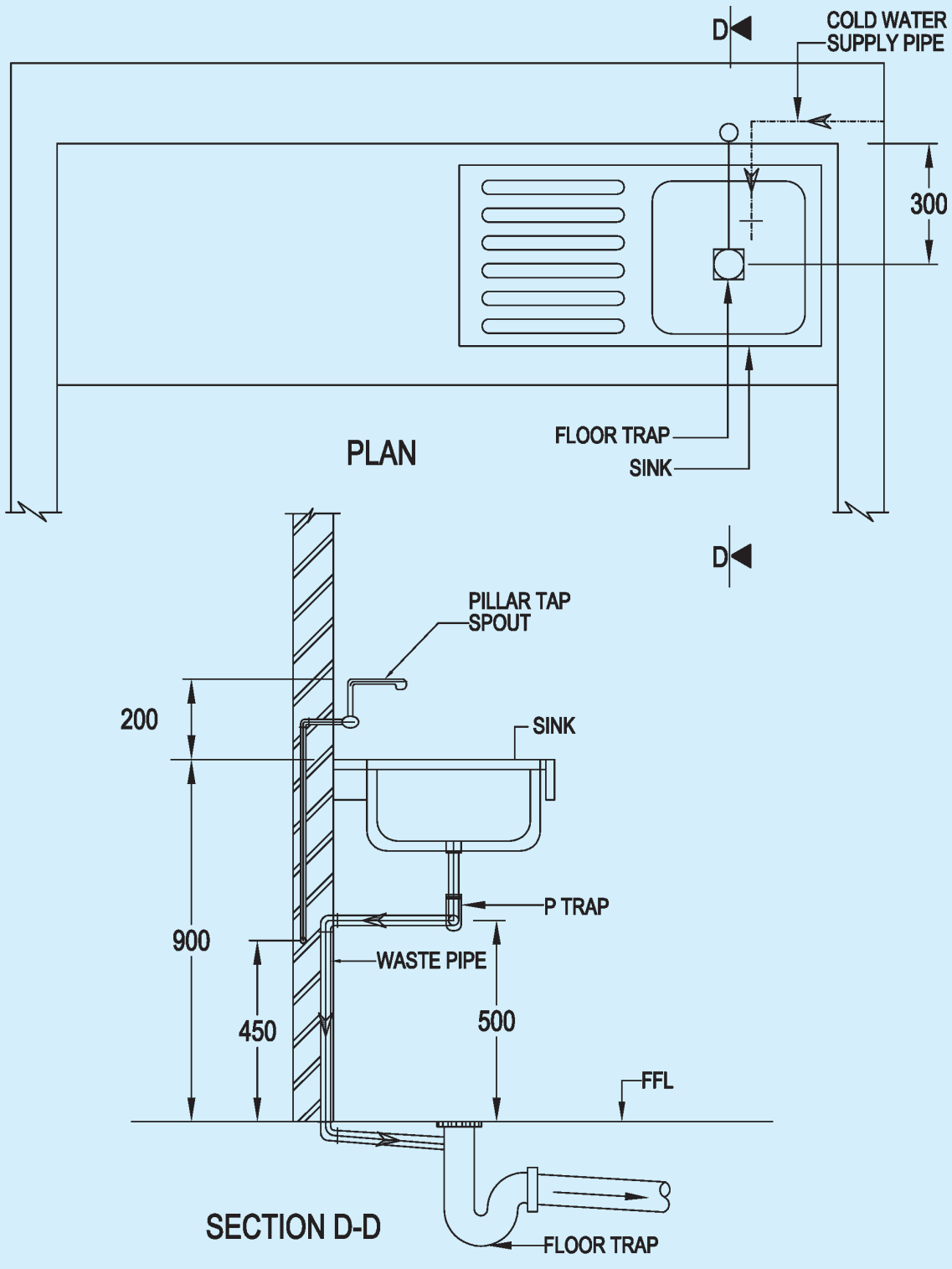


All dimensions in millimetres.

FIG. 20 OVAL WASH BASIN (BELOW COUNTER)

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D-4 ARRANGEMENT FOR SINK

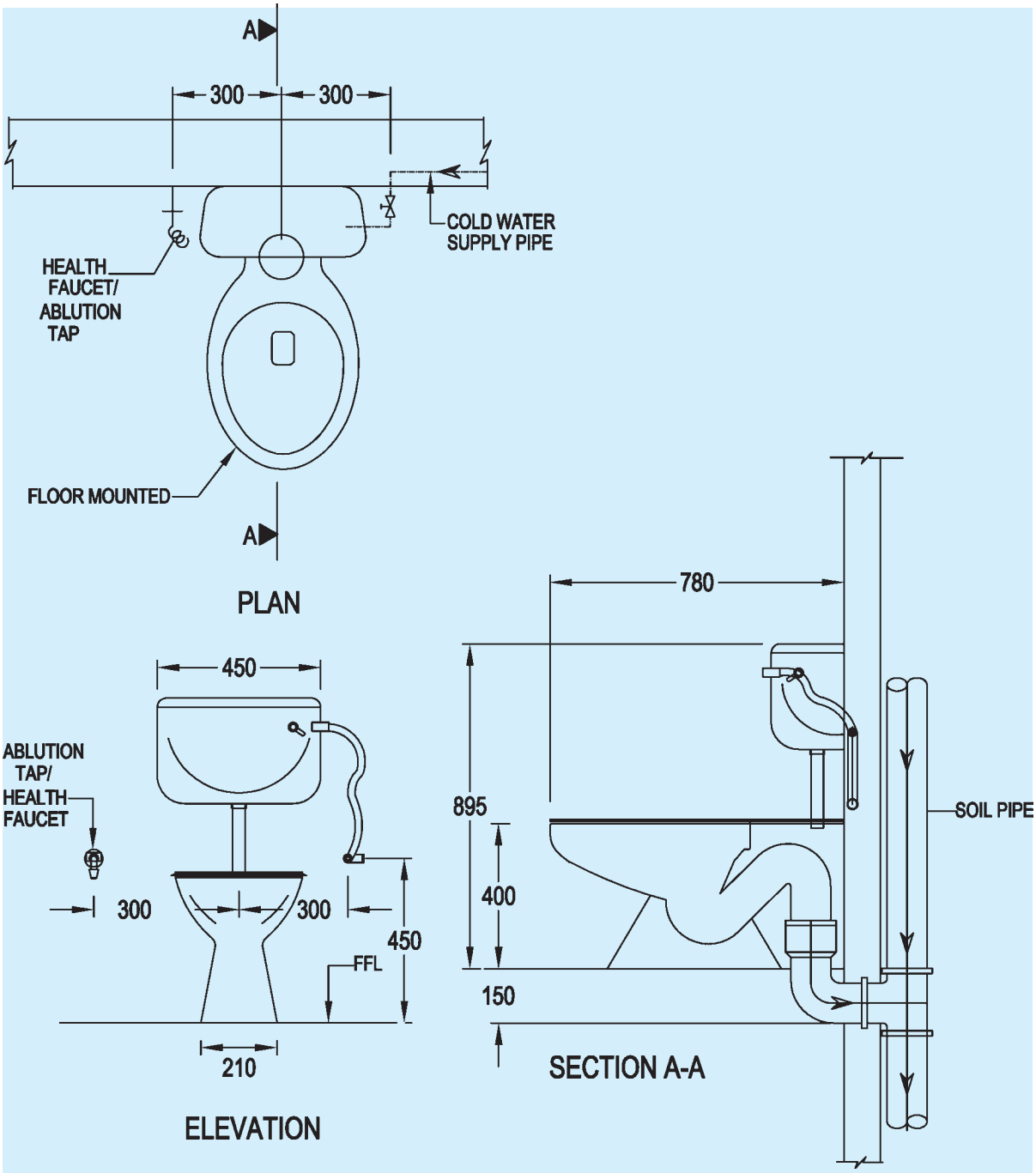


All dimensions in millimetres.

FIG. 21 SINK

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D-5 ARRANGEMENT FOR EUROPEAN WATER CLOSET (FLOOR MOUNTED WITH FLUSH TANK AND S-TRAP)

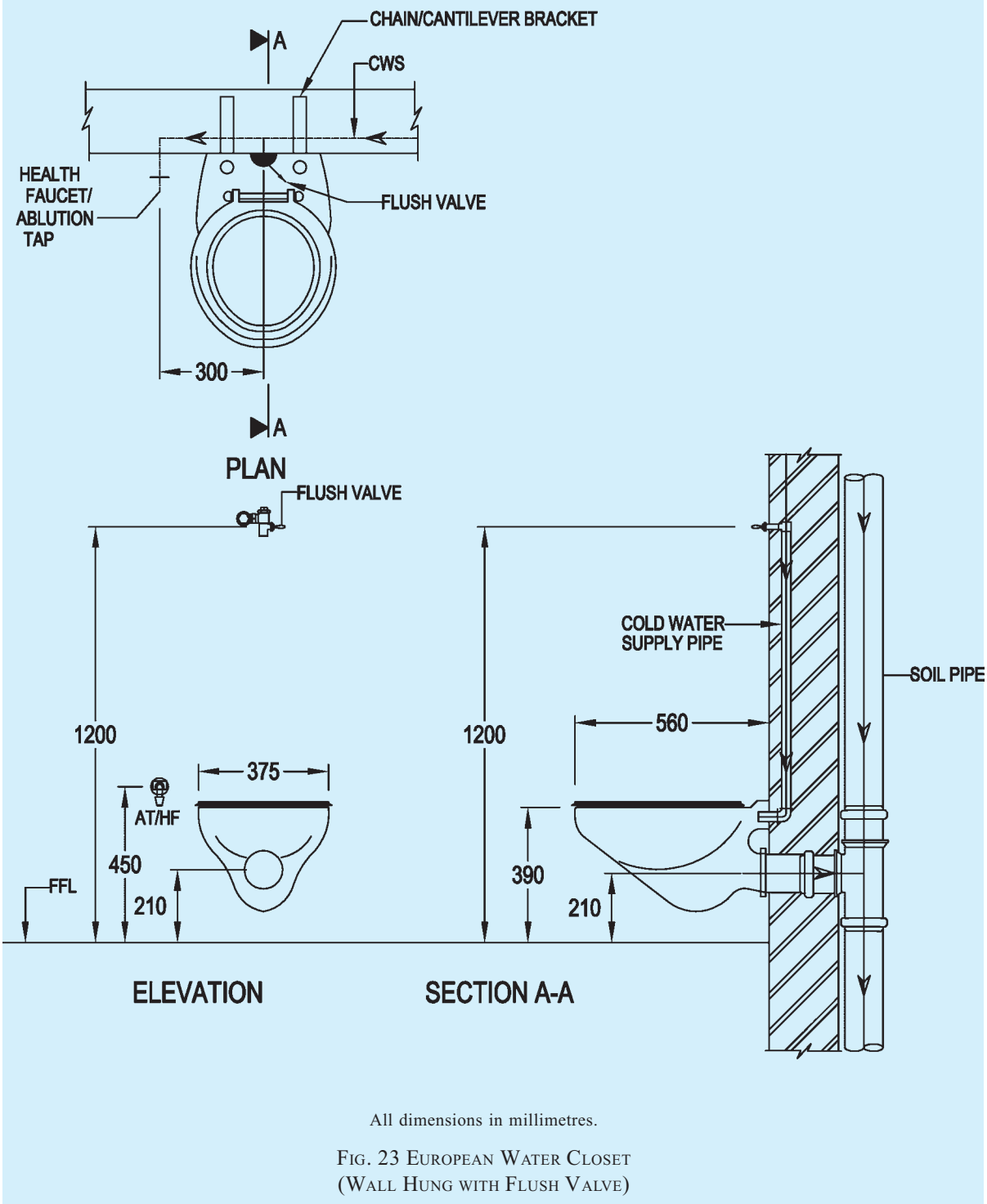


All dimensions in millimetres.

FIG. 22 EUROPEAN WATER CLOSET
(FLOOR MOUNTED WITH FLUSH TANK AND S-TRAP)

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D-6 ARRANGEMENT FOR EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSH VALVE)

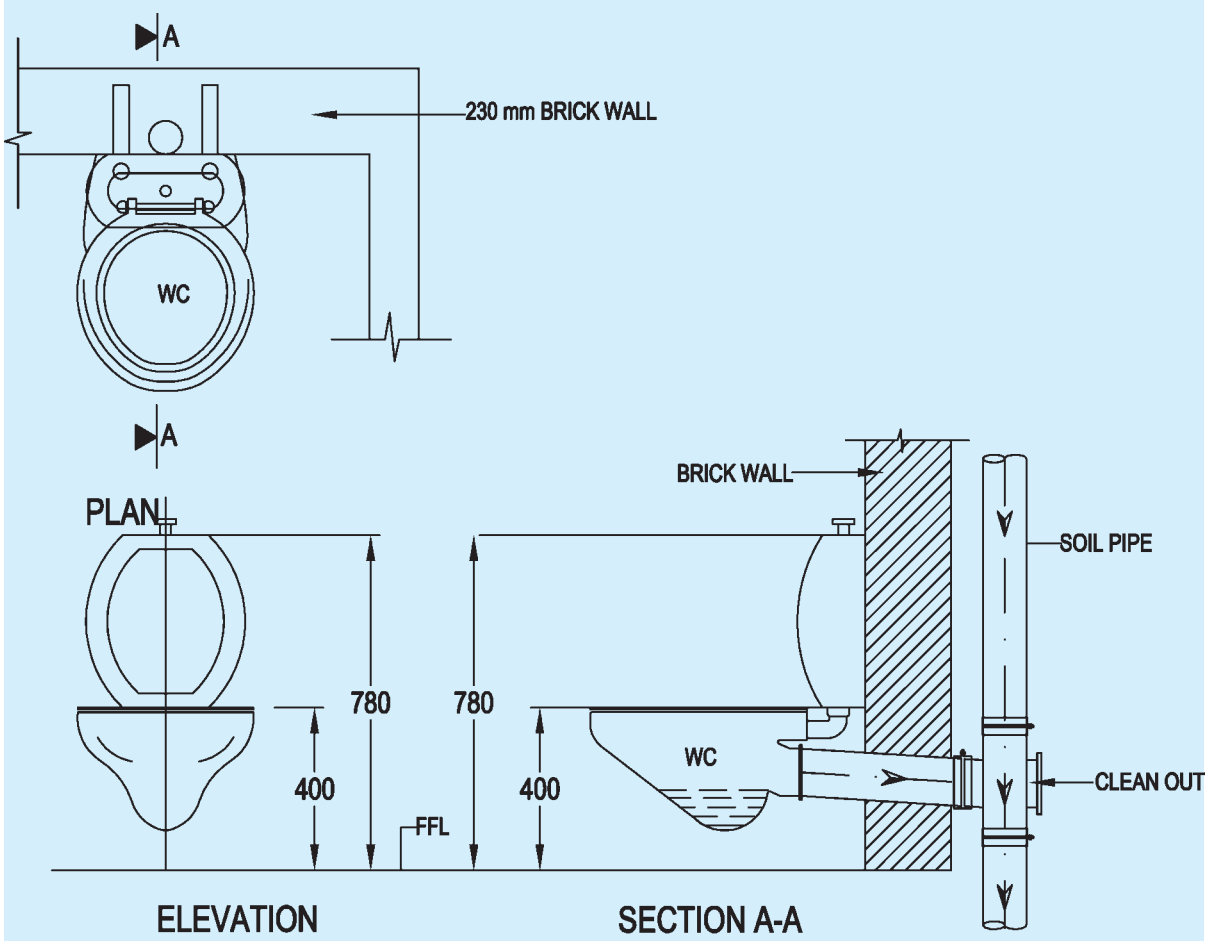


All dimensions in millimetres.

FIG. 23 EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSH VALVE)

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D-7 ARRANGEMENT FOR EUROPEAN WATER CLOSET (WALL HUNG WITH FLUSHING CISTERN)

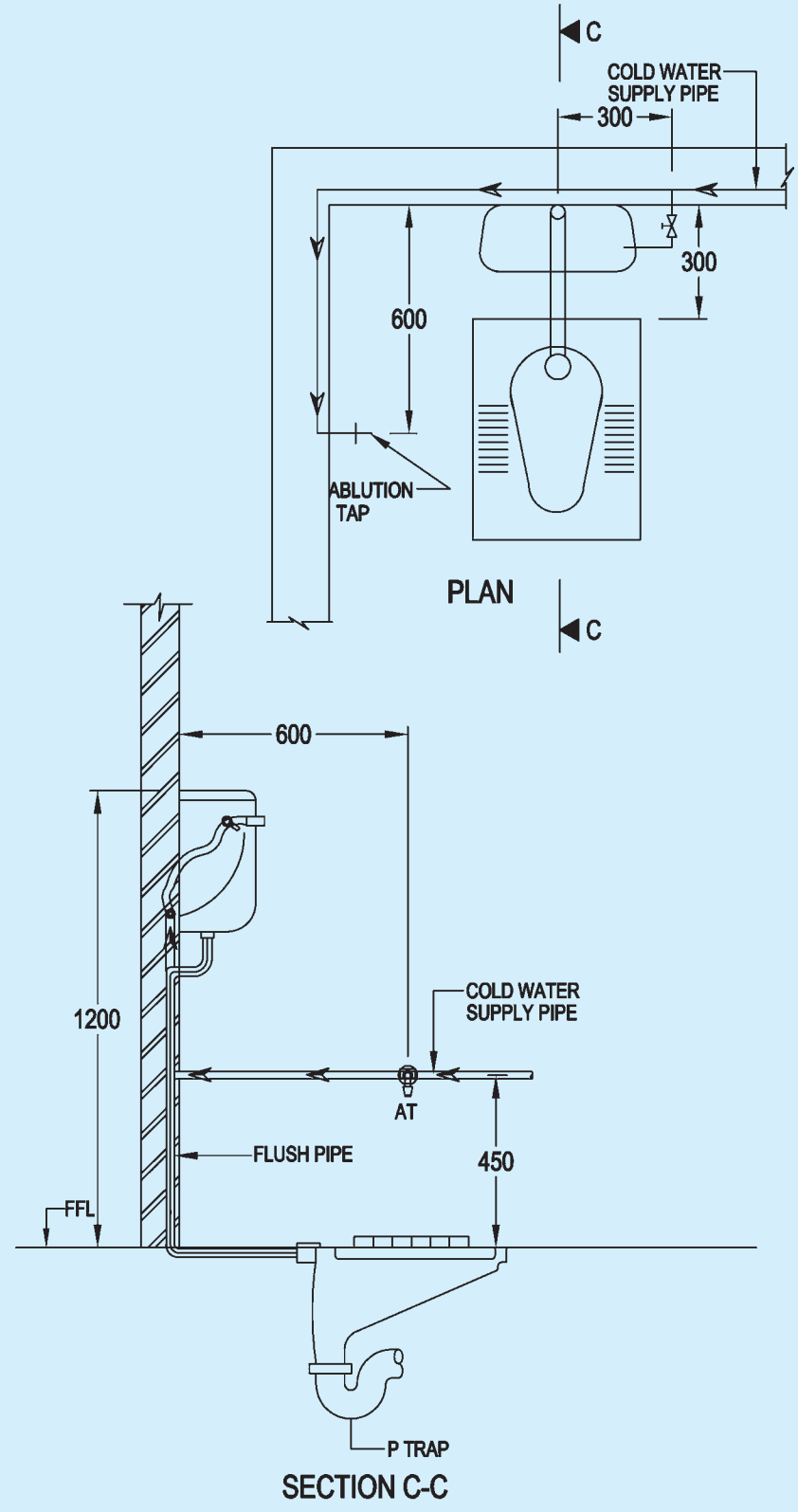


All dimensions in millimetres.

FIG. 24 EUROPEAN WATER CLOSET
(WALL HUNG WITH FLUSHING CISTERN)

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D-8 ARRANGEMENT FOR ORISSA PAN INDIAN WATER CLOSET

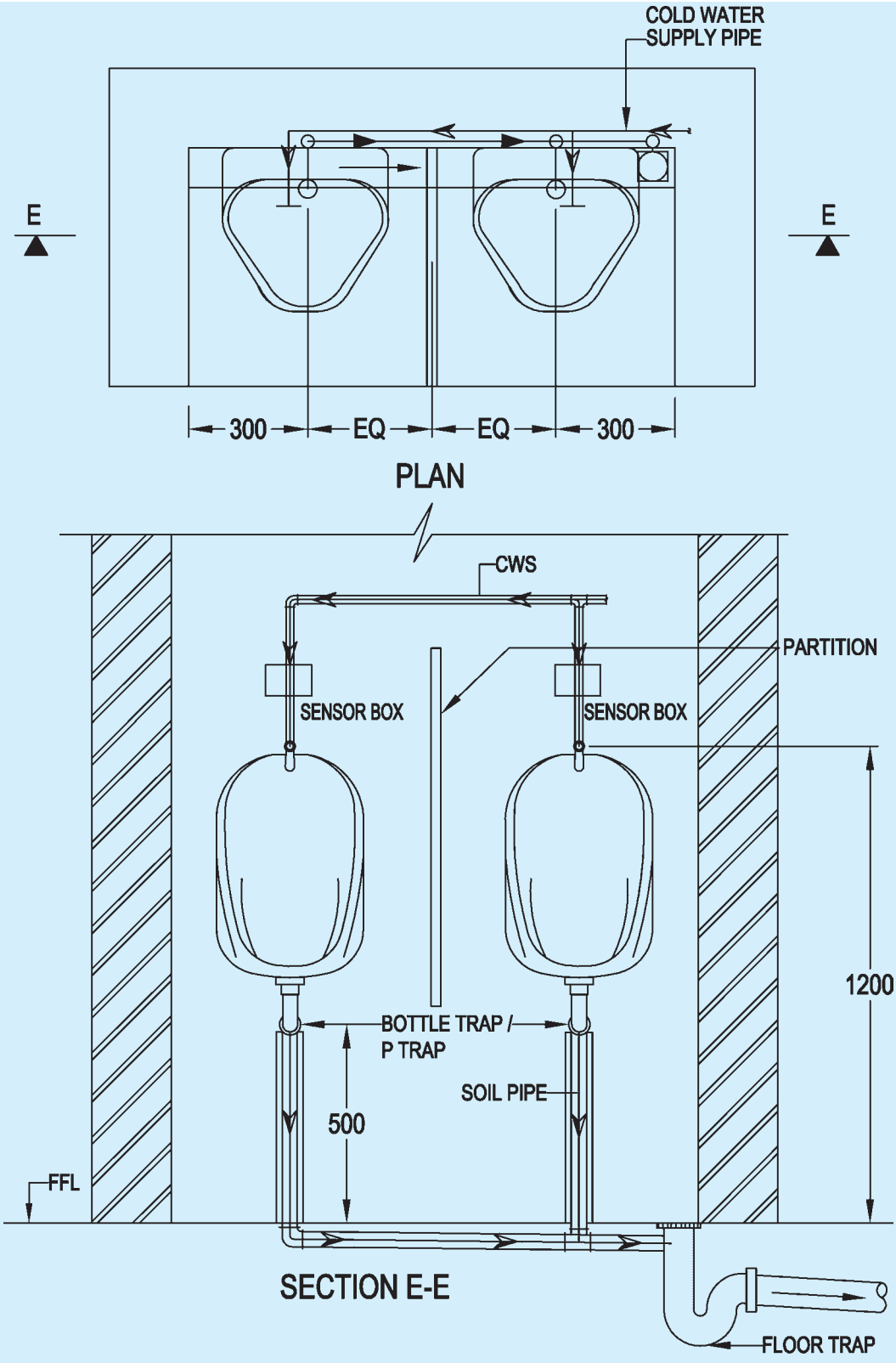


All dimensions in millimetres.

FIG. 25 ORISSA PAN INDIAN WATER CLOSET

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D-9 ARRANGEMENT FOR URINAL

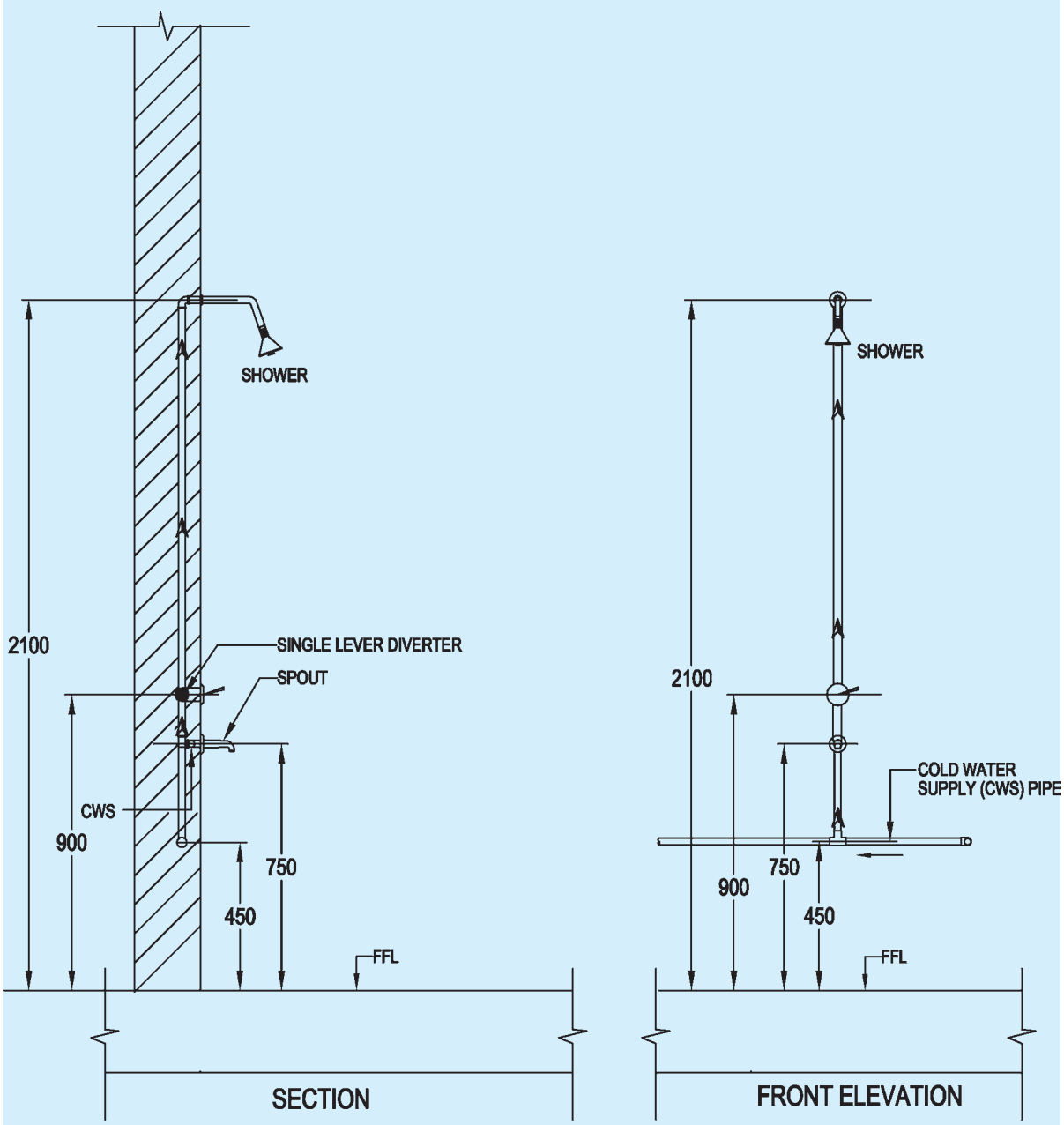


All dimensions in millimetres.

FIG. 26 URINAL

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D-10 ARRANGEMENT FOR SHOWER

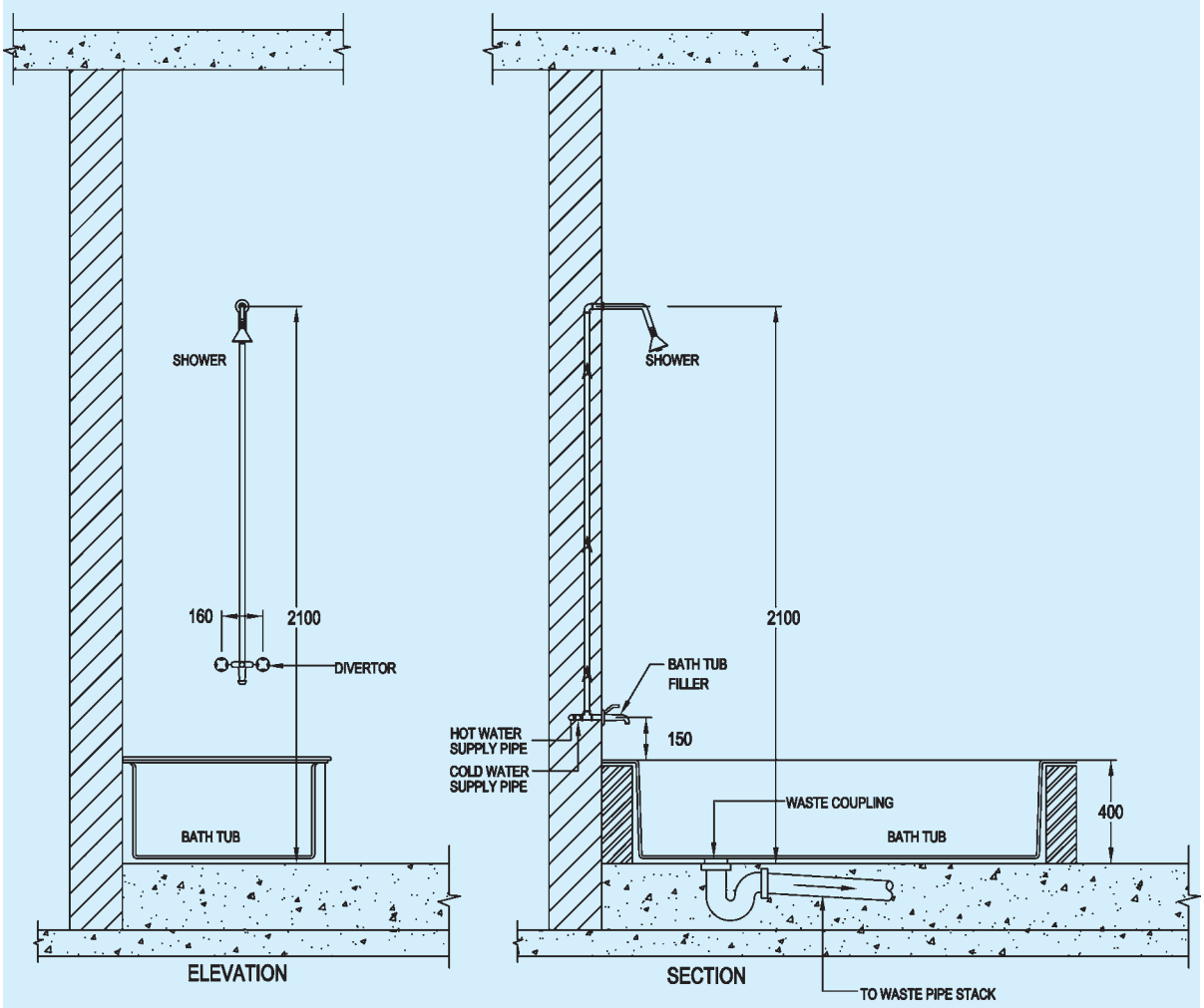


All dimensions in millimetres.

FIG. 27 SHOWER

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D-11 ARRANGEMENT FOR BATH TUB/SHOWER

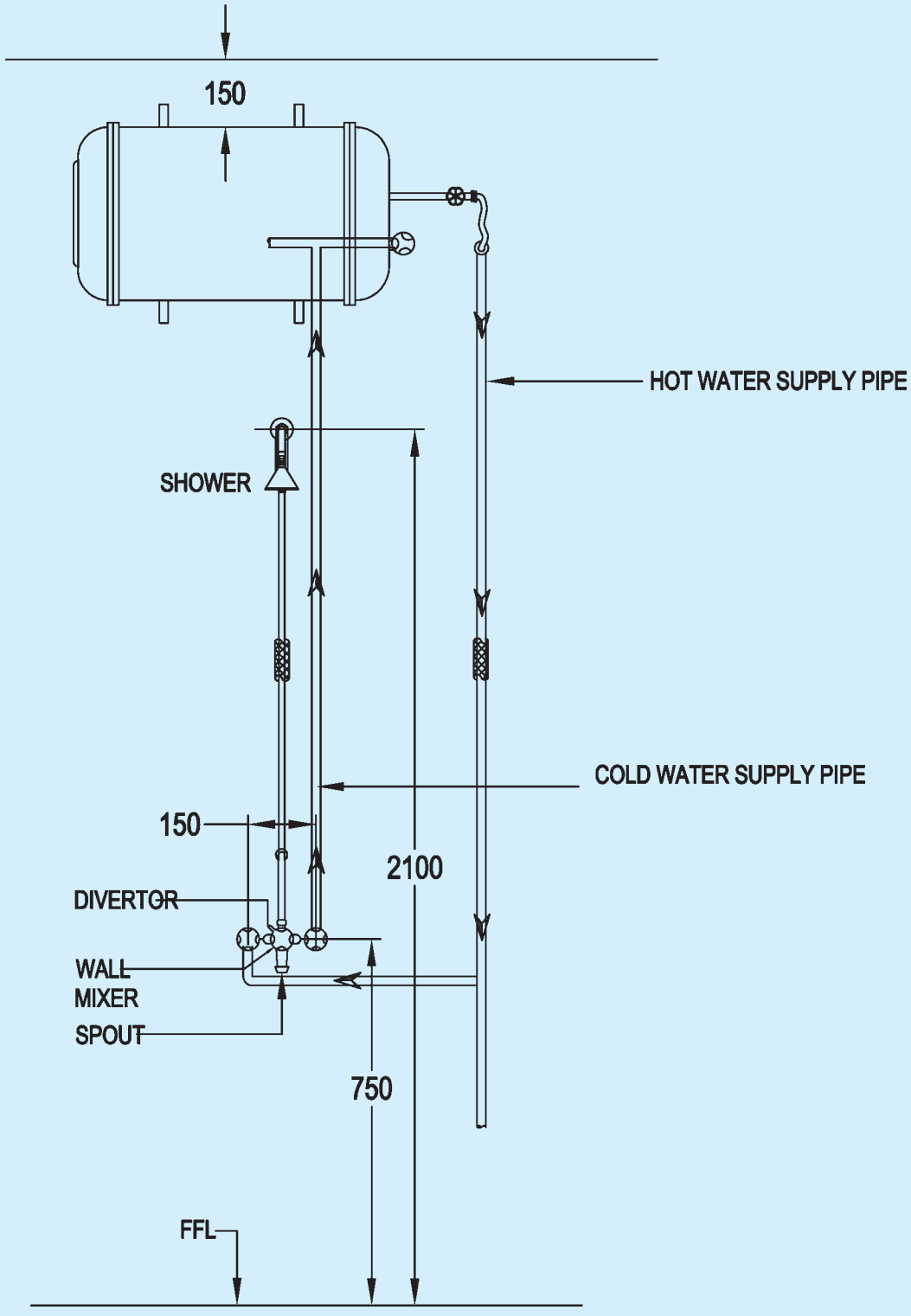


All dimensions in millimetres.

FIG. 28 BATH TUB/SHOWER

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D-12 ARRANGEMENT FOR SHOWER AND ELECTRIC WATER HEATER (HORIZONTAL MOUNTED TYPE)

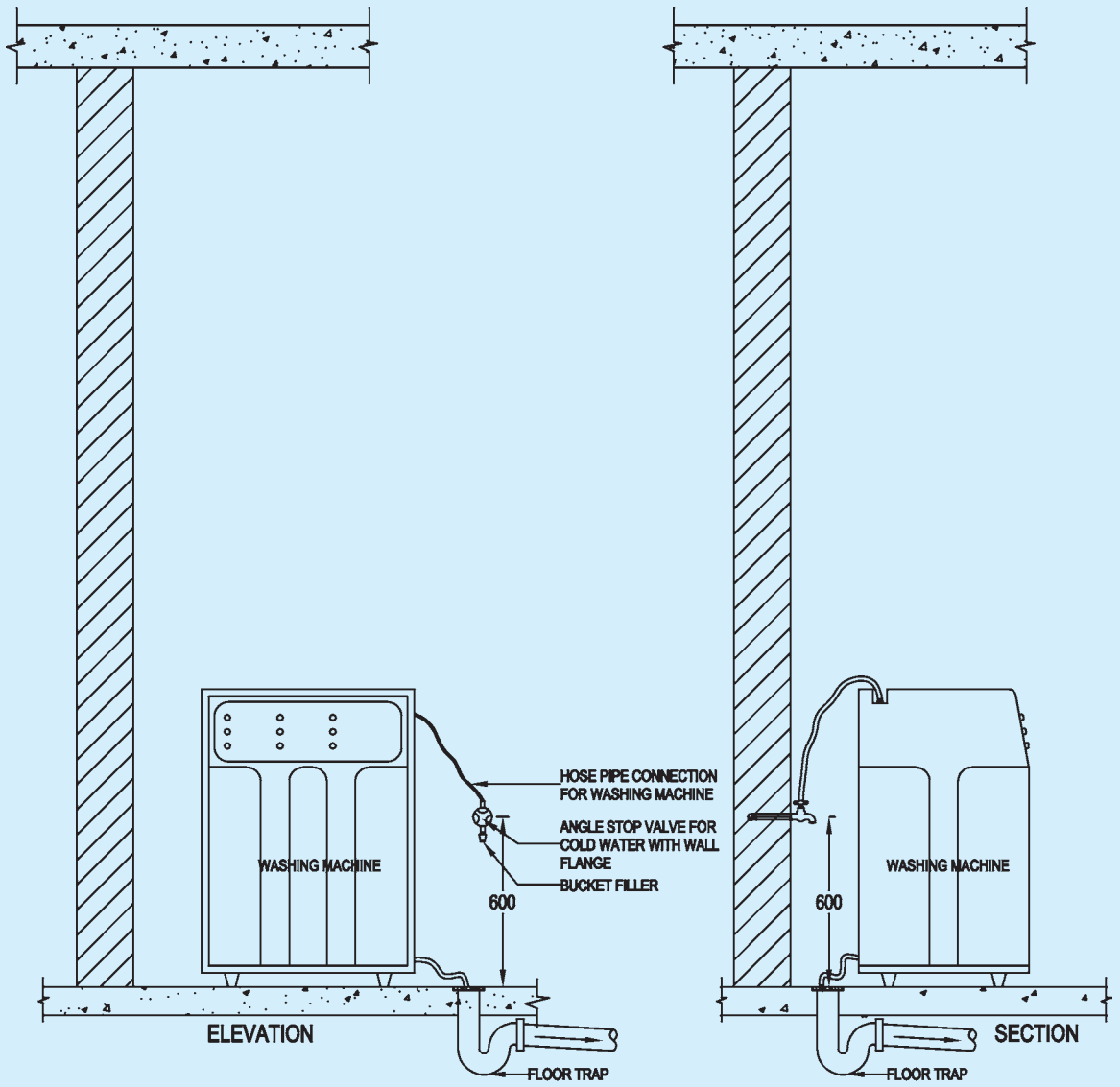


All dimensions in millimetres.

FIG. 29 SHOWER AND ELECTRIC WATER HEATER (HORIZONTAL MOUNTED TYPE)

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D-13 ARRANGEMENT FOR WASHING MACHINE



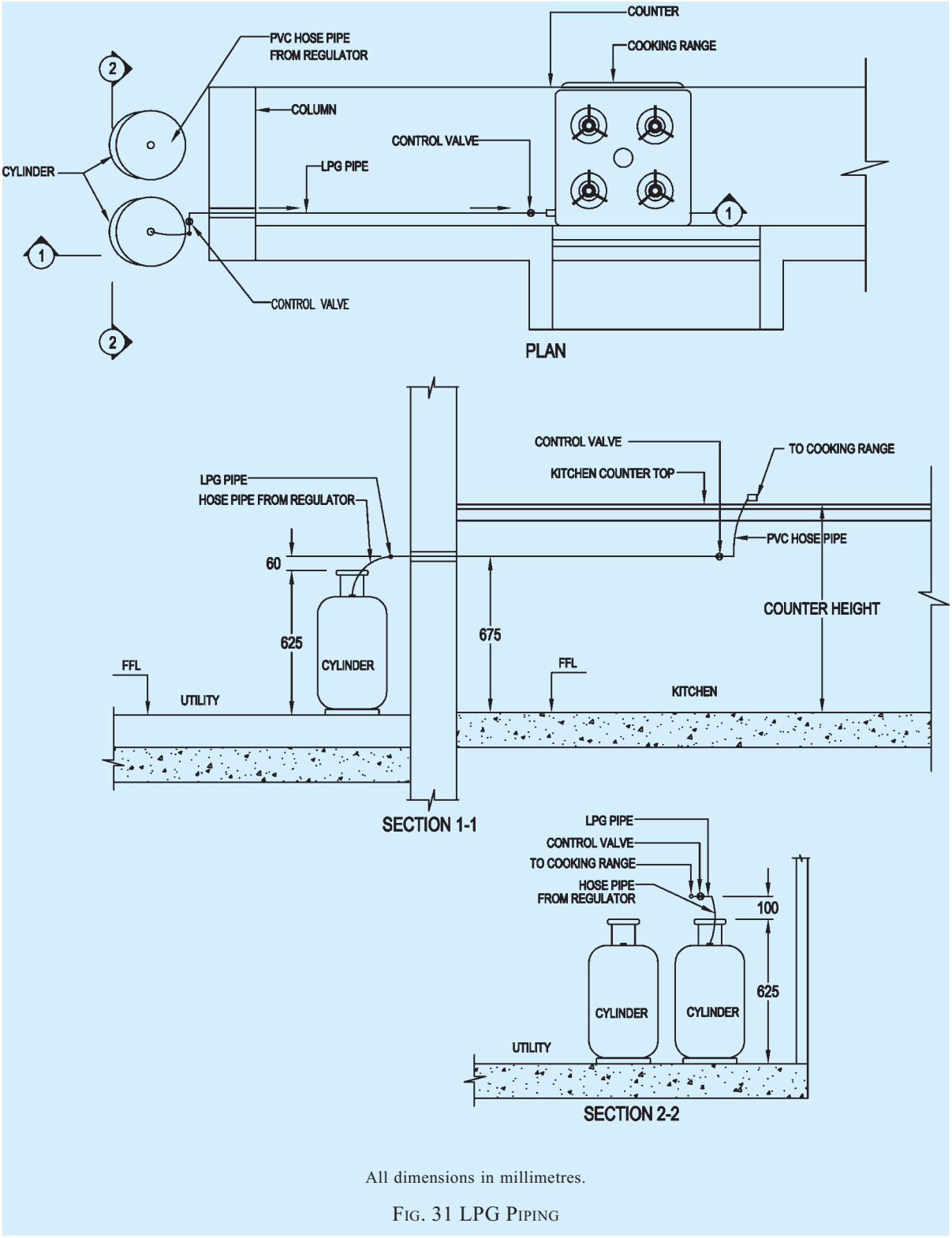
NOTE — Manual type washing machine : waste lead into floor trap.
Automatic type washing machine : Waste outlet should be 300 mm above FFL (and as per manufacturer's techinical specifications).

All dimensions in millimetres.

FIG. 30 WASHING MACHINE

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D-14 ARRANGEMENT FOR LPG PIPING



All dimensions in millimetres.

FIG. 31 LPG PIPING

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the code. The latest version of a standard shall be adopted at the time of enforcement of the code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the code.

In the following list, the number appearing in the first column with in parantheses indicates the number of reference in this Section:

	IS No.	*Title*
(1)	10446 : 1983	Glossary of terms relating to water supply and sanitation
(2)	11208 : 1985	Guidelines for registration of plumbers
(3)	771	Specification for glazed fire-clay sanitary appliances
	(Part 1) : 1979	General requirements (*second revision*)
	(Part 2) : 1985	Specific requirements of kitchen and laboratory sinks (*third revision*)
	(Part 3/Sec 1) : 1979	Specific requirements of urinals, Section 1 Slab urinals (*second revision*)
	(Part 3/Sec 2) : 1985	Specific requirements of urinals, Section 2 Stall urinals (*third revision*)
	(Part 4) : 1979	Specific requirements of postmortom slabs (*second revision*)
	(Part 5) : 1979	Specific requirements of shower trays (*second revision*)
	(Part 6) : 1979	Specific requirements of bed-pan sinks (*second revision*)
	(Part 7) : 1981	Specific requirements of slop sinks (*second revision*)
	772 : 1973	Specification for general requirements for enamelled cast iron sanitary appliances (*second revision*)
	773 : 1988	Specification for enamelled cast iron water closets railway coaching stock type (*fourth revision*)
	774 : 1984	Specification for flushing cistern for water closets and urinals (other than plastic cistern) (*fourth revision*)
	775 : 1970	Specification for cast iron brackets and supports for wash basins and sinks (*second revision*)
	1700 : 1973	Specification for drinking fountains (*first revision*)
	2326 : 1987	Specification for automatic flushing cisterns for urinals (*second revision*)
	2548	Specification for plastic seats and covers for water closets
	(Part 1) : 1996	Thermoset seats and covers (*fifth revision*)
	(Part 2) : 1996	Thermo plastic seats and covers (*fifth revision*)
	2556	Specification for vitreous sanitary appliances (vitreous china)
	(Part 1) : 1994	General requirements (*third revision*)
	(Part 2) : 1994	Specific requirements of wash-down water closets (*fourth revision*)
	(Part 3) : 1994	Specific requirements of squatting pans (*fourth revision*)
	(Part 4) : 1994	Specific requirements of wash basins (third revision)
	(Part 5) : 1994	Specific requirements of laboratory sinks (*third revision*)
	(Part 6) : 1995	Specific requirements of urinals and partition plates (*fourth revision*)
	(Part 7) : 1995	Specific requirements of accessories for sanitary appliances (*third revision*)
	(Part 8) : 1995	Specific requirements of siphonic wash down water closets (*fourth revision*)
	(Part 9) : 1995	Specific requirements of bidets (*fourth revision*)
	(Part 14) : 1995	Specific requirements of integrated squatting pans (*first revision*)
	(Part 15) : 1995	Specific requirements of universal water closets (*first revision*)
	(Part 16) : 2002	Specific requirements for wash down wallmounted water closets
	(Part 17) : 2001	Specific requirements for wall mounted bidets
	3489 : 1985	Specification for enamelled steel bath tubs (*first revision*)
	6411 : 1985	Specification for gel-coated glass fibre reinforced polyester resin bath tubs (*first revision*)
	7231 : 1994	Specification for plastic flushing cisterns for water closets and urinals (*second revision*)

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	IS No.	*Title*
	8718 : 1978	Specification for vitreous enamelled steel kitchen sinks
	8727 : 1978	Specification for vitreous enamelled steel wash basins
	9076 : 1979	Specification for vitreous integrated squatting pans for marine use
	11246 : 1992	Specification for glass fibre reinforced polyester resins (GRP) squatting pans (*first revision*)
	13983 : 1994	Specification for stainless steel sinks for domestic purposes
(4)	651 : 1992	Specification for salt glazed stoneware pipes and fittings (*fifth revision*)
	3006 : 1979	Specification for chemically resistant salt glazed stoneware pipes and fittings (*first revision*)
(5)	458 : 2003	Specification for precast concrete pipes (with and without reinforcement) (*fourth revision*)
	784 : 2001	Specification for prestressed concrete pipes (including specials) (*second revision*)
	1916 : 1989	Specification for steel cylinder with concrete lining and coating (*first revision*)
	4350 : 1967	Specification for concrete porous pipes for under drainage
	7319 : 1974	Specification for perforated concrete pipes
(6)	1536 : 2001	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*fourth revision*)
	1537 : 1976	Specification for vertically cast iron pressure pipes for water, gas and sewage (*first revision*)
	1538 : 1993	Specification for cast iron fittings for pressure pipes for water, gas and sewage (*third revision*)
	3989 : 2009	Specification for centrifugally cast (spun) spigot and socket soil, waste ventilating and rainwater pipes, fittings and accessories (*third revision*)
	7181 : 1986	Specification for horizontally cast iron double flanged pipes for water, gas and sewage (*first revision*)
(7)	1592 : 2003	Specification for asbestos cement pressure pipes and joints (*fourth revision*)
	1626	Specification for asbestos cement building pipes and pipe fittings, gutters and gutter fittings, and roofing fittings
	(Part 1) : 1994	Pipes and pipe fittings (*second revision*)
	(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
	(Part 3) : 1994	Roofing accessories (*second revision*)
	6908 : 1991	Specification for asbestos cement pipes and fittings for sewerage and drainage (*first revision*)
(8)	13592 : 2013	Specification for UPVC pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system (*first revision*)
	14333 : 1996	Specification for high density polyethylene pipe for sewerage
	14735 : 1999	Specification for unplasticized polyvinyl chloride (UPVC) injection moulded fittings for soil and waste discharge system for inside and outside buildings including ventilation and rainwater system
	15328 : 2003	Unplasticized non-pressure polyvinyl chloride (PVC-U) pipes for use in underground drainage and sewerage systems
(9)	2470	Code of practice for installation of septic tanks
	(Part 1) : 1985	Design criteria and construction (*second revision*)
	(Part 2) : 1985	Secondary treatment and disposal of septic tank effluent (*second revision*)
(10)	1536 : 2001	Specification for centrifugally cast (spun) iron pressure pipes for water, gas and sewage (*fourth revision*)
(11)	5329 : 1983	Code of practice for sanitary pipe work above ground for buildings (*first revision*)
(12)	SP 35 : 1987	Handbook on water supply and drainage with special emphasis on plumbing
(13)	2212 : 1991	Code of practice for brickwork (*first revision*)
(14)	5455 : 1969	Specification for cast iron steps for manholes
(15)	1726 : 1991	Specification for cast iron manhole covers and frames (*third revision*)

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IS No.	*Title*
12592 : 2002	Specification for precast concrete manhole covers and frames (*first revision*)
(16) 4111(Part 1) : 1986	Code of practice for ancillary structures in sewerage system : Part 1 Manholes (*first revision*)
(17) 15792 : 2008	Guidelines for artificial recharge to ground water
(18) 14961 : 2001	Guidelines for rainwater harvesting in hilly areas by roof water collection system
15797 : 2008	Guidelines for roof top rainwater harvesting
(19) 783 : 1985	Code of practice for laying of concrete pipes (*first revision*)
1742 : 1983	Code of practice for building drainage (*second revision*)
3114 : 1994	Code of practice for laying of cast iron pipes (*second revision*)
4127 : 1983	Code of practice for laying of glazed stoneware pipes (*first revision*)
6530 : 1972	Code of practice for laying of asbestos cement pressure pipes
(20) 2527 : 1984	Code of practice for fixing rainwater gutters and downpipes for roof drainage (*first revision*)
1729 : 2002	Cast iron/ductile iron drainage pipes and pipe fittings for over ground non-pressure pipeline socket and spigot series (*second revision*)
1626 (Part 1) : 1994	Asbestos cement building pipes and pipe fittings, gutters and gutter fittings and roofing fittings: Part 1 Pipe and pipe fittings (*second revision*)
1239 (Part 1) : 2004	Steel tubes, tubulars and other wrought steel fittings: Part 1 Steel tubes (*sixth revision*)
13592 : 2013	Specification for UPVC pipes for soil and waste discharge systems inside buildings including ventilation and rainwater system (*first revision*)
(21) 2064 : 1993	Code of practice for selection, installation and maintenance of sanitary appliances (*second revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 3 Solid Waste Management

BUREAU OF INDIAN STANDARDS

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3 GENERAL … 6
4 SOLID WASTE MANAGEMENT SYSTEMS … 7
5 ASSESSMENT OF PER CAPITA WASTE QUANTITY … 9
6 TREATMENT … 10

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 9/Section 3) covers the solid waste management systems, assessment of per capita solid waste quantities and treatment of solid waste within the building, building complexes and their built environments.

In the first version of the Code formulated in 1970, three separate sections of Part 9 Plumbing Services, were brought out, namely, Section 1 Water Supply, Section 2 Drainage and Sanitation, and Section 3 Gas Supply. These sections were subsequently revised in 1983 and in 2005.

In the second revision in 2005, the Part 9 was renamed as 'Plumbing Services (Including Solid Waste Management)' and provisions on solid waste management were included for the first time under Section 1 which contained in it, Water Supply, Drainage and Sanitation. Gas Supply was covered in Section 2 of Part 9 of the Code.

In this revision, to comprehensively address the various and distinct features related to the plumbing aspects, this Part 9 has been rearranged as follows:

Section 1 Water supply
Section 2 Drainage and sanitation
Section 3 Solid waste management
Section 4 Gas supply

Based on the experience gained in the use of the provisions on solid waste management included in last version, the provisions have been modified under this new Section. The significant changes include the following:

a) Certain new terminologies have been included.
b) References to latest applicable statutory Rules and Regulations have been included.
c) Provisions related to solid waste management systems have been elaborated.
d) Accessibility provisions for persons with disabilities to enable efficient operation of refuse chutes, have been included.
e) Electrically operated dumb-waiters have been recommended for new construction having 5 storeys and above, from the erstwhile 8 storeys.
f) New clause on assessment of per capita waste quantity has been included.
g) Detailed provisions suggesting treatment methods have been included.
h) An informative Annex A relating to municipal solid waste generation has been included, covering quantity, type, description and sources of solid waste generation.
j) An Annex B relating to treatment of food waste has been included.

Reference may also be made to the Manual on Solid Waste Management, 2000, CPHEEO, Ministry of Urban Development, Governement of India.

All Indian Standards, cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 3 Solid Waste Management

1 SCOPE

This Code (Part 9/Section 3) covers the solid waste management systems, assessment of per capita solid waste quantities and treatment of solid waste within the building, building complexes and their built environments.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply, and for other terms those given in the accepted standard [9-3(1)] shall apply.

2.1 Anaerobic Digestion — A controlled process involving microbial decomposition of organic matter in the absence of oxygen.

2.2 Authorization — The consent given by the State Pollution Control Board or Pollution Control Committee, as the case may be, to the operator of a facility.

2.3 Biodegradable Substance — A substance that can be degraded by microorganisms into simpler stable compounds.

2.4 Biomethanation — A process which entails enzymatic decomposition of the organic matter by microbial action to produce methane rich biogas.

2.5 Collection — Lifting and removal of solid wastes from collection points or any other location.

2.6 Composting — A controlled process involving microbial decomposition of organic matter.

2.7 Construction and Demolition Waste — Wastes from building materials debris and rubble resulting from construction, re-modelling, repair and demolition operation.

2.8 Disposal — Final disposal of municipal solid wastes in accordance with the specified measures to prevent contamination of groundwater, surface water and ambient air quality.

2.9 Generator of Wastes — Persons or establishments generating municipal solid wastes.

2.10 Landfilling — Disposal of residual solid wastes on land in a facility designed with protective measures against pollution of groundwater, surface water and air fugitive dust, wind-blown litter, bad odour, fire hazard, bird menace, pests or rodents, greenhouse gas emissions, slope instability and erosion.

2.11 Leachate — Liquid that seeps through solid wastes or other medium and has extracts of dissolved or suspended material from it.

2.12 Municipal Authority — Municipal Corporation, Municipality, Nagar Palika, Nagar Nigam, Nagar Panchayat, Municipal Council including notified area committee (NAC) or any other local body constituted under the relevant statutes and, where the management and handling of municipal solid waste is entrusted to such agency.

2.13 Municipal Solid Waste — Commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form, excluding industrial hazardous wastes and construction and demolition waste but including treated bio-medical wastes.

2.14 Operator of a Facility — A person who owns or operates a facility for collection, segregation, storage, transportation, processing and disposal of municipal solid wastes and also includes any other agency appointed as such by the municipal authority for the management and handling of municipal solid wastes in the respective areas.

2.15 Pelletization — A process whereby pellet are prepared which are small cubes or cylindrical pieces made out of solid wastes and includes fuel pellets which are also referred as refuse derived fuel.

2.16 Processing — The process by which solid wastes are transformed into new or recycled products.

2.17 Recycling — The process of transforming segregated solid wastes into raw materials for producing new products, which may or may not be similar to the original products.

2.18 Segregation — To separate the municipal solid wastes into the groups of organic, inorganic, recyclables and hazardous wastes.

2.19 Storage — The temporary containment of municipal solid wastes in a manner so as to prevent littering, attraction to vectors, stray animals and excessive foul odour.

2.20 Transportation — Conveyance of municipal solid wastes from place to place hygienically through

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specially designed transport system so as to prevent foul odour, littering, unsightly conditions and accessibility to vectors.

2.21 Vermi-composting — A process of using earthworms for conversion of biodegradable wastes into compost.

3 GENERAL

3.1 Solid waste is generated from various human activities and which is normally disposed as useless and unwanted. Broadly, depending upon the type of building and built environment, it includes solid or semi-solid domestic waste, such as sanitary waste, commercial waste, office waste, catering and market waste and other non-residential wastes, street sweepings, silt removed or collected from the surface drains, horticulture waste, construction and demolition waste, and treated bio-medical waste. Further, there may be industrial hazardous waste, bio-medical waste and e-waste.

The primary objective of solid waste management is to collect, treat and dispose of solid wastes in an environmentally and socially satisfactory manner using the most economical means available. Ideally, solid waste should not contain faecal matter or urine but despite all precautions, some pathogens and chemical residues inevitably may be present in the waste. Uncontrolled or poorly managed intermediate decomposition of organic components of solid waste can contaminate air, water and soil resources. Implementation of integrated solid waste management practices benefits substantially, both the public health and the quality of the environment.

3.2 Based on source of generation, solid waste can be broadly categorized as follows:

a) *Domestic waste* — It is generated in residential units; and consists of food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (for example, bulky items, consumer electronics, white goods, batteries, oil and tyres), and household hazardous wastes.

b) *Industrial waste* — It is generated in manufacturing units, fabrication plants, construction sites, power and chemical plants; and consists of packaging, hazardous wastes, ashes, special wastes, wood, steel, concrete, dirt, etc.

c) *Institutional and commercial waste* — It is generated in schools, hospitals, prisons, government centres, stores, hotels, restaurants, markets, office buildings, etc; and consists of domestic wastes, paper, cardboard, plastics, wood, glass, metals, special wastes and hazardous wastes.

d) *Horticulture waste* — It is generated in landscaping, parks, orchards, dairies, and consists of street sweepings; landscape and tree trimmings; etc.

3.3 Based on suitability for handling and disposal, solid waste can also be categorized as follows:

a) *Garbage* — Garbage is the term applied to animal and vegetable waste resulting from the handling, storage, sale, cooking and serving food. Such wastes contain putrescible organic matter, which produces strong odours and therefore attracts rats, flies and other vermin. It requires immediate attention in its storage, handling and disposal.

b) *Municipal waste* — Municipal waste includes waste resulting from municipal activities and services such as street wastes, dead animals, market wastes and abandoned vehicles. However, the term is commonly applied in a wider sense to incorporate domestic wastes and commercial wastes.

c) *Hazardous wastes* — Hazardous wastes may be defined as wastes of industrial, institutional or consumer origin which because of their physical, chemical or biological characteristics are potentially dangerous to human and the environment. It includes any waste that exhibits one of the hazardous characteristics, such as ignitability, corrosivity, reactivity, or toxicity, whether alone or when in contact with other wastes or substances. In some cases although the active agents may be liquid or gaseous, they are classified as solid waste because they are confined in solid containers. Typical examples are solvents, paints and pesticides whose spent containers are frequently mixed with municipal wastes. Good waste management should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them innocuous.

   A sub-category of household hazardous waste, is post-consumer utilization waste which qualifies as hazardous waste when discarded. It includes household chemicals and other consumer products used in home care, personal care, automotive care, pest control, etc. These products exhibit characteristics of reactivity, ignitability, corrosivity, toxicity, or persistence

d) *Bio-medical waste* — Bio-medical waste is

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any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining thereto or in the production or testing of biologicals. This waste is highly infectious and can be a serious threat to human health if not managed in a scientific and discriminate manner. It may include wastes like sharps, soiled waste, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc. It has been estimated that hospitals generate bio-medical waste at a rate of 1 kg per bed day. Generally these wastes are handed over to common bio-medical treatment and disposal facilities for suitable treatment and final disposal.

Biological means any preparation made from organisms or microorganisms or product of metabolism and biochemical reactions intended for use in the diagnosis, immunization or the treatment of human beings or animals or in research activities pertaining thereto.

Bio-medical waste treatment facility means any facility wherein treatment, disposal of bio-medical waste or processes incidental to such treatment and disposal is carried out, and includes common treatment facilities. The common bio-medical treatment facilities are set up based on the need for ensuring environmentally sound management of bio-medical waste keeping in view the techno-economic feasibility and viable operation of the facility with minimal impacts on human health and environment.

All healthcare establishments including hospitals, research facilities and laboratories generate solid waste in course of performing their intended functions. 75 to 90 percent of such solid waste is non-risk healthcare waste, comparable to domestic waste. It requires minimal treatment and is safely handled by housekeeping staff. The remaining 10 to 25 percent of healthcare waste is designated as bio-hazardous waste and is designated bio-medical waste. It carries a variety of health risks in its handling and disposal. It is handled by trained staff and many safety devices and apparels are deployed. In addition, bio-medical waste includes the waste originating from minor or scattered sources, such as that produced in the course of healthcare undertaken in the home (dialysis, insulin injections, etc).

e) *Plastics* — Plastics, due to their non-biodegradable nature, versatility in use and impact on environment, can be grouped under a different category of solid waste. More than 50 percent of the plastic waste generated in our country is recycled and used in the manufacture of various plastic products. Careless disposal of plastic in various forms chokes drains, blocks the porosity of the soil, causes problems for groundwater recharge, disturbs the soil microbe activity, contaminates foodstuff and when ingested by animals, it can kill them.

3.4 Efficient collection and disposal of domestic garbage from a building or activity area is of significant importance to public health and environmental sanitation and, therefore, an essential part of the built environment. Notwithstanding the provisions given herein, the solid waste management shall have to comply with relevant statutory Rules and Regulations in force from time-to-time. The provisions of the following shall govern the procedures for handling, treatment, etc, of solid wastes as applicable to the concerned building occupancy:

a) *The Environment (Protection) Act*, 1986.
b) *The Solid Waste Management Rules*, 2016.
c) *The Bio-Medical Waste Management Rules*, 2016.
d) *The E-Waste (Management) Rules*, 2016.
e) *The Batteries (Management and Handling) Rules*, 2001.
f) *The Hazardous and Other Wastes (Management and Transboundary Movement) Rules*, 2016.
g) *The Plastics Waste Management Rules*, 2016.

NOTE — Radioactive wastes are covered under the provisions of *The Atomic Energy Act*, 1962 and rules made thereunder and the enforcement agency for these is Atomic Energy Regulatory Commission (AERC).

3.5 The provisions relating to solid waste management given in **4** are applicable to municipal solid waste and specifically exclude the hazardous chemical wastes, bio-medical waste and radioactive waste.

4 SOLID WASTE MANAGEMENT SYSTEMS

4.1 ln designing a system dealing with collection of domestic garbage for a built premises/community/ environment, the aim shall be to provide speedy and efficient conveyance as an essential objective for design of the system. The various available systems may be employed in accordance with **4.2** to **4.4**, which may be adopted individually or in combination as appropriate in specific situations.

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4.1.1 The basic stages of the municipal solid waste management system include the following:

a) Waste sorting at source, collection and transportation;
b) Resource recovery through centralized sorting and recycling;
c) Resource recovery through waste processing, that is, recovery of energy; and
d) Waste transformation without recovery.

4.1.2 The functional elements of municipal solid waste management system include the following:

a) *Waste generation* — Activity in which the waste gets generated as material no longer having any value.
b) *Waste handling, sorting, storage and processing at site* — Waste handling and sorting involves the activities associated with management of waste until they are placed in storage container for collection.
c) *Collection* — Gathering of solid wastes including transportation.
d) *Transfer and transport* — Transfer of waste from smaller collection vehicle to larger transport equipment and subsequent transport of wastes over long distances to a processing or disposal site.

4.2 Sorting at Source

Sorting shall be planned based on the existing markets for recyclable materials. It is preferable to have coloured-bin system based on the usage of the facility and the types of the waste likely to be generated in the facility (such as red, green, blue, yellow).

Common sorting methods involve sorting into,

a) dry recyclable materials, for example, glass, paper, plastics, metals, etc;
b) bio-waste and garden waste;
c) bulky waste;
d) hazardous material in household waste;
e) construction and demolition waste; and
f) mingled MSW (mixed waste).

In case of sorting not done at source, it is required to plan centralized sorting. The types of sorting that may be adopted, are:

1) Hand sorting from a raised picking belt.
2) Mechanized sorting facilities using magnetic and electric field separation, density separation, etc.

Sorting at source normally recovers most of the recyclable materials for reuse. However, a small fraction of such materials may escape the sorting process. Sorting may therefore be also undertaken just prior to waste processing, waste transformation or landfilling to recover such recyclable materials.

Wherever manual sorting is adopted, care shall be taken to ensure that sorters are protected from all disease pathways and work in hygienic conditions. The movement of waste shall be planned by suitable mechanism and building shall be planned for easy movement of waste by means of garbage/material lift, ramps, etc, meeting the good engineering practices.

4.3 Refuse Chute System

4.3.1 *General*

Refuse chute system is a convenient and safe mode of transportation and collection of domestic solid wastes from buildings exceeding 5 storeys from floors at different heights. The refuse is received from the successive floor through the inlets located on the vertical system of pipes that convey refuse through it and discharge it into the collecting chamber, located at ground level, from where the refuse is cleared at suitable intervals. This system has got four functionally important components, namely, the chutes, the inlet hopper, the collection chamber and the cleaning and disinfecting arrangements.

The chute may be carried through service shafts meant for carrying drainage pipes. However, the location shall be mostly determined by the position of the inlet hopper and the collecting chamber that is most convenient for the user. It should also be considered to locate the chute away from living rooms in order to avoid noise and smell nuisance. The internal diameter of the chute shall be at least 300 mm.

In individual chute system, the inlet hopper shall be located in the passage near the kitchen and in the common chute system towards the end of the common passage. Natural ventilation should be adequate to prevent any possible odour nuisance. There should be adequate lighting at this location. For ground floor (floor 1), the inlet hoppers may be placed at a higher level, but should be easily accessible. The access to the refuse chute shall be provided from well ventilated and well illuminated common corridor or lobby and preferably it should not be located opposite or adjacent to entry of individual flats or lift.

4.3.2 *Opening for Feeding of Refuse Chute*

Opening, with top or bottom hinged shutters with appropriate lockable latch, shall be provided for convenient accessing of the refuse chute by users. It facilitates total building garbage collection at one single point and provides separate collection for dry and wet garbage. Chute system shall have the following features:

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a) Sanitation system for internal cleaning of chutes, with sprinklers at every floor intake level, with disinfectant cleaning, which may preferably be automatic in operation;
b) Exhaust system with 25 to 35 air changes per hour;
c) Discharge end fire resistant door;
d) Chute may be of masonry, R.C.C. pipe, asbestos cement pipe or suitable non-corrosive material, preferably stainless steel. It should be rigid with smooth internal finish, high ductility and alkali/acid resistant properties {*see also* good practice [9-3(2)]};
e) Fire rating shall comply with **3.4.8.3** of Part 4 'Fire and Life Safety' of the Code;
f) Fire sprinklers shall be provided inside chute;
g) Vent shall be installed at roof level to remove foul smell and gases generated;
h) Chute should discharge to trolley directly;
j) Necessary automation of the system may be planned to avoid malfunction by manual operation; and
k) All care shall be taken for ensuring accessibility to the chute for persons with disabilities. The opening of the chute shall not be higher than 700 mm and there shall be a clear space of minimum 1 500 mm × 1 500 mm in front of the chute opening to gain easy access even for persons using wheelchairs. There may be high colour contrast provided around the chute opening to make it easy to identify it. The flooring in front of the chute opening may be texturally highly different from the rest of the floor.

4.3.3 *Refuse Collection Chamber*

The collection chamber may be located in ground floor or basement level, provided appropriate arrangement is made for drainage of the collection pit by gravity flow to ensure its dryness, an appropriate ramp access is provided for convenient removal of garbage from the collection pit, and satisfactory ventilation is provided for escape of gas and odour.

The floor of the chamber shall be provided with drainage through a 100 mm diameter trap and screen to prevent any solid matters flowing into the drain and the drain shall be connected to the sewer line. The floor shall be finished with smooth hard surface for convenient cleaning.

The height of the collection chamber and vertical clearance under the bottom level of garbage chute shall be such that the garbage trolley can be conveniently placed.

The collection chamber shall be provided with appropriate shutter to prevent access of scavenging animals like cattle, dogs, cats and rats.

4.3.4 *Refuse Collection Room*

The refuse collection room should be planned in ground or basement level with appropriate ventilation and proper drainage. The room should have access for vehicle or trolley transfer of garbage.

4.3.5 *See also* accepted standards [9-3(3)].

4.4 Dumb-Waiter or Service Lift

In high rise buildings with more than 5 storeys, electrically operated dumb-waiters may be used for carrying domestic garbage in packets or closed containers. For handling of garbage by dumb-waiters in a building, a garbage chamber shall have to be provided either at ground floor or basement level and the provisions of garbage collection chamber for chute as given in **4.3** shall apply.

5 ASSESSMENT OF PER CAPITA WASTE QUANTITY

5.1 For purposes of this Section, the following municipal refuse generation rates are recommended:

a) Residential refuse : 0.3 to 0.6 kg/capita/day
b) Commercial refuse : 0.1 to 0.2 kg/capita/day
c) Street sweepings : 0.05 to 0.2 kg/capita/day
d) Institutional refuse : 0.05 to 0.2 kg/capita/day

Out of the total solid waste generated, 40 percent may be taken as organic waste and 60 percent as inorganic waste. The knowledge of chemical characteristics of waste is important for selecting and designing the waste processing and disposal facilities.

5.2 These generation rates are subject to considerable site-specific factors and are required to be supported by field data. The waste contains a high percentage of ash and fine earth. The calorific value of Indian solid waste varies between 800 and 1 000 kcal/kg and the density varies between 300 and 500 kg/m^3.

5.3 Other than municipal solid waste, the following types of waste may also be generated in urban centers:

a) *Industrial waste* — Hazardous and non-hazardous waste from industrial areas within municipal limits.
b) *Bio-medical waste* — Waste from hospitals, slaughter houses, etc.
c) *Thermal power plant waste* — Fly ash from coal-based electricity generating plant within municipal limits.

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d) *Effluent treatment plant waste* — Sludge from sewage treatment plants and industrial effluent treatment plants.

e) *Other wastes* — Special wastes from non-conforming areas or special units.

All waste streams shall be managed by their own waste management system.

6 TREATMENT

6.1 Garbage collected at one location may be treated for organic portion, and inorganic portion shall be handed over to vendors carrying out recycling. Organic waste generated in building/premises/community/ environment may be treated and reused as manure. The norms prescribed by the pollution board authorities shall be followed, keeping hygiene and safe operation for the working/operating people.

Biological or thermal treatment of waste can result in recovery of useful products such as compost or energy.

6.2 Biological Processes

Biological treatment involves using microorganisms to decompose the biodegradable components of waste. The following two types of processes may be typically used, the former being used more commonly:

a) *Aerobic processes* — It may comprise composting, aerated static pile composting and in-vessel composting; vermi-culture, etc. In the aerobic process the utilizable product is compost.

b) *Anaerobic processes* — It may comprise low-solids anaerobic digestion (wet process), high solids anaerobic digestion (dry process) and combined processes. In the anaerobic process the utilizable product is methane gas (for energy recovery).

6.2.1 *Composting*

Decomposition and stabilization of organic waste matter is a natural phenomenon. Composting is an organized method of producing compost manure by adopting this natural phenomenon.

a) *Manual composting* — It is an anaerobic method conventionally carried out in pits. Initially the waste is anaerobically stabilized in pits where alternate layers of solid waste and night soil are laid. The pit is completely filled and a final soil layer is laid to prevent fly breeding, entry of rain water into the pit and for conservation of the released energy. The material is allowed to decompose for 4 to 6 months after which the stabilized material is taken out and used as compost.

b) *Mechanical composting* — Mechanical processes are preferred where higher labour costs and limitations of space exist. It is the process using a combination of aerobic and anaerobic decomposition in enclosed containers. Organic wet waste composter is used where raw refuse is composted in large vessel, which are turned at intervals by mobile pedals or plates. Several other processes have now been developed, using different methods of processing of solid waste, using different designs of digester.

Latest technology uses electrically operated rapid processing organic waste convertor with different capacities as mechanical composters. The organic wet and dry waste is separated and shredder is used to homogenize the materials and blenders are used under controlled temperature and bio-enzyme addition in closed containers. These output manure may be used for horticultural/ agriculture works.

c) *Vermi-composting* — Vermi-compost treatment shall be provided to the organic wastes in composting pits located in shade. The pits shall be used to receive the garbage in a predetermined (periodic) cyclic order (for example, 5 pits to receive garbage in 5 days and these 5 pits together accepting daily load of garbage). The gross area of the composting pits may be about 0.1 m^2 per person.

The site for vermi-composting shall be enclosed from all sides with appropriate fencing (for keeping scavenging animals away) and provided with a small door for accessing the enclosed premises.

Composting pits shall be constructed either under the shade of trees (except Neem tree) or created under sheeting or shade-net, so as to keep the pits under shade. The pits shall be easily accessible for convenience of receiving of garbage through trolleys.

The composting pits shall be made in a manner that the pits do not have the risk of inundation by water. This may be achieved by appropriately raising the base level of the pit and providing weep holes from sides. Height of side walls of compost pits shall be 0.6 m to 0.75 m high. It is preferable to have the bottom of the pit without any lining.

Initiation of composting pits shall be done by providing a 75 mm thick layer of cow dung (fresh or partially decomposed), spreading 1 kg of vermi-compost and covering it with 75 mm to 100 mm thick layer of dry leaves/grass, etc, and sprinkling of water and allowing to decompose naturally for about 10 to 15 days.

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Sorted garbage free from inert and toxic matters shall be applied in the composting pit in layers of 75 mm and spread, and covered with a layer of 75 mm thick dry leaves, followed by sprinkling of water.

The compost may be removed from the bottom of the compost pit after intervals of 3 to 6 months. The compost so made may be used in appropriate horticultural and related applications.

See also accepted standard [9-3(4)] for manure grade municipal solid waste compost.

6.3 Thermal Processes

Thermal treatment involves conversion of waste into gaseous, liquid and solid conversion products with concurrent or subsequent release of heat energy.

Three types of systems can be adopted, namely:

a) *Combustion systems (Incinerators)* — Thermal processing with excess amounts of air.
b) *Pyrolysis systems* — Thermal processing in complete absence of oxygen (low temperature).
c) *Gasification systems* — Thermal processing with less amount of air (high temperature).

6.4 Land Filling

6.4.1 Disposal of waste on lands identified for the purpose is typical of this method of waste disposal. The depth of filling depends upon the site topography and location and varies from deep to shallow filling. A municipal solid waste landfill plant is an engineered facility used for disposal of solid waste. Landfills in which municipal waste is placed are designated as 'MSW landfills'. The main considerations in respect of landfill sites are:

a) Specifications for landfill sites,
b) Site selection,
c) Facilities at site, and
d) Specification of land filling.

6.4.2 Improper landfill generally impacts the environment in the following ways:

a) Groundwater contamination by the leachate generated by the waste dump;
b) Surface water contamination by the run-off from the waste dump;
c) Bad odour, pests, rodents and wind-blown litter in and around the waste dump;
d) Generation of inflammable gas (for example, methane) within the waste dump;
e) Bird menace above the waste dump which affects flight of aircraft;
f) Fires within the waste dump;
g) Erosion and stability problems relating to slopes of the waste dump;
h) Epidemics through stray animals;
j) Acidity to surrounding soil; and
k) Release of greenhouse gas.

6.5 Some recycling/treatment methods for food waste are given in Annex B for guidance.

6.6 *See also* accepted standards [9-3(5)] for solid waste management, and for analysis and testing of solid wastes.

6.7 Other/special wastes shall be dealt with in accordance with the statutory provisions in respect of the same (*see* **3.4**).

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ANNEX A

(*Foreword*)

MUNICIPAL SOLID WASTE GENERATION

A-1 WASTE GENERATION

A-1.1 The typical type of wastes generated may be as follows:

Types of Solid Waste	Description	Sources
Food waste (garbage)	Wastes from the preparation, cooking, and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meats and vegetable	Households, institutions and commercial such as hotels, stores, restaurants, markets, etc
Rubbish	a) *Combustible* (*primary organic*) — Paper, cardboard, cartons wood, boxes, plastics, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings b) *Non-combustible* (*primary inorganic*) — Metals, tin cans, metal foils dirt, stones, bricks, ceramics, crockery, glass bottles, other mineral refuse	-do-
Ashes and residues	Residue from fires used for cooking and for heating buildings, cinders, clinkers, thermal power plants	-do-
Bulky waste	Large auto parts, tyres, stoves refrigerators, others large, appliances, furniture, large crates, trees, branches, palm fronts, stumps	-do-
Street waste	Street sweepings, dirt, leaves, catch basin dirt, animal droppings, contents of litter receptacles, dead animals	Streets, sidewalks, alleys, vacant lots, etc
Dead animals	a) *Small animals* — Cats, dogs, poultry, etc b) *Large animals* — Horses, cows, etc	-do-
Construction and demolition waste	Lumber, roofing and sheathing scraps, crop residues, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc	Construction and demolition sites, remodelling, repairing sites
Industrial waste and sludge	Solid wastes resulting from industry processes and manufacturing operations, such as food processing wastes and boiler House cinders, wood, plastic and metal scraps and shaving, etc. Effluent treatment plant sludge of industries and sewage treatment plant sledges, coarse screening, grit and septic tank	Factories, power plants, treatment plants, etc
Hazardous wastes	Pathological waste, explosives, radioactive material, toxic waste, etc	Households, hospitals, institution, stores, industry, etc
Horticulture wastes	Tree-trimmings, leaves, waste from parks and gardens, etc	Parks, gardens, roadside trees, etc

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A-1.2 The typical quantity of waste generated measured per capita in urban areas may be as follows:

Population Range (Million)	*Average Per Capita Value (kg/capita/day)*
0.1-0.5	0.21
0.5-1.0	0.25
1.0-2.0	0.27
2.0-5.0	0.35
More than 5.0	0.50

A-2 INDUSTRIAL WASTE

The major generators are thermal power plants, integrated iron and steel mills, non-ferrous industries, pulp and paper industries and fertilizer and allied industries. Following are the source and quantum of generation of some major industrial wastes.

Name of Industry	*Quantity (Million tonne per annum)*
Steel and blast	35.0
Brine mud	0.02
Copper slag	0.016 4
Fly ash	30.0
Kiln dust	1.6
Lime sludge	3.0
Mica scraper waste	0.005
Phospho-gypsum	4.5
Red mud/Bauxite	3.0

A-3 SLAUGHTER HOUSE WASTE

Slaughtering of animals generates consisting of non-edible offal (lungs, large intestines, etc), stomach/ intestinal contents, dung, sludge from waste water and bones, etc. These have to be disposed of by methods like rendering/controlled incineration/burial/composting/anaerobic digestion, etc. The estimated waste generation may be as per the following:

Type of Slaughter House	*Annual Capacity*	*Dry Waste Generated (tonne per day)*
Large	Large animals more than 40 000 Small animals more than 600 000	6 to 7
Medium	Large animals – 10 001 to 40 000 Small animals – 100 001 to 600 000	2 to 6
Small	Large animals up to 10 000 Small animals up to 100 000	0.5 to 1.0

A-4 BIO-MEDICAL WASTE

The waste generated from medical activities can be hazardous, toxic and even lethal because of their high potential for disease transmission.

The components of bio-medical waste include,

a) human anatomical waste (tissues, organs, body parts, etc);
b) animal waste (as above, generated during research/experimentation, from veterinary hospitals, etc);
c) microbiology and biotechnology waste, such as, laboratory cultures, microorganisms, human and animal cell cultures, toxins, etc;
d) waste sharps, such as hypodermic needles, syringes, scalpels, broken glass, etc;
e) discarded medicines and cyto-toxic drugs;
f) soiled waste, such as dressing, bandages, plaster casts, material contaminated with blood, etc;
g) solid waste (disposable items like tubes, catheters, etc, excluding sharps);
h) liquid waste generated from any of the infected areas;
j) incineration ash; and
k) chemical waste.

The estimated generation of total waste is 1.5 kg/bed and the estimated generation of bio-medical waste at 25 percent of total waste generation.

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ANNEX B

(*Foreword and Clause* 6.5)

TREATMENT OF FOOD WASTE

B-1 FOOD WASTE

Food waste represents a large percentage of the solid waste. For establishments that serve food, there is an average of 400 g of food waste generated per meal served; when both pre-service and post-service waste is considered. The organic nature of food waste makes it unsuitable for disposal by landfills, though it is bio-degradable.

In order to use the nutrient and calorific value of the food waste, it is collected, stored and then recycled. When collecting, it should be ensured that food waste does not enter the drainage system. When providing temporary storage, the risk of physical contamination of kitchen working areas should be avoided. It should be a separate ventilated room with 6 total air changes per hour. In hot climates, it shall be cooled to a temperature of 24°C to minimize odour generation. The storage area should be cleaned at least once everyday.

A brief overview of some of the ways of food waste recycling/treatment is given in **B-2** to **B-4**. Before recycling/treatment, it requires non-organic materials to be removed from food waste.

B-2 FEEDING ANIMALS

Food discards can be made available for feeding animals. This may involve provisions for farmers, zoos and many other applications. Converting food discards to animal feed and pet food is common and a suitable option for recycling food scraps.

B-3 INDUSTRIAL USES

Food waste can be used in the rendering industry for converting these materials to soaps, cosmetics and biodiesel fuel.

B-4 ANAEROBIC DIGESTION

This process involves breaking down organic matter in an oxygen-free environment in order to generate biogas, which is a combination of methane and carbon dioxide. The methane is burned for energy. The material that remains after digestion (digestate) should then be composted aerobically to complete the process and produce a valuable soil amendment.

Food waste drying system can provide a fast, simple and user friendly onsite process for decomposing and dehydrating food scraps into rich soil sediments. These systems do not require microorganisms, enzymes, fresh water or other additives.

Food cycler sterilizes, deodorizes and turns potentially harmful food scraps into safe, sterilized compost that can be reused as a soil amendment. It is a multi-phase, onsite organic food waste recycling machine that dehydrates and converts daily food waste into a sterile biomass. The sterilization process takes place at 82°C and reduces the waste volume by 85 to 93 percent. After sterilization, the food waste is converted into compostable humus-rich, high-carbon organic particles. The by-products of the process can be reused as soil amendment, compost accelerant, biofuels, animal feed, pet food, etc. Further benefits can be obtained by mixing the water produced from the food cycler units with potable or non-potable supplies to reduce the amount of water used from mains for use in gardens, landscaping and cooling towers.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	9569 : 1980	Glossary of terms relating to solid wastes
(2)	6924 : 1973	Code of practice for the construction of refuse chutes in multi-storeyed buildings
(3)	12402	Mobile containers for solid waste:
	(Part 1) : 1988	General characteristics
	(Part 2) : 1988	Methods of test

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	IS No.	*Title*
	12647 : 1989	Guidelines for solid waste management system — Collection equipment
	12662	Guidelines for use of vehicles for collection of municipal solid wastes:
	(Part 1) : 1989	Selection of vehicles
	(Part 2) : 2002	Guidelines for maintenance
(4)	16556 : 2016	Specification for municipal solid waste compost, manure grade
(5)	9234 : 1979	Methods for preparation of solid waste sample for chemical and microbiological analysis
	9235 : 1979	Physical analysis and determination of moisture in solid wastes (Excluding industrial solid wastes)
	10158 : 1982	Methods of analysis of solid wastes (Excluding industrial solid wastes)
	16557 : 2016	Guidelines for solid waste management — Segregation, collection and utilization at household/community level

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES
(INCLUDING SOLID WASTE MANAGEMENT)

Section 4 Gas Supply

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 9/Section 4) covers the safe use of gases for purposes like fuel, lighting and medical in buildings.

The use of gases for fuel and lighting purposes in buildings is becoming more and more common in different parts of the country, and with the advent of new petroleum complexes and piped gas system, community gas supply is bound to become one of the important services like electricity and water supply in buildings.

The use of liquefied petroleum gas supplied in containers and cylinders is already quite popular. On release of pressure, by opening the valve, they readily convert into the gaseous phase. In this state they present a hazard comparable to any inflammable natural or manufactured gas, except that being heavier than air, low level ventilation is necessary to avoid inflammable concentration of gas. Similarly, a series of precautions and regulations are necessary for laying of natural gas pipelines from city gas distribution entity to building premises and finally in the use location. Of late, the use of medical gases in hospitals through pipelines has become quite prevalent due to associated advantages; however, this needs to be supplemented with required care and precautions.

A minimum set of safety provisions are, therefore, laid down to safeguard the gas piping installation and the mode of operation in the interest of public safety.

In the first version of the Code formulated in 1970, three separate Sections of Part 9 Plumbing services, were brought out, namely, Section 1 Water supply, Section 2 Drainage and sanitation, and Section 3 Gas supply. These Sections were subsequently revised in 1983.

In the first revision, in 1983, the safe distance between gas piping and electrical wiring system was modified as well as between gas piping and steam piping was incorporated. Additional information regarding the handling, use, storage and transportation of LPG in cylinders exceeding 500 ml water capacity were included. Provisions relating to LPG cylinders, installations regarding some aspects, such as jointing compound used at joints, painting of gas piping, details of fire extinguishers, total quantity of LPG at stationary and portable installations in proportion to the floor area were added. Also, some provisions of LPG bulk storage installations were introduced.

In the second revision in 2005, the Part 9 was renamed as ‘Plumbing Services (Including Solid Waste Management)’ and provisions on solid waste management were included for the first time under Section 1 which contained in it, Water Supply, Drainage and Sanitation. Gas Supply was covered in Section 2 of Part 9 of the Code. In this second revision, provisions with regard to pressure regulations were modified; in the provision of service shut-off valves, number of additional shut-off valves were specified; in the provision of installation of gas pipe, new materials for pipes were mentioned; the minimum diameter for gas pipe was reduced to 8 mm; the colour for pipe line for supplying natural gas was specified; the provisions regarding protection against the corrosion were modified; the process of installation of meters were clarified; and additional method for detection of leakage of gas was recommended.

In this third revision of the Code, to comprehensively address the various and distinct features related to the plumbing aspects, this Part 9 has been rearranged as follows:

Section 1	Water supply
Section 2	Drainage and sanitation
Section 3	Solid waste management
Section 4	Gas supply

Based on the experience gained in the use of this Section, the provisions have been modified in this revision. The significant changes incorporated in this revision include the following:

a) Certain terminologies have been included and others have been updated.
b) Provision of use of fire stops/sleeves at openings has been included.

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c) Clause on use of use of liquefied petroleum gas has been completely revised.
d) A new detailed clause on use of piped natural gas has been included.
e) A new clause on medical gas pipeline system has been included.
f) Cross-referred standards have been updated.

It may also be noted that the following Indian Standards have also been formulated on design and installation of natural gas pipelines:

IS 15663	Code of practice for design and installation of natural gas pipelines:
(Part 1) : 2006	Laying of pipelines
(Part 2) : 2006	Laying of pipelines in crossings
(Part 3) : 2006	Pre-commissioning and commissioning of pipelines

While implementing this standard, compliance with statutory regulations shall be ensured.

The information regarding the use of liquefied petroleum gas has been largely based on the following Indian Standards:

IS 6044	Liquefied petroleum gas storage installations — Code of practice:
(Part 1) : 2013	Residential, commercial and industrialcylinder installations (*second revision*)
(Part 2) : 2001	Commercial, industrial and domestic bulk storage installations (*first revision*)

All standards, whether given herein above or cross-referred to in the main text of this Section, are subject to revision. The parties to agreement based on this Section are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 9 PLUMBING SERVICES (INCLUDING SOLID WASTE MANAGEMENT)

Section 4 Gas Supply

1 SCOPE

1.1 This Code (Part 9/Section 4) covers the requirements regarding safety of persons and property for all piping uses and for all types of gases for purposes like fuel, lighting and medical in buildings.

1.2 This Section does not cover safety rules for gas burning appliances.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Appliance Valve — A device that will shut-off the gas supply to the burner(s).

2.2 Approved Agency — Person or agency or a corporate body approved by competent authority or distribution company to execute the job of designing, erection and maintenance of multi cylinder installation.

2.3 Authority Having Jurisdiction — The Authority which has been created by a statute and which, for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.4 Competent Authority — The Authority designated or otherwise recognized under *Gas Cylinder Rules*, 2004 for approving LPG cylinders, valves and regulators.

2.5 Customer's/Consumer's Connection — Piping tapped on riser to supply each individual customer/ consumer.

2.6 Distribution/Distributing Company — The company which is in the field of marketing LPG and PNG, and is the owner of LPG cylinders.

2.7 Gas Fitter — A qualified personnel of the authorized gas supplying organization.

2.8 Installation — A designated premises in an establishment where the complete multi-cylinder-system comprising cylinder, piping manifold, vaporizers, etc, is installed.

2.9 Manifold — A pipe header provided with several opening to which the cylinders are connected by using suitable pipe fittings.

2.10 Pilot — A small flame which is utilized to ignite the gas at the main burner(s).

2.11 Pressure Regulator — A device designed to lower the pressure of gas coming from the distribution main and to maintain it practically constants downstream. This normal operation pressure shall be practically in all cases that of the gas appliances used.

2.12 Purge — To free a gas conduit of air or gas or a mixture of gas and air.

2.13 Qualified Installing Agency — An individual, firm or agency which either in person or through a representative is engaged in and is responsible for the installation or replacement of gas piping on the outlet side of the gas meter, or the connection, installation or repair of gas supply piping and appliances within a building, and who is experienced in such work, familiar with all precautions required, and who has complied with all the requirements as to qualification, registration, licensing, etc, of the Authority.

2.14 Riser — Piping usually vertical on most of its length that supplies gas from the service to the various storeys of the building.

2.15 Service Pipe — Pipe that runs between the distribution main in the street and the riser in the case of multi-storeyed building or the meter in the case of an individual house.

2.16 Service Shut-Off Valve (Isolation Valve) — A device installed outside the premises to cut-off the main supply of gas from pipeline by the supplier.

2.17 Vent Pipe — A safety device to which certain regulators are connected to evacuate outside gas that may escape from the normal circuit when some part of system gets damaged or malfunctions or a safety valve is open.

3 PRESSURE REGULATIONS

3.1 Pressure regulation is required to economize the sizing of piping system. Where the pressure of gas supplied to domestic system or other low pressure gas piping system in buildings is in excess of the pressure to be used in the appliance, a gas pressure regulator of suitable specification shall be installed in service pipe of each system to prevent excess pressure reaching the appliance. The pressure regulators to be used can be from 400 kN/m^2 upstream pressure to 2.1 kN/m^2 for domestic consumers and 10 kN/m^2, 30 kN/m^2, 200 kN/m^2 for commercial consumers, as the case may be.

3.1.1 In some place the reduction of pressure from main

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distribution source of 400 kN/m^2 to intermediate pressure (say 7 kN/m^2) and then to operating pressure of 2.1 kN/m^2 is achieved.

3.1.2 Whereas in most of the other places the reduction of pressure from main distribution source of 400 kN/m^2 to directly operating pressure (say 2.1 kN/m^2, 10 kN/m^2, 30 kN/m^2, 200 kN/m^2) is achieved in single stage pressure reduction.

3.2 If located inside a building, the required regulator shall comply with the following:

a) If any of the diaphragms of the regulator ruptures, the gas shall be sent to an outlet vent pipe made of brass or plastic in order to ventilate or drain the gas out of the building. The vent pipe will, however, lead to outer air about 1 m above the topmost storey of the building. Means shall be employed to prevent water from entering this pipe and also to prevent stoppage of it by insects or other foreign bodies.

b) If the gas pressure at the outlet of the regulator falls below 50 percent of the operating gas pressure or rises above twice the operating gas pressure, the gas input to the pressure regulator shall be cut off.

c) In the event of malfunctioning of this safety device, a supplementary device shall connect the low pressure circuit to the outlet circuit (vent pipe) as soon as the exit pressure reaches 7 kN/m^2.

3.3 It shall also be ensured by the supply authority that the calorific value and supply pressure of gas shall not exceed the values for the type of gas used.

4 SERVICE SHUT-OFF VALVES

4.1 Service shut-off valves shall be installed on all new services including replacements in a readily accessible location.

4.2 Service shut-off valves shall be located upstream of the meter if there is no regulator or upstream of the regulator, if there is one.

4.2.1 Service shut-off valves shall be located in the upstream of the meter, if a single regulator is supplying more than one consumer and each such stream shall have one additional shut-off valve upstream of regulator.

4.3 All gas services operating at pressure greater than 7 kN/m^2 shall be equipped with an approved service shut-off valve located on the service pipe outside the building.

4.4 Underground shut-off valves shall be located in a covered durable curb box, manhole, vault or stand pipe which is designed to permit ready operation of the valve and the covers of which shall be clearly marked 'Gas'.

5 EXISTING WORK

Nothing herein shall prohibit the continued use of existing system of the gas piping without further inspection or test, unless the Authority has reason to believe that defects which make the system dangerous to life or property exist.

6 RULES FOR TURNING GAS ON

6.1 No person, unless is the employ of the gas company or having permission from the gas company, shall turn on the gas at a service shut-off valve or at any valve that controls the supply of gas to more than one consumer.

6.2 Gas shall not be turned on at any meter valve without specific permission from the gas company or other authority if any of the following conditions exists:

a) If the gas piping appliances or meter supply through the meter valve are known to leak or otherwise to be defective (*see* **10**).

b) If required inspection of the piping or appliance has not been made.

c) If the gas company or other authority has requested that the gas be left turned off.

d) If the meter valve is found shut-off for some reason not known to the gas fitter.

The gas shall not be turned on in the event of fire.

6.3 Gas shall not be turned on at any branch line valve if any of the conditions specified in **6.2** prevails. Where a branch line valve is found closed, a gas fitter shall again turn the gas on at such valve only if proper precautions to prevent leakage are taken and no other unsafe conditions are created thereby.

6.4 Gas shall not be turned on at either the meter valve or service line unless all gas keys or valves provided on all outlets in the piping system are closed or all outlets in the piping system are capped or plugged.

7 RULES FOR SHUTTING OFF THE GAS

7.1 The gas fitter shall put the gas off to any appliance, pipe or piping system and shall leave the gas turned off, until the causes for interrupting the supply has been removed in any one of the following cases:

a) If ordered to do so by the Authority.

b) If leakage of gas is noted, which appears to be sufficient to cause fire, explosion or asphyxiation.

c) If an installation of some gas appliance is found to be such as to cause a serious hazard to persons or property.

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d) If any condition exists which threatens interruption of gas supply which may cause burner outage or otherwise prove dangerous.

7.2 It shall be the duty of the installing agency when the gas supply is to be turned off to notify all affected consumers.

7.3 Before turning off the gas at the meter, for the purpose of installation, repair, replacement or maintenance of piping or appliance, all burner and pilot valves on the premises supplied with gas through the meter shall be turned off and the meter test hand observed for a sufficient length of time to ascertain that there is no gas passing through the meter. Where there is more than one meter on the premises, precaution shall be exercised to ensure that the concerned meter is turned off.

8 INSTALLATION OF GAS PIPES

8.1 Installation, repair and replacement of gas piping or appliances shall be performed only by a qualified installing agency.

8.2 Piping

8.2.1 Piping shall be of wrought iron, steel, copper, stainless steel or cast iron when the gas pressure is less than 7 kN/m^2; with higher gas pressure use of cast iron shall be prohibited.

8.2.1.1 SS 316/304/321 and flexible PE coated flexible pipe in rolls shall be permitted in low pressure system provided the pipe meets the required standard, to avoid the bends, fittings and leakages from the joint which are potential leakage points. Also, reference may be made to accepted standard [9-4(1)]. Heavy rubber flexible tube shall be permitted only as direct connection to burner from appliance valve.

8.2.1.2 For details regarding medical gas pipeline systems, a reference may be made to good practice [9-4(2)].

8.2.2 *Size of Gas Piping*

Gas piping shall be of such size and so installed as to provide supply of gas sufficient to meet the maximum demand without undue loss of pressure between the meter or service regulator when a meter is not provided, and the appliance(s).

8.2.2.1 The size of gas piping depends upon the following factors:

a) Allowable loss in pressure from meter or service regulator, when a meter is not provided, to appliance;
b) Maximum consumption to be provided;
c) Length of piping and number of fittings; and
d) Specific gravity of gas.

8.2.2.2 No gas pipe smaller than 8 mm shall be used.

8.2.3 As far as possible, straight lengths of piping should be used. Where there are bends in the pipe line, these should have a radius of at least five times the diameter of the pipe.

8.2.4 For any thread joint proper sealant shall be used on male threads only.

8.3 The gas piping shall be of the colour stipulated by explosive authority to distinguish it from other piping and the piping shall be painted silver grey with red band of 150 mm width. The gas pipeline shall be painted canary yellow in case of natural gas.

8.4 Piping Underground

8.4.1 *Protection of Piping*

Piping shall be buried to a minimum depth of 1 m or covered in a manner so as to protect the piping from physical damage.

8.4.2 *Protection Against Corrosion*

Generally all the piping within the premises where it has to run on the wall shall be exposed and should not be in contact with wall to ensure that no corrosion takes place. Epoxy sealant or polyethylene conduit shall be used to ensure no contact of pipe with the wall in the situation of pipe crossing the wall. Underground or concealed gas pipeline in contact with earth or other materials which may corrode the piping shall be protected against corrosion by application of adequate corrosion resistant coating backed up by cathodic protection system.

8.5 The building shall not be weakened by the installation of any gas piping.

8.6 Gas piping in building shall be supported with pipe hooks, metal pipe straps, bonds or hangers suitable for the size of piping and of adequate strength and quality and located at proper intervals so that the piping may not be moved accidentally from the installed position.

8.7 Pipe Entrance to Buildings

Where gas pipe enters a building through a wall or floor of masonry or concrete, any gas piping or other piping entering the walls or floors shall be suitably sealed against the entrance of water/moisture or gas.

The openings or imperfection of fit or design are also source of possible fire and smoke passing through them. Fire stops shall be provided to fill the openings around penetrating items such as gas pipes, etc, through the wall or floor openings. Non-combustible sleeving may

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also be used as an alternative to proprietary seals for penetration of pipes of lead, aluminium, aluminium alloy, fibre cement or uPVC up to a specified nominal internal diameter. Proprietary fire stopping and sealing systems which have been shown by test to maintain the fire resistance of the wall or other elements, are available and may be used. Other fire stopping materials include cement mortar; gypsum-based plaster; cement or gypsum vermiculite/perlite mixes; glass fibre, crushed rock, blast furnace slag, or ceramic based products (with or without resin binders), and intumescent mastics. These may be used in situations appropriate to the particular material. Not all of them will be suitable in every situation. When sleeving is used, its length should be greater than the thickness of wall or floor. The sleeve shall be properly grouted to maintain fire/smoke separation.

Regarding protection of openings in walls or floors, from fire, reference shall be made to Part 4 'Fire and Life Safety' of the Code.

8.7.1 *Piping in Floors*

Piping in solid floors, such as concrete, shall be laid in channels in the floor suitably covered to permit access to the piping with a minimum damage to the building.

8.7.2 Single pipe without joint shall be used for wall crossing in any building.

8.8 Gas pipe shall not be bent. Fittings shall be used when making turns in gas pipe.

8.9 Generally concealed piping shall not be allowed. However, if it is necessary then it shall be under the **8.4** of underground piping and all protection such as coating, cathodic protection shall be done.

8.10 A drip shall be provided in the gas distribution system, if the moisture contents in the gas is likely to reach saturation point at any stretch of pipe line in the system; a drip shall, however, be provided at any suitable point in the line of the pipe where condensate may collect and from where it can be easily removed. This drip should be so installed as to constitute a trap where in an accumulation of condensate will shut-off the flow of gas before it will run back into the meter.

8.10.1 Drip has to be provided in the case of gas consisting moisture content.

8.11 Prohibited Devices

No device shall be placed inside the gas piping or fittings that will reduce the cross-sectional area or otherwise obstruct the free flow of gas.

8.12 Piping shall be electrically continuous throughout its length and properly earthed except in stretches where cathodic protection system is used for protection against corrosion. It shall not, however, be used to earth any electrical equipment.

8.12.1 The distance between gas piping and electrical wiring system shall be at least 60 mm and, where necessary, they shall be securely fixed to prevent contact due to movement. The gas piping should run above the electrical wiring. In this type of installation in the event of any leakage of natural gas, the gas would move up (natural gas being lighter than air) and would not come directly in contact with the electrical wiring. If the gas to be supplied is heavier than the air then the gas piping should run below the electrical wiring.

8.13 The distance between the gas piping and steam piping, if running parallel, shall be at least 150 mm. The gas piping should preferably run below the steam piping.

8.14 Piping installation shall be thoroughly gastight.

8.15 Smoking shall not be permitted when working on piping which contains or has contaminated gas.

8.16 Meters shall be installed in such a way that there shall be no load transfer from the pipeline to the inlet/outlet of the meter and shall be easily accessible.

9 INSPECTION OF SERVICES

9.1 No person shall use or permit the use of a new system or an extension of an old system of gas piping in a building or structure before the same has been inspected and tested to ensure the tightness of the system, and a certificate has been issued by the Authority.

9.1.1 *Test of Piping for Tightness*

Before any system of gas piping is finally put in service, it shall be carefully tested to ensure that it is gastight. Where any part of the system is to be enclosed or concealed, this test should precede the work of closing in. To test for tightness the piping may be filled with city gas, air or inert gas but not with any other gas or liquid. In no case shall oxygen be used. The piping shall stand a pressure of at least 20 kN/m^2 measured with a manometer or slope gauge, for a period of not less than 10 min without showing any drop in pressure.

9.1.2 When the gas pressure exceeds 7 kN/m^2, the piping shall withstand a pressure of 0.6 MN/m^2 for 4 h (this test is for piping designed for working pressure less than 0.4 MN/m^2).

9.2 The Authority shall, within a reasonable time after being requested to do so, inspect and test a system of gas piping that is ready for such inspection and test, and if the work is found satisfactory and test requirements are complied with, it shall issue the certificate.

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10 LEAKAGE CHECK

10.1 Before turning gas under pressure into any piping, all openings from which gas may escape shall be closed.

10.2 Checking for Gas Leakage

No matches, flame or other sources of ignition shall be employed to check for gas leakage from meters, piping or appliances. Checking for gas leakage with soap and water solution is recommended.

10.3 Use of Lights

Artificial illumination used in connection with a search of gas leakage shall be restricted to electric hand flash lights (preferably of the safety type) or approved safety lamps. In searching for leaks, electric switches should not be operated. If electric lights are already turned on, they should not be turned off.

10.4 Checking for Leakage with Meter

Immediately after turning gas into the piping, the system shall be checked to ascertain that no gas is escaping. This may be done by carefully watching the test dial of the meter to determine whether gas is passing through the meter. In no case should a leakage test be made using a gas meter unless immediately prior to the test it has been determined that the meter is in operating condition.

10.5 Checking of Leakage Without Using a Meter

This may be done by attaching to an appliance, orifice or a manometer or equivalent device and momentarily turning on the gas supply and deserving the gauging device for pressure drop with the gas supply shut-off. No discernible drop in pressure shall occur during a period of 3 min.

10.6 After piping has been checked, all gas piping shall be fully purged. Piping shall not be purged into the combustion chamber of an appliance. A suggested method for purging the gas piping to an appliance is to disconnect the pilot piping at the outlet of the pilot valve.

10.7 After the gas piping has been effectively purged, all appliances shall be purged and the pilots lighted.

10.8 In addition to the checking of gas leakage with soap and water solution, a suitable gas detector is also recommended for use.

11 USE OF LIQUEFIED PETROLEUM GAS (LPG)

11.1 The cylinders used for the storage and transportation of liquefied petroleum gas (LPG) shall conform to accepted standards [9-4(3)] approved by the statutory authority.

11.2 The handing, use, storage and transportation of liquefied petroleum gas in cylinders exceeding 500 ml water capacity shall be done in accordance with good practice [9-4(4)].

11.3 LPG Cylinder Installation

The following recommendations apply to installation in commercial, industrial, educational and institutional premises.

11.3.1 *General Recommendations*

11.3.1.1 Those responsible for the installation of cylinders, equipment and piping should understand the characteristics of LPG and be trained in good practice of handling, installing and maintaining installations.

11.3.1.2 The jointing compound used at different joints in the system shall be decided by the Qualified Installing Agency. Hemp and similar materials shall not be used at the joint. In any joint in which the thread provides a gastight seal, jointing compound shall be used only on the male thread.

11.3.1.3 Fire extinguishers of dry powder type or carbon dioxide type conforming to accepted standards [9-4(5)] shall be provided in places where LPG cylinder installations are situated and shall be located near such installations. Two buckets filled with sand and two with water shall also be installed nearby. The number, type and size of the fire extinguishers shall be as follows:

	Number	*Type*	*Capacity*
a) For installations with LPG 40 kg to 200 kg	2	Dry powder	9 kg
b) For installations with LPG more than 200 kg and up to 320 kg	3	Dry powder	9 kg
c) For installations with LPG more than 320 kg and up to 1 000 kg	4	Dry powder	9 kg

NOTE — For electrical installations, one number CO_2 fire extinguisher (4.5 kg capacity) shall be provided.

11.3.1.4 Liquefied petroleum gas shall not be transferred from the cylinders in which it is received to any other container.

11.3.2 *Cylinder Location*

11.3.2.1 *Stationary installations*

a) Stationary installation not exceeding 50 kg of LPG may be installed indoors on any floor. It is recommended to have a minimum floor area of 5 m^2 for such an installation.

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b) Stationary installations each not exceeding 50 kg of LPG may be installed indoors on any floor and within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 5 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

c) Stationary installation not exceeding 100 kg of LPG may be installed indoors on any floor provided the floor area for such an installation is not less than 12 m^2.

d) Stationary installations each not exceeding 100 kg of LPG may be installed indoors on any floor and within the same workspace provided the minimum distance between two such installations is 3 m, the proportion of such installations to floor area is one installation per 12 m^2 and the aggregate quantity of gas of all such installations does not exceed 200 kg.

e) Stationary installation not exceeding 400 kg of LPG may be installed indoors in an enclosed section of a building or a room reserved exclusively for this purpose and ventilated at low level directly to the outside air.

f) Stationary installations above 400 kg [200 kg in case provision as in (e) is not possible] but not exceeding 1 000 kg shall be installed outdoors on ground floor level only. A minimum distance of 3 m shall be maintained between an installation and any building, public place, roadways, and other surroundings. The installation shall be protected from excessive weathering by sun, rain, etc, and from tampering by unauthorized persons. A lean-to roof with expanded metal on angle-iron framework on the sides is considered suitable for this purpose. In any case, adequate ventilation at ground level to the outside air shall be provided.

g) If the storage per installation is more than 1 000 kg, installations in multiples of 1 000 kg with manifold, safety devices, change over mechanism may be provided with minimum inter distance of 3 m from all sides. Total number of such installations shall not exceed 4 including stand by installation. If more than two installations are used, then number of cylinders per installations should not exceed 30.

h) For storage installations of 1 000 kg or installations in multiple of 1 000 kg the number of cylinders to be connected per manifold shall not exceed 15 and for each 1 000 kg installation two such manifolds shall be provided.

j) Cylinders shall be installed upright with the valves uppermost.

k) Cylinder containing more than 20 kg of gas shall not be located on floors above ground level.

m) Cylinders shall be located on a concrete or brick floor, preferably raised in case of outdoor installations.

n) In order to prevent the hazardous collection of gas, cylinders shall be placed at least 1 m away from culverts, depressions, or openings leading to below ground level compartment and drains.

p) Cylinders which have safety relief valves or similar devices incorporated in them shall be so positioned so that if the relief device operates, escaping gas is not hazardous.

q) Cylinder installation for commercial/ industrial/domestic/residential complexes, etc, or at any public place shall meet the following requirements:

1) For commercial and industrial cylinder installation for any public places like mall, buildings, industries, hotels, etc, the sum total of all stationery installations inside the building shall not exceed 400 kg of LPG in any case. In case sum total of net weight of all the cylinders installed indoors exceed 400 kg provision for outdoor installations shall be made. For installations where the sum total is less than 400 kg of LPG provisions of (b) to (e) shall apply.

2) For commercial and industrial cylinder installation for any public place, industry, etc, if the net weight of all the cylinders installed is more than 400 kg but less than 1 000 kg, than the installation shall be provided outdoors in line with (f). The cylinder installation shall be provided in a covered industrial shed but open from all sides for proper ventilation. In case the installed capacity increases more than 1 000 kg, than the installation shall be provided in line with (g). Two separate installations shall be provided and distance between each of the installations shall be minimum 3 m (this distance shall be between the outer edge of the two sheds).

3) For multi-storeyed buildings, flats housing society the reticulated installation of any capacity shall be provided at a safe

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place especially earmarked for this purpose. The installation shall not be provided by the side of road where there is continuous movement of vehicles or is approachable to residents especially children. The installation should be secured and should be provided in a covered shed open from all sides for ventilation. The area shall be demarcated by 1.5 m high chain link fencing having one gate. There should be minimum 3 m clear space all around the fencing and the space between the fencing and the edge of the shed should be minimum 2 m all around.

4) If the requirement is more than 1 000 kg, installations in multiples of 1 000 kg with manifold, safety devices, change over mechanism, not exceeding 4 such installations (including stand by) may be provided with minimum distance of 3 m from all sides. The number of cylinders per installations should not exceed 30.

5) Location of cylinder bank:

   i) The site for LPG cylinder manifold shall be located away from the kitchen/LPG utility area/residential building. Installation shall be slightly raised minimum 100 mm from surrounding ground level.

   ii) Cylinders installation should not be located in inaccessible location, under a stairway, basements, cellars, where air movement across cylinders is very low/not present, to prevent the cylinders from getting inadequate latent heat and unapproachable during emergency.

   iii) Cylinders installation should not be close to steam pipes, boilers, transformers, DG sets, etc, to prevent cylinders from getting affected due to radiant heat.

   iv) Cylinders shall not be installed at a place where they are likely to cause obstruction, suffer damage or be exposed to conditions likely to affect safety.

   v) Cylinders installation should not be located along the drive way. Under unavoidable conditions, minimum distance of 3 m from drive way shall be maintained. Brick masonry (minimum 230 mm thick)/concrete (minimum 100 mm thick) walls or metallic shields/barriers (minimum 1.63 mm sheet) and of minimum 2 m height should be erected between drive way and cylinder installation for the safety and security of the installation.

   vi) Cylinders shall be located on a concrete or brick floor that is firm, at level, smooth, drained in case of outdoor installation.

   vii) The cylinder shall be installed in upright position with the valve pointing upwards and minimum 1 m away from any combustible materials.

r) Cylinder storage room:

   1) The cylinder storage room shall be made out of non-flammable material that is concrete (minimum 100 mm thick) or brick masonry walls (minimum 230 mm thick) or steel structures made out of minimum 5 mm thick MS angle iron structure and 1.63 mm MS wire mesh of size minimum 11.

   2) Since LPG is heavier than air, ventilation shall be provided at floor level, that is 100 mm above inside cylinder bank room, open to atmosphere. The ventilators shall be provided with 2 layers copper or non-corroding metal wire mesh not less than 11 to the linear centimetre. The size of the ventilators should be minimum 500 mm long and 300 mm height.

   3) The storage room shall be well ventilated, that is openings/ventilators shall be provided in the walls of cylinder storage covering minimum 25 percent of wall area. It should also have adequate lighting. Both exteriors and interiors should be painted with weather proof paints. FLP fittings, approved by statutory authorities shall be provided for electrical use.

   4) The doors of the room where cylinders are installed shall open outwards and shall have louvers/wire mesh to ensure visibility and ventilation.

   5) Flammable materials like wood and plastic shall not be used. The cylinder bank storage room shall not used for storing any other materials.

11.3.2.2 *Portable installations*

When portability of cylinders is necessary, the following requirements shall be fulfilled:

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a) The sum total of capacity of the cylinders connected to each manifold shall not exceed 100 kg of LPG. The total quantity of gas thus installed in a workspace shall not exceed 200 kg.
b) If cylinders are mounted on a trolley, the trolley shall be stable. Where necessary, the cylinders shall be secured to prevent them from falling.
c) The regulator shall be connected directly to the cylinder valve or to a manifold which shall be connected to the cylinder valves by means of rigid connections to give adequate support to the regulator. The only exception to this requirement is where cylinders are mounted on a trolley and the manifold is rigidly supported on the trolley. In such a case flexible or semi-flexible connections may be used between the cylinder valves and the manifold but not between the manifold and the regulator.
d) Anytime the total quantity of gas at portable installations shall be in proportion to the floor area as specified in **11.3.2.1** (a) to (f).
e) At any time the provisions at **11.3.2.1** (a) to (r) shall be ensured for all installations.

11.3.3 *Cylinder Manifolds*

11.3.3.1 All materials, fittings, etc, used in cylinder manifold systems shall comply with the statutory provisions or relevant Indian Standards. In absence of any such provisions or Indian Standards, equivalent international norms shall be followed.

11.3.3.2 The individual component parts of manifolds, that is piping, fittings, pigtails, etc, which are subject to cylinder pressure shall be capable of withstanding a test pressure without bursting of 2.5 N/mm^2 or one and a half times the developed pressure at 65°C, whichever is more.

11.3.3.3 Where cylinder installations are made up with service and reserve batteries of cylinders, suitable change-over devices or valves shall be incorporated in the manifold header to prevent undue escape of the gas when cylinders are changed.

11.3.3.4 In case pressure regulators, manifold headers and automatic change-over devices are connected to cylinder by semi-flexible connectors, these shall be rigidly supported. Copper tube pigtails are considered to be semi-flexible for this purpose.

11.3.3.5 It is recommended that joints in manifold headers which do not have to be broken in normal use should be welded or brazed using a material which shall have a melting point of at least 540°C.

11.3.3.6 All joints between manifold headers and cylinder connectors shall be readily accessible.

11.3.3.7 All joints in the manifold should be welded (except for valve fixation) and be easily accessible for inspection/repairs, etc.

11.3.3.8 Each manifold arm shall be fabricated in such a way that minimum joints are provided. Only seamless pipes are recommended for use in manifolds. There should be a minimum gap of 300 mm between the manifold and valve protection ring of the LPG cylinders.

11.3.3.9 The cylinders connected to a manifold shall be safely spaced for easy and safe replacement of cylinder when empty. A minimum distance of 400 mm shall be maintained between two nipples provided on the manifold for connecting the cylinders to the manifold. In case the diameter of the cylinder is higher than 400 mm then the distance between the two nipples shall be diameter of the cylinder plus 100 mm.

11.3.3.10 A pressure gauge of 100 mm dial shall be provided in the manifold to indicate the gas pressure in the manifold. The pressure gauge shall be suitable for a pressure range 0 to 1.0 N/mm^2.

11.3.4 *Pressure Regulators*

11.3.4.1 Pressure regulators and other devices used to control the gas shall comply with the distributing company's stipulations and accepted standards [9-4(6)].

11.3.4.2 Pressure regulator fitted with a safety valve shall be either,

a) installed in the open air; or
b) vented to the open by means of a metal vent pipe connected to the safety valve outlet.

11.3.4.3 Care shall be taken that safety valve outlets do not become choked with dust or other foreign matter.

11.3.4.4 If the regulator is fitted with a relief valve, care should be taken in positioning the regulator to avoid unnecessary hazards if the relief valve functions.

11.3.4.5 Pressure regulators and other control devices shall be adequately supported.

11.3.5 *Instructions to Consumers*

Consumers shall be instructed by the distribution company on the following, through appropriate written instructions:

a) Operation of the whole system;
b) How to recognize gas leaks;
c) Action to be taken in case of leakage;
d) Action to be taken in case of fire; and
e) Action to be taken in case of damage to, or failure of, any part of the installation.

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11.3.6 For detailed information regarding installation of LPG cylinders in commercial, industrial, educational and institutional premises, reference may be made to good practice [9-4(7)].

11.4 LPG Bulk Storage Installations

The following recommendations apply to LPG bulk storage installations where storage tanks over 450 litre water capacity are used at industrial, commercial and domestic consumers' premises.

The maximum capacity of an individual tank and group of tanks at industrial, commercial and domestic premises shall be as follows:

Premises	*Maximum Water Capacity of an Individual Tank*	*Maximum Water Capacity of Group of Tanks*
	ℓ	*ℓ*
Industrial	130 000	260 000
Commercial	40 000	80 000
Domestic	20 000	80 000

11.4.1 *Location and Spacing of Storage Tanks*

11.4.1.1 Storage tanks shall be located outside the buildings and shall not be installed one above the other.

11.4.1.2 Each individual tank shall be located with respect to the nearest important building or group of buildings or line of adjoining property which may be built in accordance with Table 1. The distances given refer to the horizontal distance in plan between the nearest point of the storage tank and building/property line.

11.4.1.3 In heavily populated or congested areas the authority may determine the need for other reasonable protective methods to be taken, such as provision of fire walls, etc. If fire walls are to be provided, the authority may determine the extent to which the safety distances for above ground tanks may be reduced.

11.4.1.4 No LPG tank(s) shall be located within the bunded enclosures of any petroleum installation. The minimum distance of separation between LPG storage tanks and any petroleum installation shall be as prescribed under the *Petroleum Rules*, 1976 or as specified in Table 1, whichever is more.

11.4.1.5 The number of storage tanks in one storage installation shall not exceed six. In case there are more than one storage installations, the safety distance between two installations shall be the same as the distance between the tanks and the property line in accordance with Table 1.

11.4.2 *Bunding*

Since LPG is heavier than air, storage tank shall not be enclosed within bund walls. The accumulation of flammable liquid under LPG tanks shall be prevented by suitably slopping the ground.

11.4.3 *Protection*

11.4.3.1 To prevent trespassing or tampering, the area which includes tanks, direct fired vapourisers, pumping equipment and loading and unloading facilities shall be enclosed by an industrial type fence at least 2 m high along the perimeter of the safety zone. Any fence shall have at least two means of exit. Gates shall open outwards and shall not be self-locking.

11.4.3.2 When damage to LPG systems from the LPG tank lorry is a possibility, precautions against such damage shall be taken.

Table 1 Minimum Safety Distances

(*Clauses* 11.4.1.2, 11.4.1.4 *and* 11.4.1.5)

Sl No.	LPG Storage Water Capacity of Individual Tank ℓ	Distance from Building/ Property Line		Distance between Tanks	
		Above Ground m	Under Ground m	Above Ground m	Under Ground m
(1)	(2)	(3)	(4)	(5)	(6)
i)	Up to 2 000	5	5	1	1.5
ii)	Above 2 000 and up to 10 000	10	7.5	1	1.5
iii)	Above 10 000 and up to 20 000	15	10	1.5	1.5
iv)	Above 20 000 and up to 40 000 adjacent	20	15	2	0.25 × diameter of vessel or 1.5 m (*Min*)
v)	Above 40 000 and above adjacent	30	15	2	0.25 × diameter of vessel or 1.5 m (*Min*)

NOTE — If the aggregate water capacity of a multi-tank installation is 40 000 litre or greater, the above minimum safety distances shall apply to the aggregate storage capacity rather than the capacity per individual storage tank.

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11.4.3.3 Underground tanks shall be protected from above ground loading by providing a suitable curb to prevent a possible accidental damage to the tank and its fittings by LPG tank lorry.

11.4.4 *Grass and Weed Removal*

Road ignitable material, such as weeds, long grass or any combustible material shall be removed from an area within 3 m from the shell of any LPG tank of up to 2 000 litre water capacity, and within 6 m from the shell of larger tanks. If weed killers are used, chemicals which are a potential source of fire hazard shall not be selected for this purpose.

11.4.5 *Warning Signs*

No smoking or naked flames shall be permitted within the safety zone of the installation. Prominent notices to this effect shall be posted at access point. From accessibility point of view, the signs shall be in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

11.4.6 *Fire Protection*

The possibility of a major fire outbreak, leading to direct flame impingement of the storage tank, shall be minimized by sound engineering in plant design and layout, good operating practice, and proper education and training of personnel on both routine operations and on action to be taken in an emergency.

11.4.6.1 *Water supply*

Provision shall be made for an adequate supply of water and fire protection in the storage area according to the local hoses and mobile equipment, fixed monitors or by fixed spray systems which may be automatic. Control of water flow should be possible from outside any danger area.

11.4.6.2 *Fire extinguishers*

At least two dry chemical powder type fire extinguishers of 9 kg capacity each, conforming to the quality requirements in accordance with the accepted standards [9-4(5)], shall be installed at points of access to the storage installations. The fire extinguishers shall be mounted keeping in view the ease of accessibility in accordance with good practice [9-4(8)] and Part 4 'Fire and Life Safety' of the Code.

11.4.7 For detailed information regarding LPG bulk storage installations reference may be made to good practice [9-4(9)].

12 USE OF PIPED NATURAL GAS (PNG)

12.1 The PNG infrastructure shall be in complete compliance with all the requirements of *Petroleum and Natural Gas Regulatory Board* (*Technical Standards and Specifications including Safety Standards for City or Local Natural Gas Distribution Network) Regulations*, 2008.

12.1.1 The user-group/housing society concerned (referred hereinafter in these clauses as 'society') should contact the local city gas distribution (CGD) entity at the stage of the design of the building. This ensures that all the adequate provisions are incorporated in the design itself, as also the compliance with all the safety standards stipulated/required by the regulations/ gas entities, as applicable from time-to-time. This ensures avoidance/mitigation of any rework at a later stage, or even situations where incorporation of any changes may become impractical or not possible, thereby rendering the building devoid of PNG infrastructure.

12.1.2 The entire gas pipeline infrastructure proposed to be laid in the premises of the society shall be easily accessible in future by the representatives of the CGD entity. Provision should be made by the builder for the same. Builder/society should ensure communication of the same to the future customer and should incorporate it in their agreements with the customer.

12.1.3 No permanent/temporary structure shall be erected on the ground along the paths where gas pipeline exists underground.

12.2 The PNG infrastructure inside the premises of societies primarily comprises the following:

a) Underground medium pressure (MP) pipeline networks, comprising mainly polyethylene pipes and fittings;
b) Underground low pressure (LP) pipeline networks, comprising mainly polyethylene (PE) pipes and fittings;
c) Service regulator modules;
d) Above ground riser and lateral system, comprising mainly ERW GI pipes and fittings; and
e) Pipeline inside premise and/or kitchen of individual customer, comprising various components like meter regulator, diaphragm gas meter, copper pipe, brass fittings, brass valves, etc.

The guidelines mentioned under **12.3** to **12.6** give the minimum requirements to be complied with.

12.3 Guidelines for MP and LP Pipeline Networks

12.3.1 Gas pipelines are required to be laid at a minimum top cover of 1 m from the finished surface level. Underground PE pipeline shall not be laid through the basement.

12.3.2 A minimum clearance of at least 300 mm is

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required to be maintained between the gas pipelines and any other obstacles/services.

12.3.3 Gas pipelines should not be laid closer to properties than as stipulated below:

Pressure	*Minimum Proximity*
Up to 0.01 N/mm^2	0.25 m
Up to 0.4 N/mm^2	3.00 m

12.3.4 If required, provision of underground ducts may be provided by the society within their premises at the time of construction of the building, to facilitate inserting of gas pipelines at a later stage. The duct through which gas pipeline is to be laid should not be shared with pipeline of any other utility, for safety reasons.

12.3.5 The ducts/sleeves should be 150 mm of PVC. The top cover of the sleeve should be at least 1 m below finish ground level. The material of ducts, sleeves and fittings to be used for construction shall be of high quality and in compliance with the concerned Indian Standards. In some cases, if applicable, there may be multiple number of ducts required to be laid.

12.3.6 Service chambers should be provided at 15 m to 20 m centre-to-centre (in case of straight sections) and also at bends, tees, and before and after slopes. Size of the service chamber shall be 1.0 m × 0.6 m (inside dimensions) and top of the cover of the duct should be at least 1.0 m high. Cover of the chamber should be capable of sustaining expected vehicular load. The service chamber should be filled with sand after MGL PE gas pipe is laid through the ducts provided.

12.3.7 The ducts for gas pipeline should be maintained at offset distance of at least 1.0 m from electrical services and 1.5 m from any other structure. Crossing with other utilities/services should be at a difference in level of at least 300 mm.

12.3.8 During the period between laying of ducts and insertion of gas pipeline, all the ends/entries of the ducts laid shall be temporarily closed to avoid the entry of mud, debris, rodents, etc, inside the ducts.

12.3.9 After the insertion of gas pipeline through ducts, the annular space between the duct and the gas pipe at all the ends (which creates possibility of entering undesired objects) should be plugged using a RCC half round pieces and plastered with cement.

12.3.10 The ducts and other elements of the duct system should be properly maintained subsequent to their installation and till the time of insertion of gas pipeline through the same.

12.4 Guidelines for Service Regulator Modules

The user-group/society should provide adequate open spaces in the premises for installation of gas equipment like regulating stations, which will be required to facilitate supply of PNG to the residents of the building/ premise. The identified location shall be such that it does not obstruct any vehicular movement and is at a safe location in the premise.

12.5 Guidelines for Above Ground Riser and Lateral System

12.5.1 The riser and lateral system supplying gas to multi-storeyed residential buildings shall be in compliance with the requirements of the PNGRB regulations.

12.5.2 Multi-occupancy buildings having eight floors or more should have purpose-built utility shafts/ducts for accommodating riser and lateral system, which should be preferred route for constructing/locating the riser.

12.5.3 Provision shall be made for safe access to the riser and lateral system by the representatives of the CGD entity for future maintenance and repair. In the case of a continuous shaft, a concrete slab or similar flooring shall be provided for maintenance work at each floor.

12.5.4 *Ventilation*

12.5.4.1 Adequate provision for natural ventilation shall be provided in the building where PNG infrastructure is laid, so as to prevent any potential gas leaks from accumulating in the atmosphere to an unsafe level. Mechanical ventilation shall not be used to achieve the required ventilation levels. The minimum levels of ventilation in risers ducts/shafts shall be as given below:

Cross Sectional Area (CSA) of Riser Duct	*Minimum Free Area of Each High and Low Level Ventilation (Open Ventilator)*	*Typical Air Duct Size*	*Typical Ventilator Size*
m^2	m^2	mm	mm
Less than 0.01	0.002	Ø50	Ø70
0.01 to 0.375	0.010	Ø100	100 × 100
0.375 to 0.5	0.02	Ø150	100 × 200
0.5 to 7.5	0.05	Ø250	200 × 250
More than 7.5	1 percent CSA of the duct	–	–

12.5.4.2 Where the duct has a single ventilator that is part of the architectural design of the building, the free area of the ventilator to outside area shall be a minimum of 0.04 m^2 or 4 percent of the CSA of the duct, whichever is greatest.

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12.5.4.3 Pipe work shall be installed in an unventilated void.

12.5.4.4 The pipe may enter the building to gain access to the riser shaft *via* a basement or car parking area, provided the area is well ventilated.

12.5.4.5 Any duct containing a riser or lateral shall be ventilated either directly to outside air, or indirectly to outside air *via* an area that is normally occupied and is itself ventilated to outside.

12.5.4.6 The provision of ventilation should be *via* permanent ventilators within the area/duct containing pipe-work.

12.5.4.7 All flammable release sources shall be at a lower elevation than the bottom of the highest ventilation opening.

12.5.4.8 Pipes may run in the same duct (subject to availability of adequate clearance from other utilities and ventilation) as most other services, including hot and cold water services, heating pipes, electrical conduits and cables and pipes containing other fuels. However, the following services shall not be installed in the same duct as gas pipes:

a) Ventilation ducts and vacuum pipes that operate at sub-atmospheric pressure and that are not of all-welded or all-brazed construction; and
b) Services containing oxidizing or corrosive fluids.

12.5.5 There shall be provision for installing risers and laterals such that a minimum distance of 300 mm is ensured from any electrical equipment or installations and associated excess current control boxes of fuse boxes, and 25 mm is ensured from the electricity supply and distribution cables and other metal piped services.

12.5.6 In case where the gas pipeline is required to cross through a wall, provisions (like core cutting) or holes of adequate size drilled through the wall/building structure, to accommodate an easy passage of the gas pipelines through them, shall be made. The elevation of these provisions/holes shall be near the roof and not near the floor of the room.

12.6 Guidelines for Pipeline Inside Premise and/or Kitchen of Individual Customer

12.6.1 Meters will normally be located inside the property on an outside wall with a minimum length of inlet pipe-work inside the property. Kitchen is the preferred room to locate the meter, thereby minimizing the length of the outlet pipe work.

12.6.2 The gas meter shall be installed in an area with adequate ventilation and at a proper location to facilitate safe and convenient meter reading and maintenance activities in future. A minimum ventilation area of 2 percent of the internal floor area of the room shall be provided in the room where the gas meter is located. The gas pipeline inside the kitchen shall be laid along the walls of the kitchen and in a ventilated area.

12.6.3 In case pipe work is required to be laid in solid floors inside the kitchen, adequate provisions (in the shortest possible route and a minimum of 75 mm screed to provide an approximate cover of at least 50 mm over the gas pipe) shall be provided to protect the pipeline against corrosion and failure caused by movement. This method of construction consists of a base concrete raft foundation onto which a cement screed is subsequently laid in order to obtain a satisfactory surface to accept the floor finish. Provision of preformed ducts with protective covers should be made to facilitate laying of gas pipeline. It is advisable to contact the CGD entity at the designing stage so that adequate provisions are incorporated in the design of the kitchen/floor plan to facilitate easy and safe installation of PNG system.

12.6.4 Installation pipe work shall not be placed within the cavity of a cavity wall. Every pipe passing through a cavity wall shall take the shortest possible practicable route and shall be sleeved.

12.6.5 In case of provision of sleeve, the same should be of a diameter that provides a sliding fit to the pipe allowing normal pipe expansion/contraction.

13 USE OF MEDICAL GAS PIPELINE SYSTEM (MGPS)

13.1 General

A medical gas pipeline system (MGPS) is installed to provide a safe, convenient and cost effective system for the provision of medical gases to the clinical and nursing staff at the point of use. It reduces the problems associated with the use of gas cylinders such as safety, porterage, storage and noise.

MGPS generally handles distribution of oxygen, nitrous oxide, medical air, surgical air, medical vacuum only; and sometimes provides anaesthetic gas scavenging systems. All other gases used in hospitals have low volume use and are provided through cylinders at the point of use.

It is essential to ensure that there is no possibility of a cross-connection between any system and that all parts of each system to which connections can be made by users are gas specific.

Separate installations are provided for pathology, general laboratories and special laboratories. These are designated Laboratory Gases (Pipeline) Supply System (LGSS). LGSS is provided with valve controlled outlets and shall never be provided with medical gas terminal units.

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Use and storage of medical gases is governed by *Indian Drugs and Cosmetics Act*, 1940.

13.2 Design and Installation

13.2.1 *Pipelines Systems for Compressed Medical Gases and Vacuum*

The design, installation, performance, documentation, testing and commissioning of pipeline systems for compressed medical gases, gases for driving surgical tools and vacuum in healthcare facilities to ensure continuous delivery of the correct gas and the provision of vacuum from the pipeline system, shall be in accordance with the good practice [9-4(10)]. This is inclusive of the requirements for supply systems, pipeline distribution systems, control systems, monitoring and alarm systems and non-interchangeability between components of different gas systems.

13.2.2 *Anaesthetic Gas Scavenging Disposal Systems*

The design, installation, performance, documentation, testing and commissioning of anaesthetic gas scavenging disposal systems to ensure patient safety and to minimize exposure of the operator and other persons to anaesthetic gases and vapours, shall be in accordance with the good practice [9-4(11)]. This is inclusive of requirements for the power device, pipeline system, performance, non-interchangeability between key components and avoidance of cross connections between anaesthetic gas scavenging (AGS) disposal systems and medical gas and vacuum pipeline systems.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	14885 : 2001	Specification for polyethylene pipe for the supply gaseous fuel
(2)	IS/ISO 7396-1 : 2007	Medical gas pipelines systems : Pipelines systems for compressed medical gases and vacuum
	IS/ISO 7396-2 : 2007	Anaesthetic gas scavenging disposal systems
(3)	3196 (Part 1) : 2013	Specification for welded low carbon steel cylinders exceeding 5 litres water capacity for low pressure liquefiable gases: Part 1 Cylinders for liquefied petroleum gases (LPG) (*sixth revision*)
	7142 : 1995	Specification for welded low carbon steel cylinders for low pressure liquefiable gases not exceeding 5 litre water capacity (*first revision*)
(4)	8198 (Part 5) : 1984	Code of practice for steel cylinders for compressed gases: Part 5 Liquefied petroleum gas (LPG) (*first revision*)
(5)	15683 : 2006	Specification for portable fire extinguishers — Performance and construction
(6)	9798 : 2013	Low pressure regulators for use with liquefied petroleum gas (LPG) mixtures
	4786 : 2014	Specification for variable high pressure regulators for use with liquefied petroleum gas
(7)	6044 (Part 1) : 2013	Liquefied petroleum gas storage installations — Code of practice: Part 1 Residential, commercial and industrial cylinder installations (*second revision*)
(8)	2190 : 2010	Code of practice for selection, installation and maintenance of first-aid fire extinguishers (*fourth revision*)
(9)	6044 (Part 2) : 2001	Code of practice for liquefied petroleum gas storage installations : Part 2 Commercial, industrial and domestic bulk storage installations (*first revision*)
(10)	IS/ISO 7396-1 : 2007	Medical gas pipelines systems : Pipelines systems for compressed medical gases and vacuum
(11)	IS/ISO 7396-1 : 2007	Anaesthetic gas scavenging disposal systems

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NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPE DEVELOPMENT, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 1 Landscape Planning, Design and Development

BUREAU OF INDIAN STANDARDS

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National Building Code Sectional Committee, CED 46

FOREWORD

This Code (Part 10/Section 1) covers provisions relating to landscape planning, design and development with the aim of improving quality of outdoor built environment and protection of the land and its resources.

This Part of the Code was first published in 1970 and subsequently revised in 1983 and 2005. This Part earlier covered provisions relating to only signs and outdoor display structures. With growing urban development and environmental degradation, it had become imperative to determine landscape design parameters, and also provide rules, regulations, controls and procedures for the protection, preservation and modification of surrounding environment. In the last revision of 2005, this Part was, therefore, sub-divided into two sections as follows, by including a new section relating to landscaping:

Section 1 Landscape planning and design

Section 2 Signs and outdoor display structures

The components of landscape design and external development were earlier covered in the Code in its various Parts/Sections but a comprehensive treatment was given in this new Section in the last revision only. A brief clause on street furniture was also introduced in this Section in the last revision.

In this revision, the Section is now called, Section 1 Landscape planning, design and development, and accordingly various provisions have been detailed to cover relevant aspects relating to overall landscape planning, design and development. In this revision, the following modifications have been incorporated:

a) Certain terminologies have been included/modified in view of the inclusion of above mentioned provisions and technological advancements in this field.
b) A new clause relating to landscape site planning requirements has been included.
c) A new clause covering in detailed guidelines relating to general development of landscapes has been included.
d) A new clause relating to roof landscape has been added.
e) Provisions relating to earth slopes and their grading have been shifted and now covered under the clause on statutory approvals.
f) New provisions related to materials and finishes plan have been included as part of the landscape development documents required for statutory approvals.
g) Provisions relating to paved surfaces in external areas have been shifted and now included under general development of landscapes for logical sequencing.
h) Lists of various plant species for different applications have been updated under various clauses.

The work of landscape planning, design and development is to be carried out by professionals in accordance with their qualification and competence given in Part 2 ‘Administration’ of the Code keeping in view the provisions of this Section.

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPE DEVELOPMENT, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 1 Landscape Planning, Design and Development

1 SCOPE

This Code (Part 10/Section 1) covers requirements of landscape planning, design and development with the view to promoting quality of outdoor built and natural environments and the protection of land and its resources.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Avenue — A wide road or pathway lined with trees on either side.

2.2 Buffer — The use of landscape elements to reduce or curtail view, sound or dust with plants or earth berms, wall etc.

2.3 Canopy/Tree canopy — The average horizontal spread of the tree, taken from dripline to dripline.

2.4 Climber — A woody or herbaceous plant which either clings to a wall, trellis or other structures or can be supported or trained as it grows.

NOTE — It is sometimes also called creeper or vine.

2.5 Columnar — A slender, upright plant form.

2.6 Contour — The form of the land, existing or proposed; a part of the topography, indicated by map lines at intervals, to understand the landform clearly. The contour line is imaginary and indicates continuous elevation above mean sea level or an assumed datum line.

2.7 Contour Interval — The difference in elevation or the vertical distance measured between consecutive contour lines.

2.8 Drainage — Drainage is the natural or artificial removal of surface and subsurface water from an area through use of vegetated/open channel, pipes, drain boards, chambers, etc.

2.9 Egress — A way out, or exit.

2.10 Elevation — A contour line or notation of relative altitude with respect to a benchmark, useful in plotting existing or proposed feature.

2.11 Erosion — Wearing away of soils, rocks, sediments, etc, by gradual action of natural processes (such as water, wind and glacier).

2.12 Exotic — A plant that is not native to the area in which it is planted.

2.13 Fence — A barrier of plant or construction material used to define the boundary of an area and to restrict visual and/or physical access.

2.14 Foliage — The collective leaves of a plant or plants.

2.15 Geogrid — A deformed or non-deformed netlike polymeric material used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of the human made project structure or system.

2.16 Geo-Textile — Any permeable textile or fabric (natural or synthetic) used to retain or protect soil and filter and drain water as an integral part of project, structure or system such as terrace garden, etc.

2.17 Girth of Tree — Girth is a measurement of the circumference of the trunk of a tree, measured perpendicular to the axis of the trunk. It is measured at breast height (1.4 m above ground level).

2.18 Grade — The slope or lay of the land as indicated by a related series of elevations.

2.18.1 *Natural Grade* — Grade consisting of contours of unmodified natural landform.

2.18.2 *Finished Grade* — Grade accomplished after landscape features are installed and completed as shown on plan as proposed contours or spot levels.

2.19 Gradient — The degree of slope of a pipe invert or road or land surface. The gradient is a measure of the slope height as related to the length. The slope is expressed in terms of percentage or ratio.

2.20 Grading — The cutting and/or filling of earth to establish finished contours.

NOTE — Grading facilitates good drainage and shapes land to suit the intent.

2.21 Grasses — Plants that characteristically have joint stems, sheaths and narrow blades (leaves).

2.22 Grass Paver — Grass paver is a permeable structural grid cellular system (concrete, HDPE or any other polymer) for containing and stabilizing gravel or turf.

2.23 Green Roof — A roof surface of a building that is partially or completely covered with a growing medium and vegetation. Green roofs can be deep (intensive) or shallow (extensive).

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NOTE — Intensive green roofs are elevated greens which can sustain shrubs, trees, walkways and benches with their complex structural support, irrigation, drainage and root protection layers. Extensive green roofs are shallow, relatively light and are solely used for their environmental benefits. They support native ground cover that requires little maintenance.

2.24 Green Walls — A supporting structure completely or partially covered with vegetation which is grown with soil or growing medium. It can be either free standing or part of a structure. They include climbing plants such as vines that grow directly on the wall, or walls that comprise of modular panels, containers and an integrated irrigation system.

2.25 Ground Cover — The planting material that forms a carpet of low height.

2.26 Hard Landscape — Civil work component of landscape development such as pavements, walkways, roads, retaining walls, sculptures, street amenities, fountains and other elements of the built environment.

2.27 Hardy Plant — Plants that can withstand harsh temperature variations, harsh wind, pollution, dust, extreme soil conditions, and can tolerate either drought or flooding.

2.28 Heat Island Effect — A phenomenon in which air and surface temperature of an area are higher than nearby areas due to the replacement of natural land cover with pavement, building, and other infrastructure.

2.29 Hedge — Shrubs or trees (usually of the same species) planted closely together in a linear configuration. A hedge may be pruned to shape or allowed to grow to assume its natural shape.

2.30 Herb — A plant with a non-woody or fleshy structure. Certain herbs are highly useful for cooking or of high medicinal value.

2.31 Ingress — A way in, or entrance.

2.32 Invert — The lowest inside point of a pipe, culvert, or channel.

2.33 Irrigation — The artificial application of water, to assist in growing and maintenance of plants.

2.34 Kerb — A concrete or stone or similar hard edging along a pathway, or along a road, often constructed with a channel to guide the flow of stormwater.

2.35 Microclimate — A local atmospheric zone where the climate (temperature, humidity, wind, etc) differs from the surrounding areas. The term may refer to areas as small as a few square metres or as large as many square kilometres.

2.36 Mound — A small hill or bank of earth, developed as a characteristic feature in landscape.

2.37 Mulching — A practice of using a protective covering, usually of organic matter such as leaves, straw, placed around plants to retain moisture, improve soil conditions and prevent the growth of weeds.

2.38 Permeable Paving — Paving surfaces that reduce runoff by allowing rainwater to soak through the surface into the underlying sub-base where the water is stored temporarily before allowing it to seep into the ground or flow to the drains.

2.39 Plants — The living beings consisting of trees, shrubs, herbs, grasses, ferns, mosses, etc, typically growing in a permanent site, absorbing water and inorganic substances through their roots, and synthesizing nutrients in their leaves through the process of photosynthesis.

2.39.1 *Endemic Plant* — The plant which is found only in one geographic location on earth.

2.39.2 *Invasive Plant* — The species of plant which is not native to a specific location (an introduced species) and has a tendency to spread to a degree believed to cause damage to the environment.

2.39.3 *Native Plant* — A plant indigenous to a particular locale.

2.39.4 *Naturalised Plant* — A plant that is established as a part of the flora of a locale other than its place of origin.

2.40 Screen — A vegetative or constructed hedge or fence used to block wind, undesirable views, noise, glare and the like, as part of in landscape design; also known as 'screen planting' and 'buffer plantation' (*see also* **2.2**).

2.41 Sediment — The product of erosion processes; the solid material, both mineral and organic, that is in suspension, is being transported or has been moved from its site of origin by air, water, gravity or ice.

2.42 Shelterbelt — Shelterbelt is usually made up of one or more rows of trees or shrubs planted in such a manner so as to provide shelter from wind, and protect soil.

2.43 Shrub — A woody plant of low to medium height, deciduous or evergreen, generally having many stems.

2.44 Soft Landscape — The natural elements in landscape design, such as plant materials and the soil itself.

2.45 Spot Elevation — In surveying and contour layout, an existing or proposed elevation of a specific point noted as a dot on the plan.

2.46 Street/Outdoor Furniture — Items of furnishing in outdoor landscape such as benches, trash receptacle signage, play equipment.

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2.47 Swale — A linear wide and shallow depression used to temporarily store, route or filter runoff. A swale may be grassed or lined.

2.48 Topsoil — The uppermost layer of the soil.

2.49 Transplanting — Technique of moving a plant from the place where it is growing and replanting at another location.

2.50 Tree — A woody plant, generally taller than 2.00 m, with a well-distinguished trunk or trunks below the leaf crown.

2.50.1 *Deciduous Tree* — Tree that sheds all its leaves during a part of the year.

2.50.2 *Evergreen Tree* — Tree that remains green for most part of the year and sheds leave slowly throughout the year.

2.51 Tree Drip Line — The branch spread of a tree defined by the outermost circumference of a tree canopy where water drips onto the ground.

2.52 Tree Grate — A grille, installed at the base of a tree otherwise surrounded by pavement that allows the free passage of air, water, and nutrients to the tree root, but does not interfere with the foot traffic.

2.53 Tree/Plant Guard — The protection around a tree or plant to help prevent damage.

2.54 Xeriscape — A landscape that requires little or no irrigation or other maintenance.

3 STATUTORY APPROVALS

3.1 Requirements for Registration and Competence of Professionals

The qualification and competence for carrying out the landscape planning, design and development work shall be as given in Part 2 'Administration' of the Code.

3.2 Application for Statutory Approvals and Required Drawings

For any development project for which a permit or licence or statutory approval is required, an application shall be made to the Authority on the prescribed form containing such particulars as the Authority may require. The form shall be signed by the owner and shall include the information given in **3.3**. For various aspects of obtaining the permit, etc, reference shall be made to Part 2 'Administration' of the Code.

3.3 Landscape Development Documents Required for Statutory Approvals

3.3.1 *Landscape Master Plan*

The site plan to be submitted with the application for permit shall be drawn to a scale of not less than 1 in 200 for a site up to one hectare and not less than 1 in 500 for site up to 10 hectare and not less than 1 in 1 000 for site more than 10 hectare. The following information shall be provided in addition to requirements for site plan as stated in Part 2 'Administration' of the Code:

a) Existing and proposed topographic contours at intervals not exceeding 500 mm and/or spot elevations as pertinent and bench mark of site with reference to the city datum relative to the mean sea level.
b) Limits of the 100 year flood plain and water surface elevation, where applicable.
c) Location of existing major physical features, such as railway track, drainage ways.
d) Location of service utilities adjacent to the project with relevant top and invert levels clearly indicated.
e) Point of egress and ingress including locations and width of road.
f) Fully dimensioned loading spaces and manoeuvering areas.
g) Parking including, location, parking spaces, size and number, and typical parking space details for both persons with disabilities and for standard spaces.
h) Circulation for vehicles, bicycle and pedestrian, including for persons with disabilities clearly identified.
j) Detail for parking areas including type of lighting, material for paving, and security rooms, rest rooms; and type of directional signage, etc.
k) Drainage system, proposed finished ground elevations and finished grades.
m) Location of proposed fire hydrant points.
n) Location of fire lanes.
p) Proposed lighting layout.
q) Landscape irrigation points and source of irrigation water.
r) Vegetation for screening by type, material, height, location, and spacing or fences, walls.
s) Location of proposed street furniture, landscape structure.
t) Refuse container location, size, and access.
u) Landscape paving materials with location.
w) Location, type, size, and height of existing and proposed signage.
y) List of existing trees with botanical and common names and height, girth, canopy of the tree and existing grade levels (*see* **11.1.2** for plant material schedule).
z) Prior approvals, where applicable.

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3.3.2 *Grading Plan and Stormwater Management Plan*

The grading plan shall be drawn to a scale of not less than 1 in 200 for a site up to one hectare and not less than 1 in 500 for a site up to 10 hectare and not less than 1 in 1 000 for site more than 10 hectare. The grading plan should include measures for soil and sedimentation control and also measures during construction to prevent soil erosion, and also water harvesting practices (*see also* **11** and **12**).

3.3.2.1 *Grading design*

Design for changes in elevation in the outdoor environment is a primary component of landscape development. Grading of proposed external development areas should relate to the existing topography of the site and it should direct surface water runoff to the designated drainage and water harvesting area. Grading design parameters are as follows:

a) Proposed grading design should respond to the function and purpose of the activities to be accommodated within the site.
b) New development and structures to be integrated with existing landform within the site and in its immediate surroundings.
c) Stormwater to be directed away from buildings.
d) Steep slopes to be modified to minimize or eliminate erosion.
e) Legally, grades cannot be changed beyond the property line of the site.
f) Rate of stormwater runoff leaving the site after construction not to exceed the pre-construction rate.
g) Grading design should optimize cut and fill.

3.3.2.2 *Grading plan*

3.3.2.2.1 The submitted grading plan should include the following:

a) All existing and proposed features of the site, including all building with plinth level;
b) Structures such as walls, walks, steps, roads;
c) Utilities such as water lines, sewer and stormwater drainage, electrical lines; and
d) Utility structures like manholes, junction boxes, sewage treatment plant, septic tank, soak pit, water tanks, water treatment plant, transformers and all underground structures indicated appropriately.

Proposed features shall be indicated in firm lines and existing features in dash.

3.3.2.2.2 The grading plan should represent the following:

a) General landform concept graphically represented with appropriate symbols and abbreviations (*see* **3.3.2.4**).
b) Proposed contour lines should be integrated with existing and proposed elevations within the project site.
c) Location of swales and surface water flow, surface and subsurface soil drainage system or water harvesting systems.
d) Location of drainage catchments, areas of retention/detention or disposal/outfall point as the case may be.
e) Spot grades on road, walks, and swales including top level and relevant invert levels of all utilities and utilities structures as mentioned above; critical spot elevation to be established (*see* **3.3.2.3**).
f) Spot elevation of building floor finish level, steps, walls, terraces and other such structures.
g) Changes in direction or rate of slope.

3.3.2.2.3 *Spot elevations*

Spot elevations shall be used to supplement contours in the following situations:

a) To indicate variations from the normal slope or gradient between contour lines.
b) To indicate elevations of intersecting planes and lines, like corners of buildings, walls, steps and kerbs.
c) To indicate elevations at top and bottom of vertical elements like walls, steps and kerbs.
d) To indicate floor and entrance elevations.
e) To indicate elevations of high and low points.
f) To indicate top elevations of utilities and utilities structure.

3.3.2.3 *Slope calculation*

Slopes are expressed as follows:

a) Percentage (of slope) $= \frac{\text{Vertical rise} \times 100}{\text{Horizontal distance}}$,

for example, $\frac{1 \times 100}{50} = 2$ percent

b) Proportion (of slope) $= \frac{\text{Vertical rise } (1.0\text{ m})}{\text{Horizontal distance}}$,

for example 1 m in 50 m or 1 : 50

c) Degree of slope, expressed as angle, for example, 10°, 15°, etc.

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3.3.2.4 *Typical grading symbols and abbreviations*

Symbol	*Description*
- -(100)- -	Existing contour
- 100 -	Proposed contour
(100.5)	Existing spot elevation
100.5 (Bold)	Proposed spot elevation
CB	Catch basin
FFL	Finished floor level
FGL	Finished ground level
TW/BW	Top of wall/Bottom of wall
TK/BK	Top of kerb/Bottom of kerb
HP/LP	High point/Low point
IL	Invert level

3.3.3 *Planting Plan*

The planting plan shall be drawn to a scale of not less than 1 in 200 for a site up to one hectare and not less than 1 in 500 for a site up to 10 hectare and not less than 1 in 1 000 for site more than 10 hectare with part plans at 1 in 200 of two of the design areas. Planting plan should include plant material schedule as shown in Table 1. The planting plan and landscape plan shall show identical information to avoid conflict between both plans. The planting plan shall include the layouts as per the following requirements, drawn to the scale:

a) Location of proposed trees, shrubs, ground covers including grass area indicated clearly with appropriate symbols and legend shall be indicated.

b) The shape, size, diameter of canopy of plants with their possible growth in coming 3 years shall be indicated.

c) Functional attributes and growth pattern tabulation shall be attached as given in Table 2, as an annex.

d) All existing vegetation shall be marked on the landscape plan and areas designated for preservation of existing vegetation on site shall be demarcated clearly (*see also* **11.1.2**).

e) A concept plan of scale not less than 1 in 1 000 indicating the intent of the design with respect to the functions for various parts of the scheme shall be included with a short narrative, where applicable.

Table 1 Plant Material Schedule

(*Clause* 3.3.3)

Sl No.	Tree No.	Code	Botanical Name	Common Name	Quantity
(1)	(2)	(3)	(4)	(5)	(6)

Table 2 Plant Material Schedule Showing Functional Attributes and Growth Pattern of Each Plant

[*Clause* 3.3.3 (c)]

Sl No.	Relevant Features	Description Plant-1
(1)	(2)	(3)
i)	Botanical name	
ii)	Common name	
iii)	Plant code	
iv)	Type (Evergreen/Deciduous)	
v)	Height	
vi)	Spread/Canopy	
vii)	Form of tree	
viii)	Flower colour	
ix)	Seasonal duration	
x)	Zone (Functional attributes)	
xi)	Characteristics	
xii)	Function	
xiii)	Remarks (including with regard to poisonous character and health ground)	

3.3.4 *Materials and Finishes Plan*

The materials and finishing plan shall be drawn to a scale of not less than 1 in 500 for a site up to 10 hectare and not less than 1 in 1 000 for site more than 10 hectare. The plan shall include materials specifications such as type, colour, size, thickness, and surface treatment.

3.3.5 *Basic Design and Construction Details*

Construction details, specifications and methods used for the following landscape elements are to be included, where applicable:

a) All paved areas for pedestrian and vehicular use, including edges, kerbs, bumper stops, steps, ramps, planters, railings or other protective devices; tree protection with tree grating, tree guard, etc; provision for wheel chair access and movement, and other accessibility details in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

b) Boundary wall, fence, retaining wall, etc.

c) Structures in landscape such as gatehouses, kiosks, toilets, pergolas, space frame, pools, ponds, water bodies, any other special features.

d) Site utilities such as stormwater drains, manholes, catch basins, outdoor lighting fixtures, electric feeder pillars, junction box, fire hydrant, garbage collection points, litter bins.

e) Outdoor signage and street furniture.

f) Play equipment and tot lots, where appropriate.

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g) Any other relevant detail or information.

3.3.6 *Irrigation Plan*

The irrigation plan shall be drawn to a scale of not less than 1 in 500 for a site up to one hectare and not less than 1 in 1 000 for site more than one hectare. The plan shall include the following information:

a) Source of irrigation water.
b) Type of water conserving irrigation systems proposed, if any.
c) Extent of supplementary irrigation provided by water harvesting measures, if any.
d) Layout of the irrigation system proposed (including arrangement of hydrants or sprinklers indicating location and type with typical details and specifications, etc as applicable to the irrigation system).

4 LANDSCAPE SITE PLANNING REQUIREMENTS

4.1 Framing the Landscape Programme or Brief

Every site has a history of use and change. Prior to formulation of a landscape master plan and its detailed design, an assessment of the landscape requirements for the site shall be established.

4.1.1 *Location*

Landscape development brief shall include appropriate approaches for regional and bio-climatic variations.

4.1.2 *Site*

Specific site factors such as topography, site aspect, hydrology, soils, existing vegetation, visual value, drainage, utilities, subsurface conditions, vegetation, microclimate, existing site infrastructure, built mass, traffic and connectivity shall be considered while developing the brief for landscape development.

4.1.3 *Brief*

Landscape development brief shall be in consonance with the statutory/development requirements.

4.1.4 *Users*

Landscape development brief should be framed for specific uses or user groups including understanding of social, economic and safety related aspects.

4.1.5 *Landscape Development for Special Conditions*

The landscape development brief shall recognize special conditions, such as reclamation and/or rehabilitation of land, mitigation of other special existing conditions and conservation of existing value, prior to formulating a landscape master plan.

5 GENERAL LANDSCAPE DEVELOPMENT GUIDELINES

5.1 General

5.1.1 The general landscape development guidelines should be applied at two levels:

a) *Masterplan level* — This consists of those projects where the level of intervention is restricted to large scale landscape site planning; and
b) *Detailed landscape design level* — This consists of those projects where detailed landscape design is involved.

Open spaces are often further defined based upon access and ownership as public, semi-public and private. Planning and design of open spaces should consider the following aspects:

1) *Sustainability* — Environmental sustainability and green principles may be incorporated to ensure that landscape development does not hamper the existing ecology of the site and its surroundings (*see also* Part 11 'Approach to Sustainability' of the Code). Land, vegetation and water sensitive design options may be explored during the design stage by incorporating a clear grading, drainage and planting strategy while developing the landscape concept. Cut and fill of the land may be minimized while locating the built blocks and circulation spaces. Gentler slopes with adequate green cover aids in erosion control thereby retaining the humus rich top soil. Stormwater runoff within the site may be filtered and either stored or allowed to recharge the groundwater table depending on the site conditions. As far as possible, it is desirable to use native and naturalized non-invasive species.
2) *Accessibility* — The planning and design of open spaces may be accessible for a wide range of users, including pedestrians, cyclist, transit riders and those using private modes of transport (*see also* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code). An ideal public space may be well connected to a surrounding bus/metro/mass rapid transit system facility or a neighbourhood street or a regional route.
3) *Resilience* — Resilience is the ability of a landscape to adapt to change and regain its original state when subject to shock, such as flooding, drought and pest attack. Natural

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landscapes have an inherent ability to exhibit resilience, while human altered landscapes should be designed to incorporate resilience as a core principle of design.

4) *Ease of maintenance* — Ease of maintenance may be regarded as an important consideration in a well-designed landscape. This may also aid in ensuring savings in energy and resources.

5.1.2 The various guidelines for landscape spaces may be grouped as follows, which are given in **5.2** and **5.3**, respectively:

a) *Guidelines for general open spaces* — These pertain to open spaces framed for specific uses and user groups, and include understanding of social, economic and safety related aspects.

b) *Guidelines for special conditions* — These pertain to open spaces which are either ecologically or culturally significant, and may require special considerations, such as reclamation, rehabilitation, restoration and/or redevelopment.

5.2 Design Guidelines for General Types of Landscape Open Spaces

5.2.1 The design for the general type of open spaces should consider the following parameters:

a) *Hierarchy of open spaces* — Open spaces may be studied with respect to its relative size to better understand the complexities of the issues related to them, with respect to functional, visual and ecological concerns.

b) *Usage of open spaces* — Design of open spaces should have a certain character based on its usage. It is desirable that the design of these open spaces take into consideration the existing and proposed use of the open space, as well as the specific needs of the users. The design of these spaces may also be reviewed in terms of whether they are public, semi-public or exclusively private spaces. Open spaces may be planned for a variety of functional uses by different users or diverse user groups, so that they are able to provide for a variety of recreational opportunities and spatial experiences.

c) *Location of spaces* — The design guidelines may be interpreted so as to suit the bio-geoclimatic setting of these landscapes. The approach to planning and design of these open spaces would vary greatly depending on the climatic conditions and layout of the site. The specificities of the requirements for landscape should be studied in detail before commencing the planning and design process.

The following types of generic open spaces may be identified:

1) Regional parks/city parks,
2) Roads,
3) Public plazas and urban squares,
4) Multipurpose open spaces/mela grounds,
5) Urban riverfronts and waterfronts,
6) District parks/neighbourhood parks,
7) Theme parks/waterparks,
8) Sports facilities/playgrounds/stadium complexes/sports centre,
9) Golf courses/equestrian grounds,
10) Plant nurseries,
11) Pocket parks, and
12) Open spaces associated with largescale developments.

5.2.2 *Design to Take into Consideration the Site Context*

a) The site and context study are important tools for assessing the suitability of land use and nature of design intervention. The design for any particular site may be developed as an outcome of the site analysis.

b) The design may be conceptualized so as to maximize the site potentials while the site constraints should also be taken into consideration.

5.2.3 *Design for Maximising Usable Space*

a) Landscape elements, such as outdoor furniture, lighting and other required facilities, may be placed sensitively along the proposed circulation path with consideration of usage patterns.

b) Adequate shading may be provided for areas where the community congregates in warmer climatic locations, while areas designed for public gathering in cold regions may be shielded from wind.

c) The extent of the paved areas may be restricted to a minimum, keeping in mind the pedestrian routes, density of usage, spaces for congregation, etc. Paved areas may be planned so that they do not restrict any natural surface flow of water and nor do they get waterlogged during the rainy months.

d) Landscape design may be used to improve the environmental quality of the open spaces. Sufficient landscape may be provided at both

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horizontal and vertical planes to reduce the ambience temperature and glare. This may be in the form of conventional planting or devices like vertical greenwalls, green roofs, etc. Large unshaded paved plazas may contribute to urban heat island effect. *See* **7.1.2.2** and **7.4.7** of Part 11 'Approach to Sustainability' of the Code.

5.2.4 *Provision for Various User Activities Spanning Different Age Groups*

a) A variety of recreational options for different ages and interests may be provided.
b) Different cultural recreation preferences may be considered while designing open spaces by using community feedback to determine their needs and requirements.
c) A variety of amenities that encourage extended use, such as water fountains, and picnic tables, may be provided.
d) Plants for hiding and materials for making shelters may be considered. Opportunities to create appreciation for nature and the pleasure of discovering scientific phenomenon may be provided.
e) Spaces should be designed for use by people of all abilities, including those using mobility aids (for example, wheelchairs). *See* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

5.2.5 *Provision for Free and Imaginative Play Opportunities in Children's Play Areas*

a) Opportunities for children to explore imaginative play through interaction with natural elements of their environment may be provided.
b) Raised beds or planting areas, play shelters, niches, sand areas, etc, may be provided.
c) Ways of functioning of natural systems within the site may be explored. For example, hydrology and water flows that attract butterflies, birds, and frogs may be considered.
d) Science play opportunities that stimulate curiosity about science may be provided. Suggested elements may include centrifugal force, sound waves, sunlight refractors, weather stations and windmills.
e) Signage that gives cues to parents about things to show or teach their children, using equipment or other elements of the playground, may be provided.
f) All possible efforts should be made to extend opportunities to children of all abilities and age, by providing access to a variety of play features and using features that appeal to all of the senses. *See* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

5.2.6 *Design for Safety and Security*

a) Hard landscape materials and their details may be worked out so that sharp corners, injurious edges and easily breakable materials are avoided in the public landscape.
b) Plant materials may be selected taking into consideration the possible issues of allergic reactions or toxicity.
c) Level differences in the open spaces may be treated with adequate care so as to avoid potential fall/injury. Level differences of a single step may be avoided in landscaped areas since they may aggravate the chances of tripping and injury.
d) Durable, easy to repair equipment and safety surfacing may be considered for play areas. International Safety Standards, such as fall zones, safety surface, fall height, and entrapment concerns may be considered for play equipment and surfaces. The flooring material of these spaces may be impact absorbing and injury proof.
e) In areas for smaller children, the number of exits and their placement may be limited so that they are easily monitored by parents and guardians.
f) Creation of hidden areas in the landscape should be avoided. The density of vegetation and height of the understory planting may be decided so as to keep the view-lines clear.
g) Lighting may be done so as to ensure that all usable areas of the landscape are well lit and there are no dark spots in the landscape.

5.2.7 *Review of Existing Master Plans, Regulations and Initiatives*

Existing master plans, regulations, byelaws, etc, that may have defined uses, connections, materials or conventions, shall be reviewed for ensuring compliance. Design of public open spaces may address the concerns of the neighbourhood and express the identities of the neighbourhoods they pass through.

5.2.8 *Design for Continuity Between Multiple Public Open Spaces and Parks*

a) Linear parks may be used to provide continuous paths for bicycles and pedestrians.
b) Greenway plans may be researched and opportunities to connect greenway paths be explored so as to establish connections

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between adjacent neighborhoods. Pedestrian movement corridors may be given precedence over vehicular corridors.

c) Commuting or high speed bike lanes may be separated from the pedestrian paths.

d) Signage style and vocabulary along multiple open spaces and parks to guide users may be kept consistent for ease of understanding. *See* Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 2 Signs and Outdoors Display Structures' of the Code.

5.2.9 *Pathways and Pedestrian Movement Corridors*

a) Pedestrian circulation path consists of sidewalks, wheelchair ramp, and landings. Footpaths of minimum width 1.80 m may be provided along the length of road for any public or private building where pedestrian traffic is expected. *See* **4.3.2.1** of Part 3 'Development Control Rules and General Building Requirements' of the Code for computation of capacity of footpaths with respect to their widths.

b) Natural materials such as stone, or manmade materials such as tiles or cast *in-situ* concrete, of appropriate thickness may be used as paving finish in external areas. Adequate slope and drainage facility may be considered for all external paved surface integrating it with the pavement design.

c) Surface treatment of the finishes may be such that it remains anti-skid throughout the seasons. Smooth finish is not recommended for external areas except to convey any design concept.

d) Change in levels and steps may be depicted in different texture or colour as a visual clue.

e) The cross slope of sidewalk may be designed so as not to exceed two percent (1 in 50). The longitudinal slope of path may not exceed 1 in 20, unless the longitudinal slope of the road exceeds this maximum, in which case the norms applicable to a ramp should be applied. Kerb ramps may be provided at pedestrian crossings. *See also* **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

f) All ramps should have minimum width of 1.20 m, excluding edge protection. The cross slope of ramp should not exceed 1 in 50 and the longitudinal slope of ramp may not exceed 1 in 12. All ramps may have an unobstructed level landing both at top and bottom of the ramp. The landing may have the minimum width as that of the ramp. The landing may be minimum 1.50 m in length. Any ramp beside the road may be located in such a way so that vehicles cannot park blocking the access. The ramps shall also comply with the requirements of **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

g) Handrails may be provided for any ramp with a vertical height greater than 150 mm, to prevent pedestrians and wheelchair users slipping from the ramp. The height of the top handrail may be 900 mm from the top surface of the ramp. The ramp surface may be rough finished. All ramp and landing may be designed so that water does not collect on the surface of the ramp or landing.

h) Requirements of **7.4.3** of Part 11 'Approach to Sustainability' of the Code should also be taken in to consideration.

5.2.10 *Provision for Adequate Parking Requirements*

a) Parking spaces may be provided off-street or as dedicated parking pockets with ample turning radii for manoeuverability of vehicles.

b) The parking lots need to be shaded during the day while being well lit during the night and should be easily accessible.

c) Pedestrian connections to and fro the parking lots may be denoted with easily recognizable signage elements.

d) The parking spaces shall be provided in accordance with **10** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

e) Parking bays for persons with disabilities shall be provided as per **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

5.2.11 *Adopting Rational Approach to Grading*

a) Grading may be used to minimize creation of steep slopes and retaining walls in the landscaped areas by assessing the existing contours and locating the functional landscape spaces, taking into consideration the existing layout of the land.

b) Site grading may generally be limited to areas adjacent to the building, under access roads and driveways, or in areas where cut and fill are inevitable such as those sites which are prone to landslides.

c) Buildings and roads may be planned so as to generally follow the existing contours. On sloping sites, buildings may have multiple levels to maximize the potential of contoured sites.

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d) Wherever possible, measures like naturally stabilizing slopes and bio-engineering measures may be explored in order to avoid construction of retaining walls.

e) Where grading occurs, new slopes may be configured to retain the natural character of the site. New contour lines may be carved to mimic the natural contours.

5.2.12 *Designing for Road Landscapes*

a) Kerbs may be provided on the edges of the driveways to adequately control drainage within the road, prevent moisture from entering the sub-grade, separate the road from the pedestrian area, and provide adequate lateral support for the pavement structure.

b) The roads should provide clear access to fire fighting vehicles, ambulance, sanitation vehicles, etc, and also allow for safe movement for vehicles, pedestrians and wheelchair users. The road widths, alignments and service lanes, etc, may be such that they are adequate as per the relevant Indian Road Congress Standards.

c) Lane markings, kerb edges, central median, etc, may be provided for smooth movement of the traffic and also to guide the vehicles to stay within the designated driveways.

d) Driveways may preferably be shaded by trees. The choice and appropriateness of selection of plants along the road should be in accordance with **7**.

e) Pedestrian crossings (on grade/subways/foot overbridges) may be provided along the pedestrian sidewalks at vehicular intersections to allow for continuous uninterrupted pedestrian movement.

f) Pathways along vehicular roads may be physically separated by means of kerbs, graded separation, barrier, railing, or other means to prevent ingress of vehicles.

g) Roads may be designed with provision for appropriate street furniture (*see* **13** and other urban adjuncts for the convenience of the users). Benches, shelters, poles, signs, bus stops, etc, may be located on edge of the sidewalk with clear minimum width of 1.20 m to enable unhindered pedestrian circulation.

5.3 Open Spaces Design Guidelines for Ecologically Sensitive Zones and Historic Precincts

5.3.1 This category includes open spaces which may require interventions, such as reclamation, rehabilitation, restoration and/or redevelopment. These kinds of open spaces may be broadly classified into the following types:

a) *Ecologically sensitive zones*
   1) National sanctuary/nature park/reserve
   2) City forests
   3) Hills/ridge/rocky patches
   4) Open spaces governed by coastal regulation zone requirements including but not limited to beaches, estuaries, backwaters, lagoons, creeks, sandbars, saltpans, etc
   5) Wetlands, islands, river floodplains
   6) Urban landfill reclamations
   7) Greenways/Nature corridors
   8) Desert Edges and wastelands

b) *Cultural and historic zones*
   1) Tea gardens, plantations and other special landscapes
   2) Existing rural landscapes
   3) Historic city centres and heritage structures
   4) Religious and culturally significant landscapes
   5) Sacred groves
   6) Zones inhabited by tribal settlements/ indigenous communities
   7) Open spaces associated to historic precincts including but not limited to monuments, palace complexes, mausoleums, cemeteries, etc

5.3.2 *Site Processes and Climatic Considerations*

Whether designing to avoid impacts to a significant landscape area or to restore an ecological community, a detailed analysis may be conducted to understand the dominant site processes. The following processes may be considered:

a) Topography;
b) Hydrology;
c) Biotic aspects (plants and animals);
d) Biogeochemical processes; and
e) Climatic considerations.

Stormwater adjacent to restoration areas may be managed to prevent any additional stormwater runoff to these areas. For water conservation practices, *see* Part 11 'Approach to Sustainability' of the Code, in addition to the following:

1) Surface water runoff may be directed towards designed bio-retention systems (for example, swales, rain gardens, or vegetated filters).

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2) Wherever possible, stormwater may be used as a resource and the offsite impervious area water runoff may be captured so that this stormwater can be used where it is needed. Watershed impacts in landscape patches may be taken into cognizance during the design stages. Areas where upstream development may cause increased runoff may be designed with higher peak flows.
3) Planting areas may be incorporated so that they may capture and help in filtration and percolation of stormwater for ground water recharge.

5.3.3 *Design as a Response to the Existing Environment*

a) Preservation of existing elements of value, such as mature trees, rocky outcrops, etc, may be considered.
b) The historic precedents in the vicinity may be taken into consideration. Opportunities for passive recreation as well as active recreation may be considered so that it minimizes the impact on the natural condition of the open spaces especially in regional parks and city level parks encompassing large areas.
c) The processes of site inventory, and site assessment and analysis may be done to confirm the value of the site which needs to be retained or preserved.
d) The proposed usage of the site may be verified against the historical, cultural and ecological values of the site to ascertain the validity of the proposal.

5.3.4 *Designing and Locating Landscape Lighting*

a) Haphazard placement of landscape light fixtures shall be avoided. The landscape light fixtures may be chosen from a pre-determined palette or designed so as to enhance and complement the character of the site.
b) Light fixtures and fittings may be located in a sensitive manner so as to minimize the glare as well as prevent night sky pollution. *See* **7.5** of Part 11 'Approach to Sustainability' of the Code.
c) The height of light fixtures should be decided based on their spacing to prevent wastage of energy or creation of dark patches.
d) Sturdy and durable light fixtures may be chosen to prevent vandalism.

5.3.5 *Protection and Conservation of Significant Landscape Areas*

a) Barriers should be placed to prevent dumping and to restrict vehicle access, wherever necessary.
b) Hard surfaces, including bike trails and boardwalks may be developed and strategically placed so as to avoid dissecting, diminishing, or disturbing preservation areas.
c) Opportunities for ecological and conservation research may be identified.

5.3.6 *Identification of Ecological Communities and their Connectivity*

a) The type of vegetation community present, whether forest, shrub land, meadow, stream, tidal marsh or wetland, can guide the design for adjacent sites and the design and construction practices required to protect the community. Designers may familiarize themselves with the extent and history of the site. Imported soils, the elimination of a surface water source, or nutrient inputs may drastically change the structure and function of the site flora or fauna, and these changes may or may not be reversible.
b) Surrounding areas for vegetation/wildlife movement opportunities or concerns to be explored. Linked parks may provide connectivity for plant species to spread seed and for smaller animals and birds to move. However, this may be both problematic and beneficial, as both desirable and undesirable species may spread.
c) Native species may be encouraged to migrate to new areas by mimicking the conditions of successfully established habitat nearby. Barriers for the spread of invasive species may be created. Site disturbance adjacent to areas which harbour endemic species, may be minimized.

5.3.7 *Enhancement of Habitat Opportunities*

a) Habitat areas may be established in those areas where human usage is compatible or acceptably low.
b) Contiguous and dedicated open spaces may be established. The adjacent patches of species' habitat may be connected whenever possible, prioritizing areas adjacent to existing habitat for expansion.
c) For river corridors, conditions that encourage fish migration may be enhanced. If there are upstream migration blockages, they may have to be removed.
d) Planting areas that can capture stormwater may be included in the landscape. Native vegetation that is consistent with the site that

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provides wildlife food may be planted. Vegetation along water edges for fish protection from predators may be provided.

5.3.8 *Compliance with State Level, National Level and International River Revitalization Treaties, Coastal Management Program Policies, River Cleaning Missions, etc*

a) Underutilized areas may be restored.
b) Water dependent and recreational uses may be minimized.
c) Damage from flooding and erosion may be minimized using non-structural technologies.
d) The consumption of natural resources may be minimized through efficient planning and design.
e) Water quality standards should be adhered to and discharge of hazardous substances into coastal waters avoided.
f) Compatible land uses with surrounding properties may be promoted.
g) Impacts to navigable waters may be avoided.

5.3.9 *Preservation of the Character of Existing Landscapes of Ecological and Culturally Significant Landscape Areas*

a) The history of a site, including original designs, past reconstructions, master plans and other development plans are important and shall be referred to understand and preserve important cultural landscapes.
b) A cultural landscape report may be prepared if the landscape is historically important.
c) Archeological investigation may be conducted, if found necessary.
d) Sites with potential buried resources should be granted protection.
e) For cultural landscapes, existing viewsheds may be preserved and enhanced through tree preservation, removal and replanting.

5.3.10 *Design for Resilience and Ease of Maintenance*

a) Detailed as-built drawings that show locations of all hidden utilities of the external areas may be provided. The documents containing waterproofing and protection layer details should be provided to the maintenance team.
b) Hose tapping points no more than 20 m from all planting areas may be provided to minimize hose-runs.
c) The amount of funds for maintenance and manpower requirement for the external development zone may be assessed before initiating the design, and the design should be commensurate with the maintenance budget.
d) Manuals for equipment operation and maintenance, for tools, and for replacement parts may be provided, to be kept in a locked cabinet on site.
e) Adequate training should be provided to all the operations personnel and gardeners.
f) Preparation of a post-occupancy maintenance plan may be done in accordance with **7.1.2.3** of Part 11 'Approach to Sustainability' of the Code.

6 SIGNAGE

Signage shall be in accordance with Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 2 Signs and Outdoors Display Structures' of the Code.

7 PLANTING DESIGN

7.1 Plant material is a very important component of landscape development, and planting design is integral to any landscape plan. Designing with plants requires awareness and knowledge of a broad range of aspects including ecology, botany, horticulture, aesthetic value, growth and survival, and use of plants to address environmental and ecological concerns.

7.2 Plant Material

The major sets of factors that influence the choice of plant material are related to the characteristics, both botanical and physical of plant material and the context in which the plant material is to be used. The inter-relationship of these sets of factors is the basis for developing a sound approach to the process of designing with plants.

7.2.1 *Physical and Botanical Characteristics of Plant Material*

The information on plant material should be available in a systematic format to include definition, significance and design implications of the following aspects:

a) Nomenclature (botanical and trade name);
b) Origin, family and natural habitat;
c) Growth characteristic and form as a function of habit;
d) Physical characteristics, for example, bark texture, foliage, etc;
e) Propagation and maintenance; and
f) Use in landscape design.

7.2.2 *Vegetation Types (Evergreen and Deciduous)*

Some examples of the functional implications of using evergreen and deciduous plant material for specific situations are:

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a) *Evergreen trees*
   1) For places requiring shade throughout the year,
   2) For strong visual screening,
   3) As part of windbreak or shelter planting, and
   4) For areas where leaf litter is to be discouraged.

b) *Deciduous trees*
   1) For greater visual variety,
   2) As partial visual barrier,
   3) For areas where under-planting is to be encouraged (for example, grass),
   4) For emphasis on branching and flowering pattern, and
   5) For areas where shade is not required throughout the year.

7.2.3 *Growth Rate and Age of the Vegetation*

Growth rate is directly related to the life-span of a tree and slower growing trees have a life-span extending to hundreds of years. The fast growing trees to the exclusion of slower growing varieties is not recommended. Landscapes are developed to sustain future generations; slow growing long lived native trees shall be emphatically included in all major planting schemes, specially those related to institutional campuses and large urban development. However, fast growing species have a limited role, and are appropriate in situations, where,

a) quick effects are required, for example, in shelterbelts;
b) immediate results with regards to stabilization of soil, etc are necessary, for example, in soil conservation schemes; and
c) used as 'nurse plants' to protect slower growing sensitive species, when necessary.

The slower growing species would generally be appropriate in situations where sustained environmental benefits are required such as roadside planting, campuses, townships, industrial areas, and other public landscapes.

7.2.4 *Growth Habits of Various Kinds of Vegetation and their Form*

The overall physical form of a plant is usually the result of the foliage density and branching pattern. It may also be expressed as the proportionate relations between height and canopy spread. The latter is direct expression of growth habit.

A number of classifications of tree by their overall form exist, but it is almost impossible to have a variety according to regional conditions. The following classification into basic types may be useful:

a) *Trees of fastigiated or columnar habit* — Examples of trees of this type are:
   1) *Casuarina equisitifolia* (Beet-wood)
   2) *Grevillea robusta* (Silver oak)
   3) *Polyathia longifolia* (Ashok)
   4) *Populus species* (Poplar)

   Though the branching pattern of each is different, the overall shape is similar.

b) *Tall trees with broad canopy* — Examples of trees of this type are:
   1) *Dalbergia sissoo* (Sheesham)
   2) *Tamarindus indica* (Imli)
   3) *Terminalia arjuna* (Arjun)

   The canopy shape does not fit into any specific geometrical category.

c) *Trees of spreading habit* — Examples of trees of this type are:
   1) *Delonix regia* (Gulmohar)
   2) *Lagerstromia flosreginae* (Pride of India)
   3) *Pithecolobium saman* (Rain tree)

   Though these trees vary greatly in size, their basic form is similar.

d) *Trees of weeping habit* — Examples of trees of this type are:
   1) *Callistemon lanceolatus* (Bottle brush)
   2) *Salix babylonica* (Weeping willow)

The above classification is helpful in choosing various combinations of the above types to achieve desired function and visual objectives.

7.2.5 *Foliage Characteristics of Plant Material*

Visual effects imparted by vegetation, for example the perceived visual textures of plant forms depend on:

a) *Leaf size and shape* — Examples of plants with large leaves and bold foliage texture are:
   1) *Neolamarckia cadamba* (Kadam)
   2) *Ficus lyrata* (Fig)
   3) *Plumeria acutifolia* (Temple tree)
   4) *Pterospermum acerifolium* (Kanak champa)

   Leaf shape can also determine the appearance of the foliage of the plant, as for example:
   1) *Callistemon lanceolatus* (Bottle brush) — Narrow leaves giving a feathery appearance
   2) *Polyalthia longifolia* (Ashok) — Long narrow leaves
   3) S*alix babylonica* (Weeping willow) —

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Narrow leaves giving a feathery appearance

b) *Leaf texture* — The textural appearance of a plant is the result of the play of light and shade on the foliage. Plants with larger leaves generally appear bolder in texture than smaller leaves plants as the areas of light and shade are larger and therefore more clearly differentiated.

c) *Leaf and foliage colour* — Most trees in India have foliage in varying shades of green with variations in colour at the time of leaf fall and at the period when the tree is newly in leaf, when the leaves are fresh and much lighter in colour. Examples are:

1) *Lagerstroemia speciosa* (Jarul) — Leaves acquire reddish tinge before falling
2) *Polyalthia longifolia* (Ashok), *Delonix regia* (Gulmohar), *Erythrina indica* (India coral tree), etc — Leaves turn yellow before falling
3) *Ficus infectoria* (Pilkhan), *Mangifera indica* (Mango) *etc.* — Young leaves have reddish tinge

d) *Foliage density and distribution* — An important consideration is the way in which particular kinds of vegetation are perceived. Tree masses are usually seen from greater distance than shrub areas; foliage texture of different distinctive kinds of trees growing together has to be markedly distinctive for individual species to be recognizably apparent. In shrub areas subtle differences in foliage texture may suffice for creating the required visual effect.

7.2.6 *Flowering Characteristics of Plant Material*

7.2.6.1 Important considerations while identifying plant material according to flowering characteristics are as follows:

a) Season,
b) Density and distribution of flowers on the plant,
c) Botanical characteristics of flowers (for example, single/cluster, etc),
d) Colour, and
e) Presence or absence of foliage during flowering period.

7.2.6.2 For the purpose of understanding the visual effect of flowers, tree species may be divided into two types:

a) Trees on which flowers appear in profusion and therefore have a very strong visual impact, for example, *Delonix regia*, *Cassia fistula*, *Lagerstroemia flosreginae.*
b) Those on which flowers are less profuse, or perhaps last for a shorter period and visual impact is more subtle, for example, *Thespesia* spp., etc.
c) *Aromatic/Non aromatic* — for example, *Plumeria* spp.

An additional consideration when choosing shrubs for their flowering quality is the visual appearance of the flowers themselves, as shrubs are usually seen from quite close. Distinctive flowers are those of,

1) *Beleperone guttata* (Shrimp plant)
2) *Hibiscus rosa-sinensis* (Clinex hibiscus)
3) *Jasminum sambac* (Chameli)
4) *Tabernaemontana coronaria* (Cape jasmine)
5) *Thevetia peruviana* (Yellow oleander)

7.2.6.3 The olfactory characteristics, that is, odour, of flowers may be an added benefit of flowering plants. Flowers with distinctive scent include those of *Nyctanthes arbor-tristis* (Har-singar), *Jasminum pubescens* (Chameli), *Cestrum nocturnum* (Raat ki rani), etc.

7.2.6.4 Flowering characteristics of plant material may be classified as per the following format:

Botanical Name	*Characteristics of Flower*	*Seasonal Duration*	*Visual Impact*

7.2.7 *Growth Requirement of Plant Material*

Information about growth requirements of plant material applicable in landscape design pertains to the ability of particular plants to survive in specific environmental situations. These environmental conditions may arise from a number of aspects as given in **7.2.7.1** to **7.2.7.4**. Capacity of plants to grow in cultivated situations is related to the environmental conditions obtaining in their natural habitat.

7.2.7.1 *Soil conditions*

Physical as well as chemical properties of the available soil are important. These may or may not be amenable to change, they would therefore affect the choice of plant material considerably. Physical properties include consideration of light (for example, sandy) and heavy (for example, clayey) soils, and their structure. Chemical properties pertain to the presence or absence of nutrients and salts; soil, alkalinity or acidity. A preliminary soil analysis is essential for implementing effective planting schemes.

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7.2.7.2 *Availability and quality of water*

The water requirement may be derived by data of humidity and rainfall of plants' natural habitat. The water table of the area where the plantation is to be done has a crucial bearing on the design with plants as well as a financial implication for reduced maintenance if planted appropriately.

7.2.7.3 *Availability of sunlight*

The growth rate of plants is directly related to sunlight requirement and availability; such as plants that require: (a) full sunlight; (b) partial sunlight; (c) predominantly shade; and (d) complete shade.

7.2.7.4 *Quality of air*

Growth may be affected by chemical pollutants, such as sulphur dioxide or physical pollution such as dust. Certain plants have the ability to withstand pollution, such plants are imperative for industrial areas, roads, highways, etc.

7.2.8 *Maintenance*

The success of a designed landscape depends upon the growth of vegetation over an extended period of time; therefore maintenance of landscape is also a design component. Maintenance needs and practices in any given situation arise out of the inter-relationship between the growth requirements of plant material chosen and the environmental conditions existing on site.

The likely degree of maintenance should be assessed based on the following:

a) Scale of the design project,
b) Financial and manpower resource,
c) Availability of manures,
d) Future intensity of site, and
e) Environmental conditions.

In small scale projects, such as gardens and small parks, the natural environmental conditions can be changed and maintained by management practices such as irrigation and application of fertilizers. The choice of plant species is therefore not very strictly limited by the existing environmental conditions. On larger scale schemes, such as very large parks, campuses and townships, this kind of intensive maintenance may not be possible. The process of choosing plants shall therefore respond to the existing environmental conditions, and also in such cases the choice of plant material is restricted by these conditions and suitable species become limited. The type of treatment adopted, as given below, may also serve as a guide to the degree of maintenance required:

a) Low maintenance	The lowest degree of maintenance is usually possible in areas treated with native species of trees only. A slightly higher degree is necessary where native shrubs are also used, as these may require pruning.
b) Medium	Areas treated with a mixture of native and exotic trees. Exotic shrubs and trees.
c) High	Exotic shrubs and ground covers. Lawns and maintained grass areas. Annual flowers and special schemes.

7.3 Functional Aspects of Design with Plants

Plant materials in landscape design may be used to,

a) improve existing environmental conditions with respect to soil, drainage, microclimate, air pollution;
b) create a designed physical environment through the organization of open space; and
c) interpret and express the contemporary understanding of the man-nature relationship, that is, design with plants on an ecological rather than horticultural basis.

7.3.1 *Choosing of Plant Material*

Two sets of factors influence the choice of plant material in landscape design. One relates to information about plant material itself that determines the suitability of plant material from the point of view of growth requirements of plant material, and physical characteristics of the plant material. The second relates to the situation for which a planting proposal has to be made that pertains to the context in which the plant materials have to be used. Considerations of scale (that is, regional, local or very small scale situations), the existing environmental conditions, and functions which the plant material has to fulfill are important. Also the level of maintenance which is likely to be kept up, has to be considered which is especially important on very large sites. The biological history and ecological need of exotic plant should be studied prior to introduction in the landscape schemes to avoid the hazard of the species that may become invasive.

The factors determining choice of plant materials may be thus summarized as follows:

a) *Environmental conditions existing on site* — These include climatic, soil characteristics, water table, etc.
b) *Functions which plant material has to fulfill in specific situations on a given site* — These

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may be either environmental functions (pertaining to improvement of soil conditions, modification or microclimate, etc) or design functions (relating to creating spaces enclosure, framing views, providing visual relief, etc).

c) *Physical characteristics and growth requirements of plant material* — The former include foliage density, foliage texture, leaf size and shape, flower colour, rooting characteristics, etc. The latter include moisture requirements, whether the plant grows in sunny or shaded conditions, etc.

7.3.2 *Methodology of Design with Plants*

The process for designing with plants on a given site condition may be as per the format given below:

Zone	*Characteristics*	*Functions*	*Form*	*Species Chosen*	*Remarks*

Plant material used in landscape design may be broadly classified as follows:

Plant Material	*Classification*
Tree	Large
	Medium
	Small
Shrub	Tall
	Low
Ground cover	Very low shrubs less than 300 mm high

7.3.3 *Functions of Plant Material*

7.3.3.1 *Trees*

Trees perform the following functions:

a) Improvement in air quality,
b) Increase in oxygen levels,
c) Protection of soil,
d) Modification in microclimate,
e) Providing shade,
f) Providing habitat for fauna,
g) Providing enclosure,
h) Providing direction and framing views,
j) Screening,
k) Providing visual relief,
m) Reduction in noise levels,
n) Acting as windbreaks and shelterbelts, and
p) Providing fruits, seeds, etc, for consumption and therapeutic value.

NOTE — For functions of plants/shrubs to reduce noise, **3.6** of Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code may be referred.

7.3.3.2 *Shrubs*

The functions are similar to those of trees. Shrubs may be used together with trees to reinforce the functions, for example, noise barrier, shelterbelts, enclosures, etc.

Other forms in which shrubs may be used are as follows:

a) *Hedges* — These require regular maintenance.
b) *Shrubbery* — Here plants are allowed to retain their natural shape; they therefore require little maintenance.

Shrubs provide barriers, which may either be visual or physical (hedges). Barriers may be required in a range of situations, for example, they may be only for defining space, or they may be required for security and have to be, therefore, necessarily impenetrable.

7.3.3.3 *Ground cover*

Ground cover plants are those which naturally grow to a very low height. Some of the uses for which they may be used are:

a) Stabilizing soil on steep slopes such as embankments.
b) As a low maintenance substitute for grass (where the surface is not to be used).
c) For providing variety in surface treatment.
d) Contrast with paving materials, for example, to soften rigid lines of paving.
e) As a subtle means of demarcating space, as for example, in places where tall plants would be visually intrusive.
f) In combination with other plants to provide contrast or harmony in form.

7.3.3.4 *Climbers*

Certain climbers because of their spreading habits may also be used as ground cover (for example, *Asparagus* spp.). Also, climbers can increase the green cover without taking a lot of ground space. Climbers are useful for shading exposed walls from direct sunlight. They may also be used for stabilizing soil on embankments (for example, *Ficus stipulata, Ipomea biloba*). On sites where a high degree of security makes fencing necessary, climbers and spreading plants like *Bougainvillea* species, may be trained on boundary wall.

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7.4 Planting for Shelter and Soil Conservation

The use of vegetation for controlling wind is widely recognized as an effective way of conserving soil and reducing erosion by wind. Vegetation may therefore be used for modifying the microclimate, by obstructing, guiding, deflecting or filtering wind current.

Vegetation areas designed to fulfill these general functions are usually classified as windbreaks and shelterbelts. Windbreak is grown protective planting around gardens and orchards. Windbreaks generally consist of single or double row of trees. Shelterbelt provides an extensive barrier of trees with several rows of trees. Plant species are chosen with particular regard to their physical and growth characteristics, and their effectiveness in achieving the desired results. Both windbreaks and shelterbelts have considerable visual impact in the landscape in which they are situated, they therefore need to be designed so that they make a positive visual and aesthetic contribution to their environment.

7.4.1 *Function*

Windbreaks and shelterbelts fulfill essential micro-climatic functions in rural and urban environments. Benefits accruing from plantation of shelter planting may be as follows:

a) Reduction in wind velocity resulting in the arrest of movements of sand and soil particles.
b) Prevention of soil erosion.
c) Modification of micro-climate; moderation of change in air temperature.
d) Protection of crops from being blown by high winds.
e) Protection of livestock.
f) Reduction in loss of soil moisture by evaporation.
g) Increase in soil moisture due to greater dewfall in sheltered areas has been found to be 200 percent higher than on exposed ground; heaviest dew fall is over a distance of 2 to 3 times the height of the shelterbelt.
h) Beneficial effect on growth of plants that are affected by high winds.
j) Extensive shelterbelts may also be used to augment the supply of fuel in rural areas.
k) The zone of influence of shelterbelt on crop yield extends to a distance of 20 times the height of the belt, with the maximum effect being observed 10 times the height of the tree belt, on the leeward side.

7.4.2 *Wind Erosion*

Some of the basic functions of windbreaks and shelterbelts in arid and semi-arid areas are to conserve soil and reduce erosion by wind. The latter is a natural phenomenon in lands having very little rainfall (125 mm to 250 mm) and in areas adjoining a river, lake or sea. Wind erosion is a serious problem in areas where the ground is virtually bare and devoid of vegetation.

Factors which influence the degree and kind of wind erosion are as follows:

a) *Features of wind* — Speed, direction, temperature, humility, burden carried, etc.
b) *Character of surface* — Rough or smooth plant cover, obstruction, temperature, etc.
c) *Topography* — Flat, undulating broken, etc.
d) *Character of soil* — Texture, organic matter, moisture content, etc.

7.4.2.1 *Techniques for control of wind erosion*

The principal method of reducing surface velocity of wind, upon which depends the abrasive and transportation capacity of wind, is by vegetation measures. Vegetation methods are found to be most effective in the form of windbreaks and shelterbelts. In aerodynamic terms, these provide protection as follows:

a) Sheltered zone on the leeward side extends to approximately 15-30 times the height of the belt.
b) A dense belt provides greater shelter immediately to leeward side but the sheltered area is not as extensive as when a more permeable zone of vegetation is provided.
c) Porosity is important in the effectiveness of shelterbelt and proper selection of tree species is necessary. Porosity near ground level is desirable.
d) Effectiveness of shelter planting depends more on height and permeability than on width. The width influences the general microclimate but above a certain minimum width, it does not affect greater reduction in wind velocity.

Protection obtained varies in relation to height (*H*) of shelterbelts, as given below:

Distance	*Wind Reduced by*
	Percent
H	90
2*H*	75
5*H*	50
10*H*	20

This indicates that it is better to have several windbreaks 5*H* to 6*H* apart rather than large forest stands with wide open spaces in between.

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7.4.3 *Profiles*

A belt which rises and falls abruptly on windward and leeward sides is said to be more effective. Smaller trees and shrubs should occupy the inter-spaces between tall trees.

NOTE — Some authorities maintain that triangular section of shelterbelt planting can be more effective.

The depth of the shelterbelt should be approximately ten times its height. This is, however, only a thumb rule. Much lesser widths of 20 m to 30 m have also been found to be useful in particular situations; 15 m should be considered as minimum width.

Apart from factors such as climate, soil, fast rate of growth, one of the more significant considerations in choosing species for shelter planting is the possibility of a particular species serving the dual role of wood-production (for fuel, fodder) as well as shelter.

7.4.3.1 *Spacing of plants in windbreaks and shelterbelts*

Windbreaks usually consist of a single or multiple rows of trees planted closely according to species. Normally, one year old trees are used. As the roots of tree extend for some distance beyond the rows in which they are planted, the same should be taken into account while planting windbreaks. The most common layout where shelter planting is part of an extensive planned programme, is that of tree belts arranged in a chessboard pattern, each field being protected from every side. This pattern gives full protection to all the fields, provided that the right distance between the fields has been chosen. Efficient protection is achieved if belts are separated by a distance of not more than 20 times the height of the trees. A considerable mixture of species is recommended so as to compensate for different rates of growth and also to achieve variety in the form of crowns.

7.4.3.2 Within shelterbelts, close spacing of trees is the general practice. The recommended spacing for shrubs is 1 m and for tree such as *Casuarina* spp. and *Grevellia robusta* (Silver oak) 2.5 m. Spacing between rows should be 2.0 m to 4.0 m to enable mechanized cultivation. Five rows of tree and shrubs are considered necessary for proper protection.

7.4.4 *Management*

Shelterbelts should be regarded as living groups of trees to be managed in perpetuity and the following shall be taken into consideration for management thereof:

a) Thinnings are limited to a strict minimum.
b) Cutting is done individually by single tree selection method.
c) Continuous cultivation may be required in areas with scanty rainfall.
d) If individual trees do not survive, they should be replaced immediately to avoid gaps in the vegetation belt .The shelterbelt should be protected from cattle, either by fencing or by other means, especially in the early stages.

The location of shelterbelt may be related to local features such as public and private road networks, buildings, irrigation and water conservation works and methods of soil management practice (contour bunding, contour cultivation, etc). Careful choice of site will provide maximum protection to adjacent land and give shelter and shade.

The application of the concept of shelterbelts to landscape planning and design may be effective in the creation of landscape structure of very large developments at the regional scale, or townships or campuses. Shelterbelts can also be established in association with, or instead of road side planting. This itself creates a distinctive landscape pattern. The advantages of using native species in shelter planting are:

a) New development is merged into the existing landscape. The original character of the landscape is therefore not obtruded upon.
b) The shelterbelt is a component of land management (previous waste or barren land is conserved).
c) Additional habitat for wildlife are brought into existence.

7.4.5 Species suitable for windbreaks are:

a) *For dry and arid regions*
   1) *Ailanthus excelsa* (Maharukh)
   2) *Albilzia lebbeck* (Siris)
   3) *Azadiracta indica* (Neem)
   4) *Casuarina equisetifolia* (Beef-wood)
   5) *Dalbergia sissoo* (Sisham)
   6) *Eugenia jambolana* (Jamun)
   7) *Grevillea robusta* (Silver oak)
   8) *Peltophorum ferrugineum* (Cooper pod)
   9) *Tamarindus indica* (Imli)
   10) *Pongamia glabra* (Indian beech)
   11) *Tamarix articulata* (Tamarisk)
b) *For coastal areas*
   1) *Anacardium occidentale* (Cashew)
   2) *Ailanthus triphysa* (Halmaadi)
   3) *Casuarina equisetifolia* (Beef-wood)
   4) *Pongamia glabra* (Indian beech)
   5) *Sesbania aculeata* (Sesban)
   6) *Thevetia peruviana* (Yellow oleander)
   7) *Thespesia populnea* (Indian tulip)
   8) *Vitex negundo* (Sephali)

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7.5 Air Pollution Control by Plants

Air pollution may be caused by areas or point sources such as cities, burning of wastes, industrial emissions, factories, construction activities or by linear sources such as highways. Vegetation buffers can minimize the build-up of pollution levels in urban areas, by acting as pollution sinks.

Studies have established that air pollution, smoke and sulphur dioxide leads to an exacerbation of chronic respiratory diseases and they are linked to increased risks of lung cancer, pneumonia, tuberculosis, chest disease in children, stomach cancer and cardiovascular diseases. Lead from vehicle exhausts may have an adverse effect on mental health of children, asbestos from disintegrating clutch and brake linings has been considered as a causal factor in lung cancer.

7.5.1 *Effect of Plants*

Plant leaves function as efficient gas exchange systems. Their internal structure allows rapid diffusion of water-soluble gases. These characteristics allow the plant to respire and photosynthesize, and they can also remove pollutant from the air. Some of the beneficial results of plantations may be:

a) They are good absorbers of sulphur dioxide.
b) Parks with trees have sulphur dioxide level lower than city streets.
c) Roadside planting can reduce traffic generated air borne lead, on leeward side.
d) Heavy roadside planting in the form of shelterbelts can result in a reduction in airborne lead.
e) Complete dust interception can be achieved by a 30 m belt of trees. Even a single row of trees may bring about 25 percent reduction in airborne particulate.

7.5.2 *Choosing Plants*

The three main criteria for selection of plants may be:

a) Trees, shrubs should have a dense foliage with a large surface area, because leaves reduce pollutants.
b) Evergreen trees are found to be more effective.
c) The species chosen should be resistant to pollutants, particularly in the early stages of their growth.

The following species may be examined for their likely potential for pollution control:

1) *Acacia arabica* (Babul),
2) *Citrus* spp.,
3) *Diospyros* spp.,
4) *Ficus bengalensis* (Banyan),
5) *Ficus religiosa* (Peepal),
6) *Lilium* spp. (Lily),
7) *Polyalthia longifolia* (Ashok),
8) *Tamarindus indica* (Imli),
9) *Thuja occidentalis* (Cedar),
10) *Prosopis juliflora* (Mesquite), and
11) *Zizyphus jujuba* (Jujuba), etc.

Filtering of pollutants is most effective when plants are close to the source of pollution. The design of shelterbelts against pollution is similar to those for protection from wind. They should be permeable to encourage air turbulence and mixing within the belt. There should be no large gaps. The profile should be rough and irregular and should present a tall vertical leading edge to the wing. Spaces should be left within the shelterbelt to allow gravity settlement of particles.

7.5.3 *Applications*

Air pollution shelterbelts maybe used to protect sensitive land uses from air pollution. For instance school playgrounds, children play area and residential estates close to major roads may be so protected. Shelterbelt protection may also be provided for hospitals, institutions, etc, where the vegetation may also be a visual screen and a partial noise barrier. Vegetation may also be used where the existing means of pollution control have proved inadequate.

8 SPECIFICATIONS FOR PLANTING WORKS

The requirements relating to plant materials and other materials; execution of work of tree planting, shrub planting and grassing; maintenance; etc, shall be as given in **8.1** to **8.6**. The contractor shall furnish all materials, labour and related items necessary to complete the work indicated on drawing and specified herein and shall carry out maintenance of the premises for 12 months after completion of the work or as specified by the landscape architect.

8.1 Materials

8.1.1 *Plant Materials*

Plant materials shall be well formed and shaped true to type, and free from disease, insects and defects such as knots, windburn, injuries, abrasion or disfigurement. All plant materials shall be healthy, sound, vigorous, free from disease, insect pests, or their eggs, and shall have healthy, well-developed root systems. All plants shall be hardy under climatic conditions similar to those in the locality of the project. Plants supplied shall conform to the names listed on both the plan and the plant list. No plant material shall be accepted if

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branches are damaged or broken. All material shall be protected from sun and adverse weather until planted. Nursery stock shall be inspected and approved by the landscape architect and the horticulturist/botanist shall do the botanical authenticity of the selected species.

All plants shall conform to the requirements specified in the plant list, except those plants larger than specified may be used if approved, but use of such plants shall not increase the contract price. If the use of the larger plant is approved, the spread of roots or ball of earth shall be increased in proportion to the size of the plant. Plants shall be delivered with legible identification labels.

The minimum acceptable size of all trees after pruning, with branches in normal positions, shall conform to the measurement specified in the bill of quantities unless stated otherwise. Caliper measurement shall be taken at a point on the trunk 1.0 m above natural ground. All trees supplied shall have terminal shoots. All specimen trees shall have a minimum crown spread of not less than half the size of the overall height.

8.1.2 *Topsoil (Good Earth) with p*H *Range between 6.5 and 7.5*

Topsoil or good earth shall be a friable loam; typical of cultivated top soils of the locality contains at least 2 percent of decayed organic matter (humus). It shall be taken from a well-drained arable site. It shall be free of subsoil, stones, earth clods, sticks, roots or other objectionable extraneous matter or debris. It shall contain no toxic material. No topsoil shall be delivered in a muddy condition.

Top soil in the project area shall be stripped, stacked, stored and used for filling on completion of construction.

8.1.3 *Fertilizer*

Dry farm yard manure shall be used. It shall be free from extraneous matter, harmful bacteria, insects or chemicals.

8.1.4 *Root System*

The root system shall be conducive to successful transplantation. Where necessary, the root-ball shall be preserved by support with hessian or other suitable material. On soils where retention of a good ball is not possible, the roots should be suitably protected in some other way which should not cause any damage to roots.

8.1.5 *Condition*

Trees and shrubs shall be substantially free from pests and diseases, and shall be materially undamaged. Torn or lacerated roots shall be pruned before dispatch. No roots shall be subjected to adverse conditions, such as prolonged exposure to drying winds or subjection to water logging, between lifting and delivery.

8.1.6 *Marking*

Each specimen of tree and shrub, or each bundle, shall be legibly labelled with the following:

a) Its name;
b) Name of the supplier, unless otherwise agreed; and
c) Date of dispatch from the nursery.

8.2 Execution

8.2.1 *Fine Grading*

Grades should be smooth and even on a uniform plane without abrupt changes or pockets and slope away from the buildings. The nominated landscape contractor should verify the surface drainage of planting areas and notify the landscape architect of any discrepancies, obstructions or other conditions considered detrimental to proper execution of the work and plant growth.

8.2.2 Landscape work should be tied to the existing condition such as existing trees, landscape features, utility lines, pavement kerbs. Finished grade should bear proper relationship to such control. The nominated landscape contractor shall adjust all works as necessary to meet the conditions and fulfill the intention of the drawings. After initial settlement the finish grade should be as follows:

a) Turf : 20 mm lower than adjacent walks/kerbs.
b) Shrubs and ground covers : 40 mm lower than adjacent walks/kerbs.

Prior to planting operation, the contractor should ensure all planting areas free of weeds, debris, rocks over 25 mm in diameter and clumps of earth that do not break up.

8.3 Tree Planting

8.3.1 Trees should be supplied with adequate protection as approved. After delivery, if planting is not to be carried out immediately, balled plants should be placed cheek to cheek and the ball covered with sand to prevent drying out. Bare rooted plants can be heeled in by placing the roots in a prepared trench and covering them with earth which should be watered in to avoid air pockets round the roots.

8.3.2 *Digging of Pits*

Tree pits shall be dug a minimum of three weeks prior to backfilling. The pits shall be 1 200 mm in diameter and 1 200 mm deep. While digging the pits, the topsoil up to a depth of 300 mm may be kept aside, if found

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good (depending upon site conditions), and mixed with the rest of the soil. If the soil is bad below, it shall be replaced with the soil mixture as specified further herein. If the soil is normal it shall be mixed with manure; river sand shall be added to the soil if it is heavy.

8.3.3 *Flooding of Pits to Reduce Air Pockets*

The soil backfilled, watered through and gently pressed down, a day previous to planting, to make sure that it may not further settle down after planting. The soil shall be pressed down firmly by treading it down, leaving a shallow depression all round for watering.

8.3.4 *Planting*

No tree pits shall be dug until final tree positions have been pegged out for approval. Care shall be taken that the plant sapling when planted is not buried deeper than in the nursery, or in the pot. Planting should not be carried out in water logged soil. Trees should be planted up to the original soil depth; the soil marks on the stem is an indication of this and it should be maintained on the finished level, allowing for setting of the soil after planting. All plastic and other imperishable containers should be removed before planting. Any broken or damaged roots should be cut back to sound growth.

The bottom of the planting pit should be covered with 50 mm to 75 mm of soil. Bare roots should be spread evenly in the planting pit; and small mound in the centre of the pits on which the roots are placed will aid an even spread. Soil should be placed around the roots, gently shaking the trees to allow soil particles to shift into the root system to ensure close contact with all roots and to prevent air pockets. Back fill soil should be firm as filling proceeds, layer by layer, care being taken to avoid damaging the roots.

8.3.5 *Staking*

Newly planted trees shall be held firmly although not rigidly by staking to prevent a pocket forming around the stem and newly formed fibrous roots being broken by mechanical pulling as the tree rocks.

The main methods of staking shall be:

a) A single vertical stake, 900 mm longer than the clear stem of the tree, driven 600 mm to 900 mm into the soil.
b) Two stakes as above driven firmly on either side of the tree with cross-bar to which the stem is attached (suitable for small bare-rooted or balled material).
c) A single stake driven in at an angle 45° and leaning towards the prevailing wind, the stem just below the lowest branch being attached to the stake (suitable for small bare-rooted or balled material).
d) For plant material 3 m to 4.5 m high with a single stem, a three-wire adjustable guy system may be used in exposed situations.

The end of stake should be pointed and the lower 1.0 m to 1.2 m should be coated with non-injurious wood preservative allowing at least 150 mm above ground level.

8.3.6 *Tying*

Each tree should be firmly secured to the stake so as to prevent excessive movement. Abrasion shall be avoided by using a buffer, rubber or hessian, between the tree and stake. The tree should be secured at a point just below its lowest branch, and also just above ground level; normally two ties should be used for tree. These should be adjusted or replaced to allow for growth.

8.3.7 *Watering*

The contractor should allow for the adequate watering in all newly planted trees and shrubs immediately after planting and shall, during the following growing season, keep the plant material well-watered.

8.4 Shrub Planting in Planters and Beds

All areas to be planted with shrubs shall be excavated, trenched to a depth of 750 mm, refilling the excavated earth after breaking clods and mixing with manure in the ratio 8 : 1 (8 parts of stacked volume of earth after reduction by 20 percent; 1 part of stacked volume of manure after reduction by 8 percent).

Tall shrubs may need staking, which shall be provided if approved by the landscape architect depending upon the conditions of individual plant specimen.

For planting shrubs and ground cover shrubs in planters, good earth shall be mixed with manure in proportion as above and filled in planters.

Positions of shrubs to be planted should be marked out in accordance with the planting plan. When shrubs are set out, precautions should be taken to prevent root drying. Planting holes 400 mm in diameter and 400 mm deep should be excavated for longer shrubs. Polythene and other non-perishable containers should be removed and any badly damaged roots carefully pruned. The shrubs should then be set in holes so that the soil level, after settlement, will be at the original soil mark on the stem of the shrub. The hole should be back-filled to half its depth and firmed by treading. The remainder of the soil may then be returned and again firmed by treading.

8.5 Grassing

8.5.1 *Preparation*

During the period prior to planting, the ground shall

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be maintained free from weeds. Grading and final levelling of the lawn shall be completed at least three weeks prior to the actual sowing. Regular watering shall be continued until sowing by dividing the lawn area into portions of approximately 5 m^2 by constructing small bunds to retain water. These bunds shall be levelled just prior to sowing of grass plants. At the time of actual planting of grass, it shall be ensured that the soil has completely settled.

8.5.2 *Soil*

The soil itself shall be ensured to the satisfaction of the landscape architect to be a good fibrous loam, rich in humus.

8.5.3 *Sowing the Grass Roots*

Grass roots shall be obtained from a grass patch, seen and approved beforehand. The grass roots stock received at site shall be manually cleared of all weeds and water sprayed over the same after keeping the stock in a place protected from sun and dry winds. Grass stock received at site may be stored for a maximum of three days. In case grassing for some areas is scheduled for a later date fresh stock of grass roots shall be ordered and obtained. Small roots shall be dibbled about 75 mm apart into the prepared grounds. Grass areas will only be accepted as reaching practical completion when germination has proved satisfactory and all weeds have been removed.

8.5.4 *Maintenance of Grassing*

As soon as the grass is approximately 30 mm high, it shall be rolled with a light wooden roller in fine, dry weather. When it has grown to 50 mm to 80 mm above ground, weeds shall be removed and regular cutting with a scythe and rolling shall be then begun. A top-dressing of farm yard manure, bone meal at the rate of 50 g/m^2 and NPK (Nitrogen, phosphorus and potassium fertilizer) at the rate of 10 g/m^2 shall be applied when the grass is sufficiently secure in the ground to bear the mowing machine, the blades shall be raised 25 mm above the normal level for the first two or three cuttings. That is to say, the grass should be cut so that it is from 40 mm to 50 mm in length, instead of the 30 mm necessary for mature grass.

In the absence of rain, during monsoon, the lawn shall be watered with sprinklers, every three days, soaking the soil to a depth of at least 200 mm. Damage, failure or dying back of grass due to neglect of watering specially for seeding out of normal season shall be the responsibility of the contractor.

Any shrinkage below the specified levels during the contract or defects liability period shall be rectified at the contractor's expense. The contractor shall exercise care in the use of rotary cultivator and mowing machines to reduce to a minimum the hazards of flying stones and brickbats. All rotary mowing machines are to be fitted with safety guards.

8.5.5 *Rolling*

Lawn mower with roller shall be used periodically, taking care that the lawn is not too wet and sodden.

8.5.6 *Edgings*

These shall be kept neat and shall be cut regularly with the edging shears.

8.5.7 *Watering*

Water shall be applied at least once in three days during dry weather. Whenever watering is done, it should be thorough and should wet the soil at least up to a depth of 200 mm.

8.5.8 *Weeding*

Prior to regular mowing, the contractor shall carefully remove rank and unsightly weeds.

8.6 Maintenance

8.6.1 The landscape contractor shall maintain all planted areas within the landscape contract boundaries for one year until the area is handed over in whole or in phases. Maintenance shall include replacement of dead plants, watering, weeding, cultivating, control of insects, fungus and other diseases by means of spraying with an approved insecticide or fungicide, pruning, and other horticulture operations necessary for the proper growth of the plants and for keeping the landscape contract area neat in appearance.

8.6.2 *Pruning and Repairs*

Upon completion of planting work under the contract, all trees should be pruned and all injuries repaired, where necessary. The amount of pruning shall be limited to the minimum necessary to remove dead or injured twigs and branches, and to compensate for the loss of roots and result of transplanting operations.

Pruning and removal of any part of plant materials should be done with clean sharp tools. Tools used to carry out the pruning work shall be appropriate for the task. The surface of tools and equipment shall be sterilized after use on the plant materials that are suspected or known to be diseased. Cuts on plant materials shall be made into the living tissues to induce callousing. Cut surface shall be flat, sharp and without jagged or torn edges.

Pruning shall be done in such a manner as not to change the natural habitat or special shape of the trees. Pruning operation shall consider carefully the natural growth pattern of branches on the tree, palm or shrub. Tree branches shall be pruned back to the collar at the base of the branch.

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8.6.3 *Tree Guards*

Where tree guards are necessary, care should be taken to ensure that they do not impede natural movement or restrict growth.

8.6.4 *Nursery Stock*

Planting should be carried out as soon as possible after reaching the site. Where planting needs to be delayed, care should be taken to protect the plants from pilfering or damage from people or animals. Plants with bare roots should be heeled-in as soon as received or otherwise protected from drying out, and others set closely together and protected from the wind. If planting needs to be delayed for more than a week, packed plants should be unpacked, the bundles opened up and each group of plants heeled-in separately and clearly labelled. If for any reason the surface of the roots becomes dry, the roots should be thoroughly soaked before planting.

8.6.5 *Protective Fencing*

According to local environment, shrubs shall be protected adequately from vandalism, until established.

8.6.6 *Routine Maintenance Work Schedule*

Sl No.	*Operation*	*Frequency*
(1)	(2)	(3)
i)	Watering	Checking all planting areas and pits and water as often as necessary to ensure that planting material does not dry out
ii)	Weeding	Monthly
iii)	Edging	Monthly
iv)	Fertilizing:	
	a) Trees/palms	Once every three months
	b) Shrubs/ground covers	Monthly
	c) Grass	Once every three months
v)	Loosening of soil	Monthly
vi)	Control of pest by applying appropriate insecticides	Fortnightly
vii)	Control of disease by applying appropriate fungicides	Monthly, increasing the frequency to fortnightly during rainy season
viii)	Grass cutting	Fortnightly
ix)	Pruning and shaping trees/ palms	Once every six month for small and low sagging branches
x)	Staking	As and when required
xi)	Trimming shrubs/ ground covers	Monthly or as when required

8.6.7 *Clean-Up Works*

There shall be areas designated by landscape architect for the contractor to carry out clean-up works. These shall include the following:

a) Removal of dead and/or overhanging branches of existing trees, palms, shrubs and ground covers.
b) Removal of any garbage and unsightly foreign materials.
c) Removal of dead vines and plant materials.

The contractor shall prevent damages to the existing plant materials, identified to be conserved. The plant materials that are to be conserved if damaged beyond use during the clean-up operations, the contractor shall be liable to replace the plant materials at his expense.

8.6.8 *Restoration*

The contractor is responsible for the use of all materials, labour and equipment and any injury to the plant material, labour and equipment shall be repaired or the same replaced by the contractor at his own expense.

8.6.9 *Completion*

On completion, the ground shall be formed over and left tidy.

9 SERVICE/UTILITIES IN LANDSCAPE DEVELOPMENT

9.1 Designed integration of structures and elements related to external services (underground and over ground utilities) with landscape is most essential for any outdoor space. This may, therefore, be taken care of in conjunction with the provisions under Part 4 'Fire and Life Safety', Part 8 'Building Services', Part 9 'Plumbing Services' and Part 11 'Approach to Sustainability' of the Code.

The following services, generally, are the subject of design coordination work for external areas:

a) *Stormwater drainage*
    1) Stormwater network;
    2) Open drain and swale;
    3) Subsurface drainage system;
    4) Catch basin and manholes;
    5) Culvert and bridge;
    6) Percolation pits;
    7) Water harvesting units;
    8) Retention walls and tanks;
    9) Connection of all service lines up to out-fall; and
    10) Other related structures.

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b) *Sewage disposal system*
   1) Sewerage network;
   2) Manholes, inspection chambers and grease trap;
   3) Septic tank, soak-pits, sewage treatment plant and root zone unit;
   4) Solid waste management units;
   5) Connection of all service lines up to out-fall; and
   6) Other related structures.

c) *Water supply (including irrigation)*
   1) Water supply network;
   2) Inspection chamber and valve chamber;
   3) Water tank and treatment plant;
   4) Tube well, bore well and associated pump houses, etc;
   5) Service lines, elements associated with water features and pools; and
   6) Irrigation lines and allied requirements.

d) *Fire lines*
   1) Yard hydrant lines;
   2) Yard or fire hydrants and hose reel box;
   3) Fire water tank and pumps; and
   4) Inspection chamber and valve chamber.

e) *Electrical works*
   1) Electrical network;
   2) Light fixtures for road, pedestrian paths, special landscape features and building façade;
   3) Inspection chambers, junction boxes and feeder pillars;
   4) Electric poles, high voltage lines and towers;
   5) Transformer, substation and distribution box; and
   6) Other related structures.

f) *Telephone and underground cable network*
   1) Telephone network;
   2) Inspection chambers;
   3) Telephone poles, transmission towers; and
   4) Other related structures.

g) *Fuel and gas line*
   1) Supply network;
   2) Inspection chamber and valve chamber;
   3) Fuel tank and gas tank; and
   4) Other related structures.

h) *HVAC*
   1) Ventilation shafts for basement ventilation; and
   2) Chiller and cooling towers.

9.1.1 The following guidelines shall be applied for the designed integration of external services networks and elements in the landscape proposal:

a) Manholes and inspection chamber covers for all external services should be adequately designed for the imposed load (pedestrian or vehicular) and the top finish level has to be in alignment or flushed with the pavement or finished ground level. The alignment of these structures should be such that it is in geometric perpendicular or parallel with adjacent building or landscape lines. This would facilitate easy and unobstructed movement for pedestrians and increase the accessibility for wheelchair users in public place and also aid the landscape geometry to be maintained.

b) Fire hydrants should be prominently located and integrated with the landscape. Aesthetically designed fire hose cabinet with clear access as per statutory norms for fire safety, to be located in geometric relation with adjacent building or landscape lines. These structures should not be a hindrance to vehicular or pedestrian movement.

c) Irrigation hydrants should be unobtrusively located and generally at the edge of shrub planting and additionally in close proximity to a drainage chamber or catch basin to avoid waterlog. Hydrants should not be located inside the chamber to minimize waterlog from leaking pipes causing various health related hazards. Hydrants should be located 200 mm above the ground level.

d) Landscape lighting is a specialized activity and illumination consultant or designer should develop the landscape lighting plan taking into consideration energy saving measures, safety aspects, lighting pollution and illumination level. Light fixtures are an important part of street furniture and it is advisable to use pole mounted light fixtures for public landscape than bollards that are prone to vandalism and damage.

e) Water body and fountains in public spaces should have filtration facility to avoid health hazards related to stagnant water. The piping should be concealed and the pump room, balancing tank and all other service structures to be designed as an integral part of landscape.

f) Storage facilities for inflammable liquid fuel and gas should be designed as an integral part of the landscape and should be housed in designed enclosures taking into consideration all statutory norms these structures are subjected to.

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g) All underground service lines have to be well coordinated and stacked appropriately in the design stage to avoid overlaps and marked with indicators above the ground for ease in maintenance and servicing. Underground service stacks should be generally aligned in soft areas with no tree plantation, this would facilitate easy maintenance without disrupting the hard surface.

h) Designed façade for service structures that are above the ground in external areas is advisable so as to assist in developing aesthetically pleasing exterior environment. Such structures should be designed in a modular way so that it would be part of the street furniture.

10 ROOF LANDSCAPE

10.1 Green roof design include the following:

a) Understanding the structural stability and load bearing capacity (dead and imposed loads) of roof. The structural loading is a combination of dead loads; all permanently placed parts of the roof, including hardscape, plants, growing medium, features, etc; and the imposed loads, such as people and temporary components.

b) Waterproofing of the structure and the green areas.

c) Arrangement of surface and subsurface drainage of the roof.

d) Soil fill, and planting with limited root zone.

e) Location and planting of trees.

f) Location and design of pavements, walls, landscape features and structures.

10.2 Design Guidelines

The guidelines given below shall be followed for the design of green roofs (*see* Fig. 1)

a) *Screed* — A concrete layer shall be laid on the roof slab to provide slopes for subsurface drainage of vegetated areas, drains. Where there is a large green area on the roof, perforated pipes laid in screed shall be used to channelize subsurface water to the adjoining drainage chambers.

b) *Waterproofing membrane* — A protective layer shall be laid on the sloped concrete surface to protect the building's structure and the waterproofing membrane on the building slab.

c) *Drainage* — Drainage shall comprise of surface drainage and subsurface drainage. Subsurface drainage layer shall be very porous to permit water to pass easily through it. It should be permanent and continuous over the entire roof surface and strong enough to support the weight of the plant materials and hardscape above it. This layer shall be kept free of any materials that could prevent the free flow of water to the drains. Drainage cells may be used to increase soil depth. Surface drainage shall allow for easy flow of water from the roof surface to the drainage chambers on grade. It shall comprise of drains, catch basins. They shall be carefully designed to avoid expansion joints on the roof.

d) *Filter membrane* — Helps in containing the roots and the growing medium, while allowing for water penetration and prevents clogging of the drainage layer and roof drains.

e) *Soil* — Shall be as described in **8.1.2**. The depth of soil shall depend on type of planting, screed thickness and structural allowance for fill above slab.

f) *Vegetation* — Shall be grass, shrubs, ground covers, trees. Type of vegetation shall depend on the structural allowance for fill above slab.

g) *Irrigation* — Shall be adequately provided. The thin depth and well-drained soil used in green roof construction cannot provide the plantings with the subsurface water normally available to ground level plantings. Care shall be exercised to prevent the soil mass from drying out and causing damage to the plant materials.

h) *Services/Utilities* — As described in **9.1** shall be integrated with the landscape

j) *Hardscape* — Includes paving, street furniture and water features, walls, fences, screens, pergolas, kerbs, fire paths, roads. The landscape elements shall be considered in relationship to the structural limitations of the roof and its supports below. The street furniture, including lighting fixtures shall be carefully anchored on rooftops.

11 PROTECTION OF LANDSCAPE DURING CONSTRUCTION

Development projects involve disturbance to the existing soil conditions, removal of existing trees and overall change in the microclimate and drainage pattern. Measures to minimize hazardous effects should be put into effect as explained below.

11.1 Pre-Construction Measures

Measures for the prevention of soil erosion, sediment control and management of stormwater shall be implemented as given in **11.1.1** to **11.1.5**.

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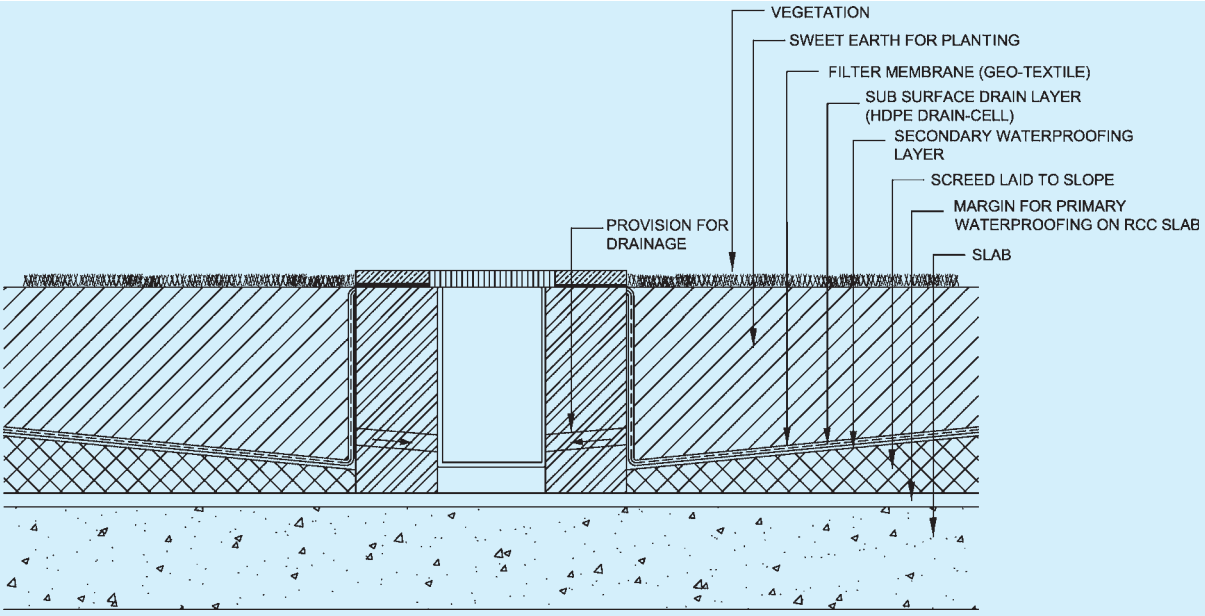


FIG. 1 TYPICAL DETAILS OF GREEN ROOF

11.1.1 *Timing of Construction*

Construction work and erosion control applications shall be scheduled and sequenced during dry weather periods when the potential for erosion is the lowest. Slope protection techniques to control erosion shall be used when construction during wet season is unavoidable. Sedimentation collection systems, drainage systems, and runoff diversion devices shall be installed before construction activity. The landscape architect/engineer-in-charge shall monitor the site conditions and progress of work and schedule appropriate timing and sequencing of construction.

11.1.2 *Preservation of Existing Vegetation*

11.1.2.1 Protection of existing vegetation (including trees, shrubs, grasses and other plants) where possible, by preventing disturbance or damage to specified areas during construction is recommended. This practice minimizes the amount of bare soil exposed to erosive forces. All existing vegetation shall be marked on a site survey plan. A tree survey in prescribed format shall be carried out as indicated in Table 3.

Table 3 Plant Material Schedule for Tree Survey

(*Clause* 11.1.2.1)

Sl No.	Tree No.	Botanical Name	Common Name	Girth mm	Height mm	Spread mm	Condition
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

The landscape plan should indicate trees, which have been preserved, and also those, which had to be transplanted or removed clearly differentiating between these three categories.

11.1.2.2 Trees retained on the project site shall be protected during the construction period by following measures:

a) Damage to roots shall be prevented during trenching, placing backfill, driving or parking heavy equipment, dumping of trash, oil, paint, and other materials detrimental to plant health by restricting these activities to outside the area of the canopy of the tree.

b) Trees shall not be used for support; their trunks shall not be damaged by cutting and carving or by nailing posters, advertisements or other material.

c) Lighting of fires or carrying out heat or gas emitting construction activity within the ground, covered by canopy of the tree shall not be permitted.

d) Young trees or saplings identified for preservation (height less than 2.00 m, 0.10 m trunk girth at 1.00 m height from finish ground, 2.00 m crown diameter) within the construction site have to be protected using tree guards of approved specification.

e) Existing drainage patterns through or into any preservation area shall not be modified unless specifically directed by the landscape architect/engineer-in-charge.

f) Existing grades shall be maintained around existing vegetation and lowering or raising the

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levels around the vegetation is not allowed unless specifically directed by the landscape architect/engineer-in-charge.

g) Maintenance activities shall be performed as needed to ensure that the vegetation remains healthy.

h) The preserved vegetated area shall be inspected by the landscape architect/engineer-in-charge at regular intervals so that they remain undisturbed. The date of inspection, type of maintenance or restorative action followed shall be recorded in the logbook.

11.1.3 *Staging Areas*

Measures shall be followed for collecting runoff from construction areas and material storage sites; diverting water flow away from such polluted areas, so that pollutants do not mix with stormwater runoff from undisturbed areas.

Temporary drainage channels, perimeter dike/swale, etc, shall be constructed to carry the pollutant-laden water directly to treatment device or facility. The plan shall indicate how the above is accomplished on site, well in advance of the commencing of the construction activity.

11.1.4 *Preservation of Topsoil*

Topsoil removal and preservation shall be mandatory for development projects larger than 1.00 hectare. Topsoil shall be stripped to a depth of 200 mm from areas proposed to be occupied by buildings, roads, paved areas and external services. Topsoil is rich in organic content and is essential to establish new vegetation. It shall be stockpiled to a height of 400 mm in designated areas and shall be reapplied to site during plantation of the proposed vegetation. Topsoil shall be separated from subsoil debris and stones larger than 50 mm diameter. The stored topsoil may be used as finished grade for planting areas.

11.1.5 *Spill Prevention and Control*

Spill prevention and control plans shall be made, clearly stating measures to stop the source of the spill, to contain the spill, to dispose the contaminated material and hazardous wastes, and stating designation of personnel trained to prevent and control spills. Hazardous wastes include pesticides, paints, cleaners, petroleum products, fertilizers and solvents.

11.2 Measures During Construction

During construction soil becomes unconsolidated due to removal of stabilizing material such as vegetation and disturbance of stabilized existing grade resulting in loss of topsoil and also deposition in undesirable places. A soil erosion and sedimentation control plan to be prepared prior to construction. The soil erosion, sediment control and stormwater practices should be considered whilst construction is proceeding, in accordance with **11.2.1** to **11.2.4**.

11.2.1 *Sedimentation Basin*

A temporary dam or basin at the lowest point of the site has to be constructed for collecting, trapping and storing sediment produced by the construction activities, together with a flow detention facility for reducing peak runoff rates. This would allow most of the sediments to settle before the runoff is directed towards the outfall.

11.2.2 *Contour Trenching*

Contour trenching is an earth embankment or ridge-and-channel arrangement constructed parallel to the contours along the face of the slope at regular intervals on long and steep slopes (in sloping areas with slopes greater than 10 percent) (*see* Fig. 2). They are used for reducing runoff velocity, increasing the distance of overland runoff flow, and to hold moisture and minimize sediment loading of surface runoff. Vegetative cover of tree and native grasses in the channels may be planted to stabilize the slopes and reduce erosion.

11.2.3 *Mulching*

Mulching shall be used with seeding and planting in steep slope areas (slopes greater than 33 percent) that are prone to heavy erosion. Netting or anchoring shall be used to hold it in place. Other surface runoff control measures like contour terracing to break up concentrated flows shall be installed prior to seeding and mulching. Materials such as straw, grass, grass hay and compost shall be placed on or incorporated into

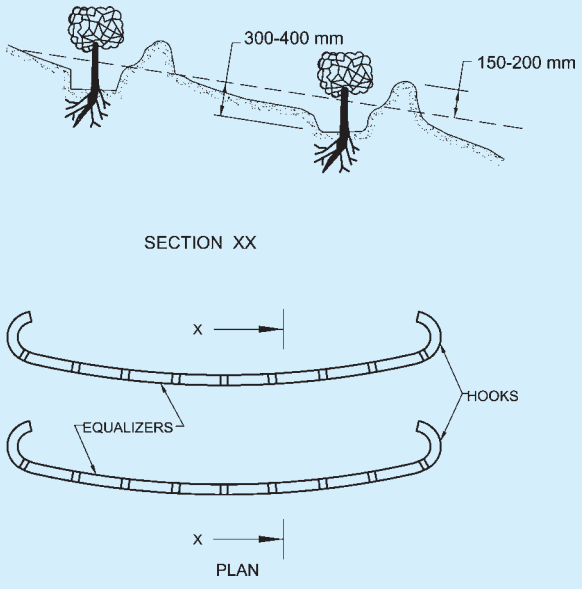


FIG. 2 TYPICAL CONTOUR TRENCHES

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the soil surface. In addition to stabilizing soils, mulching will reduce the stormwater runoff over an area. Together with seeding or planting, mulching aids plant growth by holding the seed, fertilizers and topsoil in place. It retains moisture and insulates the soil against extreme temperatures.

11.2.4 *Geo-Grids*

A deformed or non-deformed netlike polymeric material used with foundation, soil, rock, earth or any other geo-technical engineering-related material as an integral part of the human made project structure or system, called geo-grids may be used as control measure. On filling with lightly compacted soil or fine aggregate, a monolithic structure is created providing an effective means of confinement for unconsolidated materials within the cells and preventing their movement even on steep slopes. If required the area can then be seeded to maintain 'green' environment. The junctions have a central opening through which water can permeate ensuring that organic material receives moisture for rapid growth.

12 SOIL AND WATER CONSERVATION

The soil conservation, sediment control and stormwater management practices as given under **12.1** to **12.3** shall be followed after construction is completed.

12.1 Vegetative Measures

The vegetative measures shall include the following.

12.1.1 *Topsoil Laying*

This includes the placement of topsoil or other suitable plant material over disturbed lands to provide suitable soil medium for vegetative growth. Topsoil laying shall involve replacing fertile topsoil that were stripped and stockpiled during earlier site development activities; the laid soil shall be stabilized before the next monsoon by planting grass, shrubs and trees.

The following guidelines shall apply to the placement of topsoil:

a) Existing or established grade of subsoil should be maintained.

b) A *p*H of 6.0 to 7.5 and organic content of not less than 1.5 percent by mass is recommended for topsoil. Where *p*H is less than 6.0, lime shall be applied to adjust *p*H to 6.5 or higher up to 7.5. Any soils having soluble salt content greater than 500 parts per million shall not be used.

c) Prior to spreading the topsoil, the sub-grade shall be loosened to a depth of 50 mm to permit bonding. Topsoil shall be spread uniformly at a minimum compacted depth of on grade of 1:3 or steeper slopes; a minimum depth of 100 mm on shallower slopes is essential. A depth of 300 mm is preferred on relatively flatter land.

12.1.2 *Planting/Vegetation Cover*

The most effective way to prevent soil erosion, sedimentation and to stabilize disturbed and undisturbed land is through the provision of vegetative cover by effective planting practices. The foliage and roots of plants provide dust control and a reduction in erosion potential by increasing the infiltration, trapping sediment, stabilizing soil, and dissipating the energy of hard rain. Temporary seeding shall be used in areas disturbed after rough grading to provide soil protection until final cover is established. Permanent seeding/ planting is used in buffer areas, vegetated swales and steep slopes. The vegetative cover also increases the percolation of rainwater thereby increasing the ground water recharge.

12.2 Stormwater Management and Filtration Techniques

The surface water flow is increased in urban areas due to predominance of hard surfaces. Stormwater management techniques assure conservation of water thereby increasing the ground water recharge. Filters facilitate draining pollutants out from surface water runoff through straining before discharge into the drainage way. Rain water harvesting and sullage recycle systems need to be implemented on all new constructions over 1 000 m^2 in urban areas. *See also* Part 9 'Plumbing Services, Section 2 Drainage and Sanitation' and **7.2** of Part 11 'Approach to Sustainability' of the Code.

12.2.1 *Rain Water Harvesting Structures in Urban Environment*

12.2.1.1 Water harvesting refers to the collection and storage of rainwater and also harvesting surface and ground water, prevention of loss through evaporation and seepage, and other hydrological and engineering interventions aimed at conserving water.

12.2.1.2 The advantages of using rain water harvesting structures in urban areas are as follows:

a) Water harvesting recharges ground water and is an ideal solution to water problems in areas with inadequate water resources.

b) Increase in ground water aquifer level due to methods enhancing infiltration.

c) Mitigation of the effect of drought.

d) Reduction of stormwater runoff into the public drainage system.

e) Reduction of flooding of the roads during monsoons.

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f) Removal of pollutants and soil from the stormwater runoff.

g) Reduction of soil erosion.

12.2.1.3 Methods of ground water recharge may be as follows:

a) Recharge pits.

b) Recharge trenches.

c) Reuse of abandoned dug wells.

d) Reuse of abandoned hand pumps.

e) Recharge shafts.

f) Lateral shafts with bore wells.

g) Spreading techniques like percolation ponds, check dams or gabion structures.

12.2.2 *Structures for Rain Water Harvesting and Soil and Water Conservation*

These may be as given in **12.2.2.1** and **12.2.2.2**.

12.2.2.1 *Infiltration techniques*

a) *Infiltration trenches* — An infiltration trench is a rock filled trench that receives stormwater runoff. Stormwater passes through a combination of pre-treatment measures, a grass swale and into the trench to be stored in void spaces and then infiltrates into the soil matrix.

b) *Bio-filtration swale/grass swale* — Bio-filtration swales are vegetated channels with a slope similar to that of standard storm drain channels (less than 0.6 percent), but wider and shallower to maximize flow residence time and promote pollutant removal by filtration through the use of properly selected vegetation. It has to be designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration and reduce the flow velocity of the stormwater runoff. It shall be integrated with stormwater system (*see* Fig. 3).

c) *Sand filter* — Sand filters are devices that filter stormwater runoff through a sand layer into an underground drain system which conveys the water to a detention facility. They are effective in removing total suspended solids. The effectiveness of sand filtration is improved if it is preceded by a grass swale with infiltration trench.

12.2.2.2 *Detention facilities*

a) *Wet ponds* — Wet ponds are constructed basins that have a permanent pool of water throughout the year (or at least throughout the wet season). Wet ponds retain the stormwater runoff in a permanent pool and facilitate pollution removal through settling and biological update.

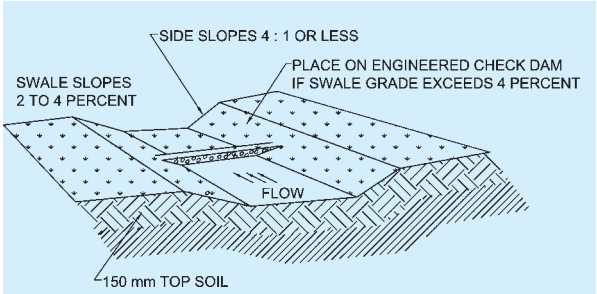


FIG. 3 GRASS SWALE

b) *Stormwater wet lands* — Stormwater wet lands are structures similar to wet ponds that incorporate wetland plants into the design. They have to be designed for treating stormwater runoff, and typically have less biodiversity than natural wetland systems. A distinction should be made between using a constructed wet land for stormwater management and diverting stormwater into natural wetland. The latter is not recommended because it would degrade the resource.

c) *Wet vaults and storage tanks* — Wet vaults and tanks are underground facilities used for the storage of surface water, and typically constructed from reinforced cement concrete (vaults) or corrugated pipes (tanks). The water that is captured in these vaults and tanks may be used later for irrigation.

12.3 Conservation and Reuse of Water for Irrigation

The following measures shall be followed for design of irrigation systems for landscape works:

a) Water conserving irrigation systems should differentiate between systems for different water use zones on the site. Supplementary irrigation sources should be used by means of appropriate water harvesting measures.

b) The irrigation system should be designed considering the prevailing wind direction, slope and proposed grade, type of soil, soil percolation, and the type of vegetation to be watered.

c) Spray irrigation to be designed to provide total head to head cover to avoid dry spots and spray on to paved areas and unplanted surfaces.

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d) Spray irrigation is to be avoided in areas of width less than 3.00 m.

e) Sullage recycle systems are ideal for large housing complexes and residential colonies. Sullage (or water from kitchens and bathrooms) is treated and recycled for gardening and toilet flushing reducing fresh water requirement by 60 percent. Irrigation system should be designed keeping sullage recycle in view.

f) For requirements regarding, the volume of water for different kinds of landscapes, Part 9 'Plumbing Services, Section 1 Water Supply' of the Code may be referred.

13 STREET FURNITURE

The design elements for outdoor spaces may be classified under the following categories:

a) *Pavement and other pedestrian movement spaces, covering*
   1) Footpath with heavy pedestrian traffic,
   2) Footpath with light pedestrian traffic,
   3) Plaza and public assembly spaces,
   4) Kerb to footpath, and
   5) Steps and ramps.

b) *Parking and vehicular movement corridor, covering*
   1) Parking unit,
   2) Median and road divider,
   3) Road marking, and
   4) Speed breaker.

c) *Traffic management units, covering*
   1) Bollards,
   2) Barriers,
   3) Crash guard,
   4) Gate/Access control,
   5) Vehicular height restrictors, and
   6) Traffic separators.

d) *Outdoor public conveniences, covering*
   1) Seating,
   2) Drinking fountains, and
   3) Toilet/Wash rooms.

e) *Shelter and kiosks, covering*
   1) Bus shelters,
   2) Police booth,
   3) Telephone booth,
   4) Milk booth/food stall,
   5) Florist,
   6) Information desk, and
   7) Snack and coffee stall.

f) *Outdoor illumination, covering*
   1) Street light,
   2) Façade light, and
   3) Ambient light.

g) *Tree protection units, covering*
   1) Tree guard,
   2) Tree grate, and
   3) Planter.

h) *Garbage collection units, covering*
   1) Litter bin, and
   2) Spittoons.

j) *Service utilities, relating to*
   1) Water supply network,
   2) Stormwater network,
   3) Sewerage network,
   4) Electrical network,
   5) Telephone lines,
   6) Cable e-net,
   7) Gas, and
   8) Irrigation network.

k) *Display and signage* — Location of the street furniture shall be coordinated with the traffic flow pattern of vehicles and pedestrians and external services.

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NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPE DEVELOPMENT, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 2 Signs and Outdoor Display Structures

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 10/Section 2) covers the requirements of signs and outdoor display structures with regard to public safety, structural safety and fire safety. With the growing industrialization followed by urbanization of large number of cities and towns, the advertising signs and their appurtenant structures had increased. In the absence of any definite rules, the display of advertising signs had proceeded unrestrained, resulting in a city or town littered indiscriminately with hoardings and advertising signs of all types. Consideration of the aspects of urban aesthetics and public safety, pointed to the necessity for building regulations for the control of advertising signs and structures.

This Section was, therefore, first published in 1970 as Part 10 of the Code and was subsequently revised in 1983 and 2005. In the first revision, comments and suggestions received during its use were incorporated. In the second revision of 2005, the scope of Part 10 was enlarged to cover landscaping along with signs and outdoor display structures. The Part 10 was brought out in two sections, namely, Section 1 Landscape planning and design, and Section 2 Signs and outdoor display structures. In the last revision of this Section, few terminologies related to signs; few explanatory figures; guidelines for signs in urban and rural areas; and guidelines for environmental graphics for the cityscape were introduced.

Based on the experience gained in the use of this Section, the provisions have been modified in this revision. Also certain terminologies have been included. Further, this Section has been linked with Part 3 ‘Development Control Rules and General Building Requirements’ of the Code through reference to the same, for ensuring appropriate controls of signs as applicable for the purpose of accessibility for persons with disabilities.

The provisions of this Section are without prejudice to the regulations already in vogue in areas requiring special controls in harmony with their historical monuments/environment.

For signs coming on highways, relevant IRC rules shall apply. In this connection reference may be made to the following:

IRC 46 : 1972	A policy on road advertisements
IRC 67 : 2012	Code of practice for road signs (*third revision*)
IRC SP 85 : 2010	Guidelines for variable message signs

For the purpose of deciding whether a particular requirement of this Section is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Section.

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NATIONAL BUILDING CODE OF INDIA

PART 10 LANDSCAPE DEVELOPMENT, SIGNS AND OUTDOOR DISPLAY STRUCTURES

Section 2 Signs and Outdoor Display Structures

1 SCOPE

1.1 This Code (Part 10/Section 2) covers the requirements with regard to public safety, structural safety and fire safety of all signs and outdoor display structures.

1.2 The requirements for signs and related aspects for the persons with disabilities shall be complied with in accordance with **13** of Part 3 'Development Control Rules and General Building Requirements' of the Code.

2 TERMINOLOGY

For the purpose of this Section, the following definitions shall apply.

2.1 Signs

2.1.1 *Abandoned Sign* — A sign structure that has ceased to be used, and the owner intends no longer to use the same, for the display of sign copy, or as otherwise defined by state law.

2.1.2 *Advertising Sign* — Any surface or structure with characters, letters or illustrations applied thereto and displayed in any manner whatsoever out of doors, for purposes of advertising or to give information regarding or to attract the public to any place, person, public performance, article or merchandise whatsoever, and which surface or structure is attached to, forms part of or is connected with any building, or is fixed to a tree or to the ground or to any pole, screen, fence or hoarding or displayed in space.

2.1.3 *Animated Sign* — A sign employing actual motion or the illusion of motion. Animated signs, which are differentiated from changeable signs (*see* **2.1.7**), include the following types:

a) Electrically activated (flashing/patterned illusionary movement);
b) Environmentally activated; and
c) Mechanically activated.

2.1.4 *Banner* — A flexible substrate on which copy or graphics may be displayed.

2.1.5 *Banner Sign* — A sign utilizing a banner as its display surface.

2.1.6 *Canopy Sign* — A sign affixed to the visible surface(s) of an attached or freestanding canopy.

2.1.7 *Changeable Sign* — A sign with the capability of content change by means of manual or remote input, including signs which are electrically activated and manually activated

2.1.8 *Closed Sign* — An advertising sign in which at least more than fifty percent of the area is solid or tightly enclosed or covered.

2.1.9 *Combination Sign* — A sign that is supported partly by a pole and partly by a building structure.

2.1.10 *Direction Sign* — A sign which is usually included with an arrow and used for indicating a change in route or confirmation to a correct direction.

2.1.11 *Electric Sign* — An advertising sign in which electric fittings, which are an integral part of the signs, are used.

2.1.12 *Exterior Sign* — Any sign placed outside a building.

2.1.13 *Freestanding Sign* — A sign principally supported by a structure affixed to the ground, and not supported by a building, including signs supported by one or more columns, poles or braces placed in or upon the ground.

2.1.14 *Ground Sign* — An advertising sign detached from a building, and erected or painted on the ground or on any pole, screen, fence or hoarding and visible to the public.

2.1.15 *Identification Sign* — A sign that gives specific location information, identifies specific items, for example, 'Parking Lot B', 'Building No. 5', 'First Aid', etc.

2.1.16 *Illuminated Sign* — An advertising sign, permanent or otherwise, the functioning of which depends upon its being illuminated by direct or indirect light, and other than an electric sign.

2.1.17 *Informational Sign* — A sign used for overall information for general organization of a series of elements, such as campus plan, bus route, building layout and shopping mall plan.

2.1.18 *International Symbol of Accessibility* — The symbol consisting of a square overlaid with a stylized image of a person using a wheelchair. It is also known as the (international) wheelchair symbol.

NOTE — The symbol is often provided where access has been improved, particularly for wheelchair users and other mobility impaired persons. The symbol denotes a barrier free environment to help older people, parents with prams and travellers with luggage besides persons with disabilities. The wheelchair symbol is always facing to the right.

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2.1.19 *Mansard* — An inclined decorative roof-like projection that is attached to an exterior building façade.

2.1.20 *Marquee Sign* — An advertising sign attached to or hung from a marquee canopy or other covered structure projecting from and supported by the building and extending beyond the building wall, building line.

2.1.21 *Open Sign* — An advertising sign in which at least fifty percent of the enclosed area is uncovered or open to the transmission of wind.

2.1.22 *Parapet* — A low wall or railing built along the edge of a roof or floor.

2.1.23 *Portable Sign* — Any sign not permanently attached to the ground or to a building or building surface.

2.1.24 *Projecting Sign* — An advertising sign affixed to any building element and projecting more than 300 mm therefrom.

2.1.25 *Regulatory Sign* — Sign that gives operational requirements, restrictions or gives warnings, usually used for traffic delineation or control, for example 'Stop', 'No Parking', 'One Way', etc.

2.1.26 *Roof Sign* — An advertising sign erected or placed on or above the parapet or any portion of a roof of a building including signs painted on the roof of a building.

2.1.27 *Sky Sign* — An advertising sign displayed in space like,

a) a gas filled balloon anchored to a point on the ground and afloat in the air with or without a streamer of cloth, etc; or
b) sky-writing, that is, a sign or word traced in the atmosphere by smoke discharged from an aeroplane.

2.1.28 *Sign* — Any device visible from a public place that displays either commercial or non-commercial messages by means of graphic presentation of alphabetic or pictorial symbols or representations. Non-commercial flags or any flags displayed from flagpoles or staffs shall not be considered as signs.

2.1.29 *Sign Area* — The area of the smallest geometric figure, or the sum of the combination of regular geometric figures, which comprise the sign face. The area of any double-sided or 'V' shaped sign shall be the area of the largest single face only. The area of a sphere shall be computed as the area of a circle. The area of all other multiple-sided signs shall be computed as 50 percent of the sum of the area of all faces of the sign.

2.1.30 *Sign Copy* — Those letters, numerals, figures, symbols, logos and graphic elements comprising the content or message of a sign, exclusive of numerals identifying a street address only.

2.1.31 *Sign Face* — The surface upon, against or through which the sign copy is displayed or illustrated, not including structural supports, architectural features of a building or sign structure, nonstructural or decorative trim, or any areas that are separated from the background surface upon which the sign copy is displayed by a distinct delineation, such as a reveal or border.

2.1.32 *Sign Structure* — Any structure supporting a sign.

2.1.33 *Temporary Sign* — An advertising sign, banner or other advertising device constructed of cloth, canvas, fabric or any other light material, with or without a structural frame, intended for a limited period of display; including decorative displays for holidays or public demonstrations.

2.1.34 *Verandah Sign* — An advertising sign attached to, posted on or hung from a *Verandah*.

2.1.35 *Wall Sign* — An advertising sign, other than a projecting sign, which is directly attached to or painted or pasted on the exterior surface of or structural element of any building.

2.1.36 *Window Sign* — A sign affixed to the surface of a window with its message intended to be visible to and readable from the public way or from adjacent property.

2.2 General

2.2.1 *Approved* — Approved by the Authority having jurisdiction.

2.2.2 *Area of Special Control* — Any area declared an area of special control by the Authority in respect of the display of advertising signs, where the requirements for such display are more restrictive than elsewhere in the area controlled by the Authority.

2.2.3 *Authority Having Jurisdiction* — The authority which has been created by a statute and which for the purpose of administering the Code/Part, may authorize a committee or an official to act on its behalf; hereinafter called the 'Authority'.

2.2.4 *Building Line* — The line up to which the plinth of a building adjoining a street or an extension of a street or on a future street may lawfully extend. It includes the lines prescribed, if any, in any scheme.

2.2.5 *Combustible Material* — A material is combustible, if it burns or adds heat to a fire when tested for non-combustibility in accordance with good practice [10-2(1)].

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2.2.6 *Owner* — A person, a group of persons or a body having a legal interest in land and/or building thereon. This includes freeholders, leaseholders or those holding a sub-lease, who will have legal right to occupation and have liabilities in respect of safety or building condition.

In the case of lease or sub-lease holders, as far as ownership with respect to the structure is concerned, the structure of a flat or structure on a plot belongs to the allottee/lessee till the allotment/lease subsists.

NOTE—For the purpose of the Code, the word 'owner' will also cover the generally understood terms like 'client', 'user', etc.

2.2.7 *Street Line* — The line defining the side limits of a street.

3 PERMITS

3.1 Application

3.1.1 *Conditions for Grant of Permit*

No sign shall be erected, altered or maintained without first obtaining a permit for the same from the Authority and shall be subjected to the following conditions:

a) Written permission shall not be granted or renewed at any one time, for a period exceeding three years from the date of grant of such permission or renewal.

b) Written permission or the renewal granted by the Authority shall become void,

   1) if any sign or the part thereof falls either through an accident or any other causes;

   2) if any addition is made except for the purpose of making it secure under the direction of the Authority;

   3) if any change is made in the sign or part thereof;

   4) if any addition or alternation is made to the building or structure upon or over which the sign is erected and if such addition or alteration involves disturbance of the sign or any part thereof; or

   5) if the building or structure upon or over which the sign is erected fixed or restrained becomes demolished or destroyed.

c) Light and ventilation of buildings, if any, situated near the signs and hoardings, shall not be obstructed in any way;

d) Advertisements displayed shall not be of any objectionable or obscene nature given under **3.3**;

e) In the public interest, the Authority shall have the right to suspend the licence even before the expiry period, upon which the licensee shall remove the signs;

f) Licensee shall be responsible for the observance of all the rules and regulations laid down by the Authority;

g) Signs should not mar the aesthetic beauty of the locality;

h) Signs, other than those pertaining to building, shall not be permitted to come in front of buildings such as hospitals, educational institutions, public offices, museums, buildings devoted to religious worship and buildings of national importance;

j) Maintenance and inspection of advertising signs and their supports shall be as given under **4**.

k) No hoarding sign on the highways shall be put without the permission of the Authority maintaining/in-charge of flyovers, highways/ roads; and

m) In addition all signs shall conform to the general requirements given under **6**.

n) Signs shall not be nailed or tied to trees or any other woody vegetation.

3.1.2 *Application for Licence or Permit and Required Drawings*

Every person intending to erect, alter or display an advertising sign for which a permit or licence is required, shall make application to the Authority on the prescribed form containing such particulars as the Authority may require. Such form (*see* Annex A) shall be signed by the applicant and by the owner of the site upon which such sign is or is to be situated and shall include the following information:

a) Full specifications showing the length, height and weight of the sign, the location where it is to be erected, the manufacturer's name and address and where applicable, the number of lights and electrical details of the same.

b) Such form shall be accompanied by a location plan indicating the position of the sign on the site drawn to a scale of 1:500 and by full detail drawing drawn to a scale of 1:20 or an exact multiple thereof in ink or on prints including, if required by the Authority, an elevation showing the sign in relation to the façade.

c) In the case of roof signs, projecting signs or ground signs in addition to the foregoing, the size of all members of supporting frameworks and anchorages, and, if required by the Authority, the necessary design calculations shall be furnished with the application.

d) Any other particulars as may be desired by the Authority as covered in **6**.

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e) In the case of sky signs, necessary information as desired by the Authority may be supplied.

3.1.3 The Authority may, on the receipt of an application for permit, either sanction or refuse such a permit or sanction with modifications as deemed necessary and shall communicate decision to the applicant. If within 30 days or receiving an application for a permit the Authority fails to intimate in writing to the applicant, the permit along with the plans shall be deemed as sanctioned.

3.1.4 When a sign has to be altered, information only on such plans and statements, as may be necessary, shall be included in the form. However, the changing of movable parts of an approved sign that is designed for such changes, shall not be deemed an alteration provided the conditions of the original approval and the requirements of this part are not violated.

3.1.5 *Existing Advertising Signs*

Advertising signs in existence at the date of promulgation of the Code and covered by a valid licence or permit issued by the Authority shall not require to be licensed under the Code until such licence or permit has expired, provided it is maintained in a good and safe condition.

3.1.6 For advertising signs, application shall be submitted through a structural engineer along with necessary drawings and structural calculations. The wind load taken in the design calculations shall be in accordance with Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

3.2 Exemptions

3.2.1 No permit shall be required for signs and outdoor display structures of the following types:

a) If the signs are exhibited within the window of any building provided it does not affect light and ventilation of the building.

b) If it relates to the trade or business carried on within the land or building upon which such advertisement is exhibited or to any sale, entertainment or meeting or lettering of such land or building or any effects therein; or to the trade or business carried on by the owner of any tramcar, omnibus or other vehicle upon which such advertisements is exhibited, provided it is not more than 1.2 m^2.

c) In addition no permission shall be required for the signs covered by the provisions **3.2.2** to **3.2.5**. Such exemptions, however shall not construed to relieve the owner of the sign from the responsibility of erection and maintenance in compliance with the Code.

3.2.2 *Wall Signs*

The wall signs listed in **3.2.2.1** to **3.2.2.3** shall not require a permit.

3.2.2.1 *Store signs*

Non-illuminated signs erected over a show window or over the door of a store or business establishment which announce the name of the proprietor and the nature of the business conducted therein; the sign shall not be more than 1 m in height and the width of the business establishment.

3.2.2.2 *Government building signs*

Signs erected on a municipal, state or central government building which announce the name, nature of the occupancy and information.

3.2.2.3 *Name plates*

Any wall sign erected on a building or structure indicating the name of the occupant of building, which is not more than 0.5 m^2 in area.

3.2.3 *Ground Signs*

3.2.3.1 *Transit directions*

The erection or maintenance of a sign designating the location of a transit line, a rail track, station or other public carrier when not more than 0.5 m^2 in area.

3.2.3.2 *Highway signs*

In general, advertisements of the following classes are permissible without permission though these should reasonably conform to the principles set out in **3.5.1**:

a) *Class (1) Functional Advertisements*

1) Official warning signs, traffic directions, sign posting and notices or advertisements posted or displayed by or under the directions of any public or court officer in the performance of his official or directed duties.

Example:

DIVERSION AHEAD

2) Direction signs to places of public amenity, such as petrol filling stations, hospitals, first-aid posts, police stations and fire stations.

Examples:

HOSPITAL	BUS STATION

3) Signs relating solely to any city, town, village or historic place, shrine, place of tourist interest.

Examples:

ELLORA CAVES	FARIDABAD TOWN

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4) Signs, notices, etc, erected by the Defence Department for information of members of the armed forces or the public.

Example:

ARTILLERY RANGE AHEAD

5) Signs restricting trespass of property, limited to 0.2 m^2 in area or less.

Examples:

PRIVATE PROPERTY

TRESPASSERS WILL BE PROSECUTED

6) Signs or notices, 0.2 m^2 in area or less, placed so as to show direction to a residence and planted sufficiently away from the carriageway.

b) *Class (2) Advertisements Relating to the Premises on which these are Displayed*

1) Advertisements for the purpose of identification, direction or warning with respect to the land or building on which they are displayed, provided not exceeding 0.2 m^2 in area in the case of any such advertisement.

Examples:

MIND THE STEP

PROPERTY OF MOHAN LAL & CO

USHA KIRAN

2) Advertisements relating to any person, partnership or company separately carrying on a profession, business trade at the premises where any such advertisement is displayed; limited to one advertisement not exceeding 0.3 m^2 in area in respect of each such person, partnership or company.

Example:

RAM LAL & COMPANY

3) Advertisements relating to any institution of a religious, educational, cultural, recreational, medical or similar character or any hotel, public house, DAK bungalow, block of flats, club, boarding house or hostel situated on the land on which any such advertisement is displayed; limited to one advertisement not exceeding 1.2 m^2 in area in respect of each such person, partnership or company.

Examples:

COLLEGE OF ENGINEERING

HOLIDLAY HOUSE

ROTARY CLUB

c) *Class (3) Advertisements of Temporary Nature*

1) Advertisements relating to the sale or letting of the land on which they are displayed; limited in respect of each such sale or letting to one advertisement not exceeding 2 m^2 in area.

Examples:

TO LET

HOUSE FOR SALE

2) Advertisements announcing sale of goods or livestock, and displayed on the land where such goods or livestock are situated or where such sale is held, limited to one advertisement not exceeding 1.2 m^2 in area.

Examples:

SALE THIS WEEK

CATTLE SALE

3) Advertisements relating to the carrying out of building or similar work on the land on which they displayed exceeding 2 m^2 in area.

Example:

CAUTION EXCAVATION IN PROGRESS

4) Advertisements announcing any local event of a religious, educational, cultural, political, social or recreational character, not being an activity promoted or carried on for commercial purposes; limited to a display of advertisements occupying an area not exceeding 0.6 m^2 on any premises.

Examples:

DIWALI MELA

FLOWER SHOW

3.2.4 *Temporary Signs*

3.2.4.1 *Construction site signs*

Construction signs, engineers' and architects' signs and other similar signs which may be authorized by the Authority in connection with construction operations (*see* Table 1).

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3.2.4.2 *Special displays signs*

Special decorative displays used for holidays, public demonstrations or promotion of civic welfare or charitable purposes, on which there is no commercial advertising, provided that the Authority is not held responsible for any resulting damage (*see* **15.2.2**).

3.2.5 The qualitative requirements of signs given in Table 1 shall not require any permit.

3.3 Unsafe and Unlawful Signs

3.3.1 *Notice of Unsafe and Unlawful Signs*

When any sign becomes insecure, or in danger of falling, or otherwise unsafe, or if any sign shall be unlawfully installed, erected or maintained in violation of any of the provisions of the Code, the owner thereof, or the person or firm maintaining the same, shall upon written notice of the Authority, forthwith in the case of immediate danger and in any case within not more than three days, make such sign conform to the provisions of this Section or shall remove it. If within three days the order is not complied with, the Authority may remove such sign at the expense of the owner.

3.3.1.1 Notwithstanding the above, it shall be the responsibility of the owner to ensure the safety of the advertising signs, even without a reference from the Authority. The owner shall also ensure to remove the remnant structures of the abandoned sign.

3.3.2 Any sign which in the opinion of the Authority is an obscene, repulsive, revolting, or objectionable character; or prejudicial to the Authority; or savouring undesirable political propaganda; or of a nature calculated to produce pernicious or injurious effect on public or any particular class of persons; or is displayed in such a place, in such a manner or by any such means as, in the opinion of the Authority, could be likely to affect injuriously the amenities of, or to disfigure any neighbourhood, shall not be permitted under any circumstances.

3.4 Area of Special Control

3.4.1 Whenever in the opinion of the Authority it is likely that any advertising device otherwise permitted in terms of the Code may affect injuriously or disfigure any particular area within the jurisdiction of the Authority it may proclaim such area as an area of special control. Parks and land for public use may also be included as areas of special control.

3.4.2 Subject to the provisions of **3.4.1** within such area, the erection and display of any advertising sign shall be prohibited or restricted in any manner deemed necessary by the Authority. The Authority shall publish its intention of proclaiming such an area in one or more newspapers circulating in the area of jurisdiction of the Authority. Any owner of property within such area who may feel aggrieved by such proclamation may appeal within one month from such publication against proclamation of such an area to the Authority whose decision shall be final.

3.4.3 The wording on any *Verandah* sign, permitted by the Authority, in any area of special control, shall be restricted to the name of the proprietor or firm occupying the premises, the name of the building or institution, the general business or trade carried on, such as 'JEWELLER', 'CAFÉ', 'DANCING', or information regarding the location of the building entrance, box office or regarding the theatre programme or similar information. No *Verandah* sign in any area of special control shall advertise any particular article of merchandise nor shall any such sign refer to price or reduction in price.

3.4.3.1 Normally no other advertising sign shall, except as for **3.4.3**, be within a distance of 30 m from the area of special control.

3.5 Prohibition of Advertising Signs on Certain Sites

Where the Authority is of the opinion that any site is unsuitable for display of advertising signs by virtue of the general characteristics of the locality in regard to historic, architectural, cultural or similar interest, or by virtue of its position, the display *o*f such signs is likely to affect in any way the safety of any form of transport, erection of advertising signs on such a site shall be prohibited.

3.5.1 *Highways and Roads*

In general the following advertisements should not be permitted:

a) At or within 100 m of any road junction, bridge or railway crossing or another crossing. In urban areas, this distance may be reduced to 50 m, provided there is no conflict with the requirements stated further on.

   NOTE — The safe stopping distance for a vehicle traveling at a speed of 50 km/h is 60 m. This should be the 'uninfluenced distance' for a driver approaching a junction. Assuming that 3 s is the time during which the influence of an advertisement board persists, the distance travelled in this time will be about 40 m. The sign should, therefore, be more than 100 m away from the junction. Hence 100 m is suggested.

b) In such manner and at such places as to obstruct or interfere with the visibility of approaching, merging or intersecting traffic;

c) Within 10 m of the edge of a carriageway;

   NOTE — A distance of 10 m may be taken as the normal minimum setback from the edge of the

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carriageway, the maximum area of the advertisement being 0.3 m^2 for every metre of setback.

d) Within 50 m along the road, of any sign board erected for the regulation of traffic under the orders of a Public Authority, such as a Traffic Authority, a Public Transport Authority, or a Local Authority;

e) In such a form as will obscure or hinder interpretation of any sign, signal or other device erected for traffic control by the Public Authorities. For instance, the advertisements should not imitate or resemble, in colour or shape, the standard legal traffic signs, or employ such words as 'STOP' in the same manner as used on traffic signs;

f) On boards, placards, cloth banners or sheets (except traffic signs) hung across a road as they distract the attention of the driver and are, therefore, hazardous;

NOTE — Any advertisement allowed on the sides of a foot over bridge or flyover across the carriage-ways shall be restricted in size and shape such that no part of the advertisement board projects beyond the top, bottom and sides of the parapet of foot over bridge or flyover.

g) In such form as will obstruct the path of pedestrians and hinder their visibility at crossings;

h) Within right-of-way of the road; and

j) When these will affect local amenity.

3.5.2 Illuminated advertisements of the following description are objectionable from the angle or traffic safety and should not be allowed:

a) Advertisements which contain, include or are illuminated by any flashing, intermittent or moving light or lights except those giving public service information, such as time, temperature, weather or date;

b) Illuminated advertisements of such intensity or brilliance as to cause glare or impair vision of the driver or pedestrians, or which otherwise interfere with any operations of driving; and

c) Advertisements illuminated in such a way as to obscure or diminish effectiveness of any official sign, device or signal.

4 MAINTENANCE AND INSPECTION

4.1 Maintenance

All signs for which a permit is required, together with all their supports, braces, guys and anchors shall be kept in good repair, both structurally and aesthetically, and when not galvanized or constructed of approved corrosion-resistive non-combustible materials, shall be painted, when necessary to prevent corrosion.

4.2 Housekeeping

It shall be the duty and responsibility of the owner of every sign to maintain the immediate premises occupied by the sign, in a clean, sanitary and healthy condition.

4.3 Inspection

Every sign for which a permit has been issued and every existing sign for which a permit is required shall be inspected by the Authority at least once in every calendar year.

5 TYPES OF SIGNS

In this Section, the following types of signs are covered [*see also* a few explanatory figures of general sign types (*see* Fig. 1A), comparison of roof and wall or fascia sign (*see* Fig. 1B) and sign area computation methodology (*see* Figs. 1C and 1D)].

a) Electric and illuminated signs (*see* **7**);

b) Ground signs (*see* **8**);

c) Roof signs (*see* **9**);

d) *Verandah* signs (*see* **10**);

e) Wall signs (*see* **11**);

f) Projecting signs (*see* **12**);

g) Marquee signs (*see* **13**);

h) Sky signs (*see* **14**); and

j) Miscellaneous and temporary signs (*see* **15**).

6 GENERAL REQUIREMENTS FOR ALL SIGNS

6.1 Loads

Every advertising sign shall be designed so as to withstand safely the wind, dead, seismic and other loads as set out in Part 6 'Structural Design, Section 1 Loads, Forces and Effects' of the Code.

6.2 Illumination

No sign shall be illuminated by other than electrical means, and electrical devices and wiring shall be installed in accordance with the requirements of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code. In no case, shall any open spark or flame be used for display purposes unless specifically approved by the Authority.

Table 1 Advertising Signs for Which No Permit or Licence is Required

(*Clause* 3.2.5)

Sl No.	Class (with Sample)		Area of Each Separate Sign (or Aggregate)	Maximum Height Above Ground Floor Level to Top of Sign	Illumination Provided	Description of Sign		Remarks
						Number Permitted	Maximum Dimension of Letters, Symbols, etc	
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
i)	Functional signs of certain authorities statutory undertakings, public transport undertakings, fire brigades, etc	BUS STATION	As may be reasonably required for the safe and efficient performance of the function	As stated in col 3	As stated in col 3	As stated in col 3	As stated in col 3	
ii)	Miscellaneous signs relating to premises on which they are displayed:		Not more than 4 m^2	Not more than 5 m (in area of special control 4m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed[1)]	Any number	Not more than 750 mm (in area of special control 300 mm)	
	a) Identification, direction, or warning	X-RAY UNIT MIND THE STEP						
	b) Person partnership or company carrying profession business, or trade; name or private person	CHAWLA & CO. LTD S. BOSE	Not more than 0.3 m^2 each	Not more than 5 m (in area of special control 4 m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed[1)]	One at each entrance	Not more than 750 mm (in area of special control 300 mm)	
	c) Relating to any institution of a religious, educational, cultural, or medical character; name of building or premises	COLLEGE OF COMMERCE XYZ FLATS	Not more than 1.2 m^2 each	Not more than 5 m (in area of special control 4 m)	Only to indicate that medical or similar services or supplies are available on premises where advertisement is displayed[1)]	One on each frontage	Not more than 750 mm (in area of special control 300 mm)	
iii)	Temporary signs (cloth banners):							
	a) Signs relating to the sale or letting off the land (within the site of the building) on which they are displayed	HOUSE FOR SALE	Not more than 2.4 m^2 (ratio of width to depth 2:1) in aggregate area. No sign to project more than 1 m when displayed on a building (within the site)	Not more than 5 m (in area of special control 4 m)	None	Any number but aggregate area not to exceed that given in col 3	Not more than 750 mm (in area of special control 300 mm)	Shall not be displayed earlier than 28 days before the sale or other matter is due to start and shall be removed within 14 days after the conclusion of such sale or matter

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
a)	Signs relating to the carrying out of building or similar operations on the land where sign is displayed THIS FACTORY IS BEING ERECTED BY XYZ CONSTRUCTION CO Building and Engineering Contractor	Not more than 4 m^2	Not more than 5 m (in area of special control 4 m)	None	One for each road frontage for each contractor or sub-contractor	Not more than 750 mm (in area of special control 300 mm)	May be displayed only while such works are in progress
b)	Signs announcing any local event in connection with an activity promoted for non-commercial purposes by various local organizations DIWALI MELA	Not more than 1.5 m^2 (in aggregate area 4 m^2)	Not more than 5 m (in area of special control 4 m)	None	Any number but aggregate area not to exceed that given in col 3 on any premises	Not more than 750 mm (in area of special control 300 mm)	Shall not be displayed earlier than 28 days before the event is due to start and shall be removed within 14 days of its conclusion
c)	Signs and business premises for areas of special control, signs on business premises with reference to the business, the goods sold, or the services provided, etc, in these premises and the name and qualifications of the person carrying on such activity XYZQR BANK	Not to exceed one-twelfth of area of each face (up to a height of 4 m)	Not more than 4 m	Only to indicate that medical or similar services or supplies are available where advertisement is displayed[1)]	Any number but aggregate area not to exceed that given in col 3	Not more than 300 mm	Area to be computed as if the advertisement were laid flat against the face of the building

[1)] Or where connected with danger.

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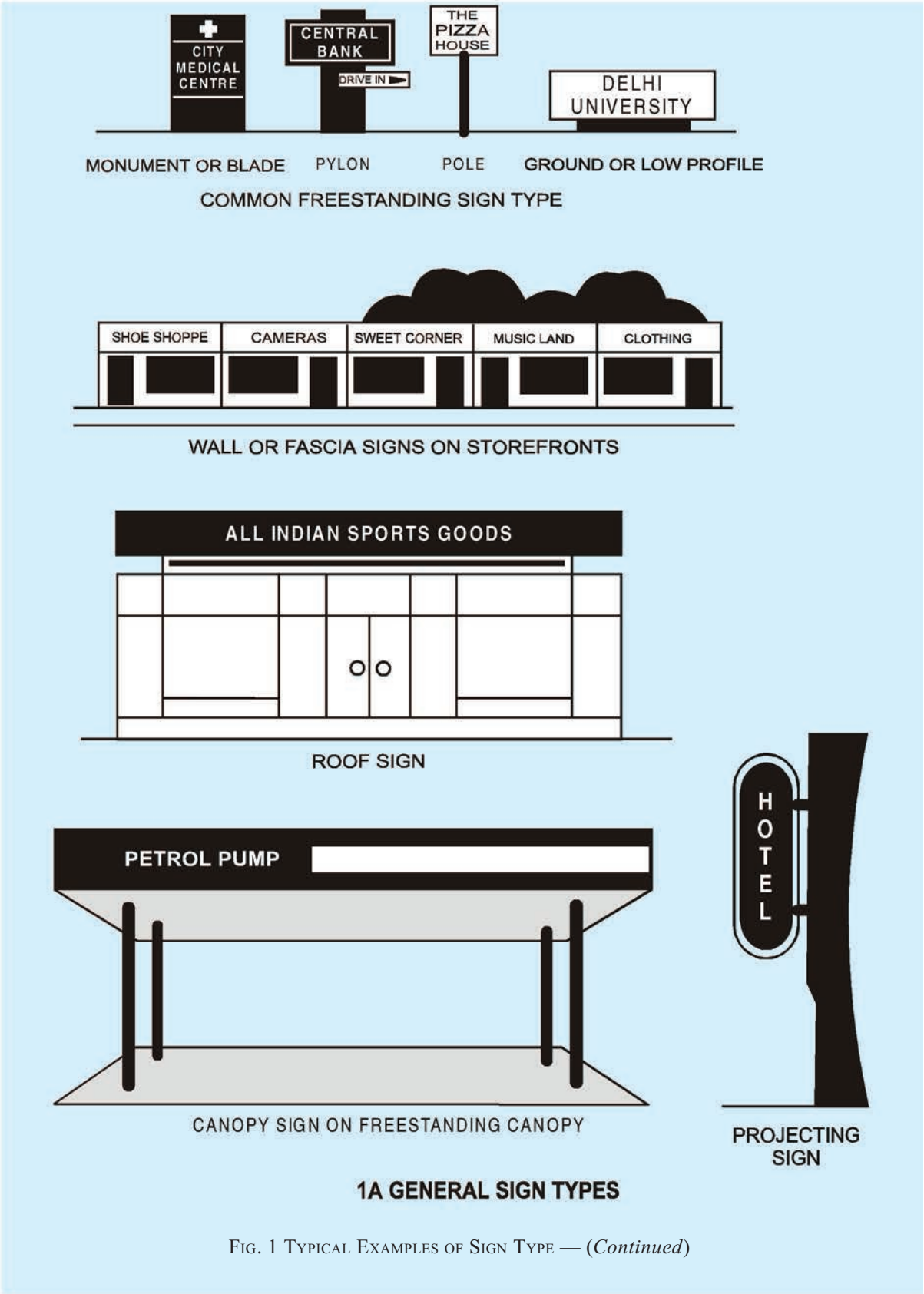


FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — (*Continued*)

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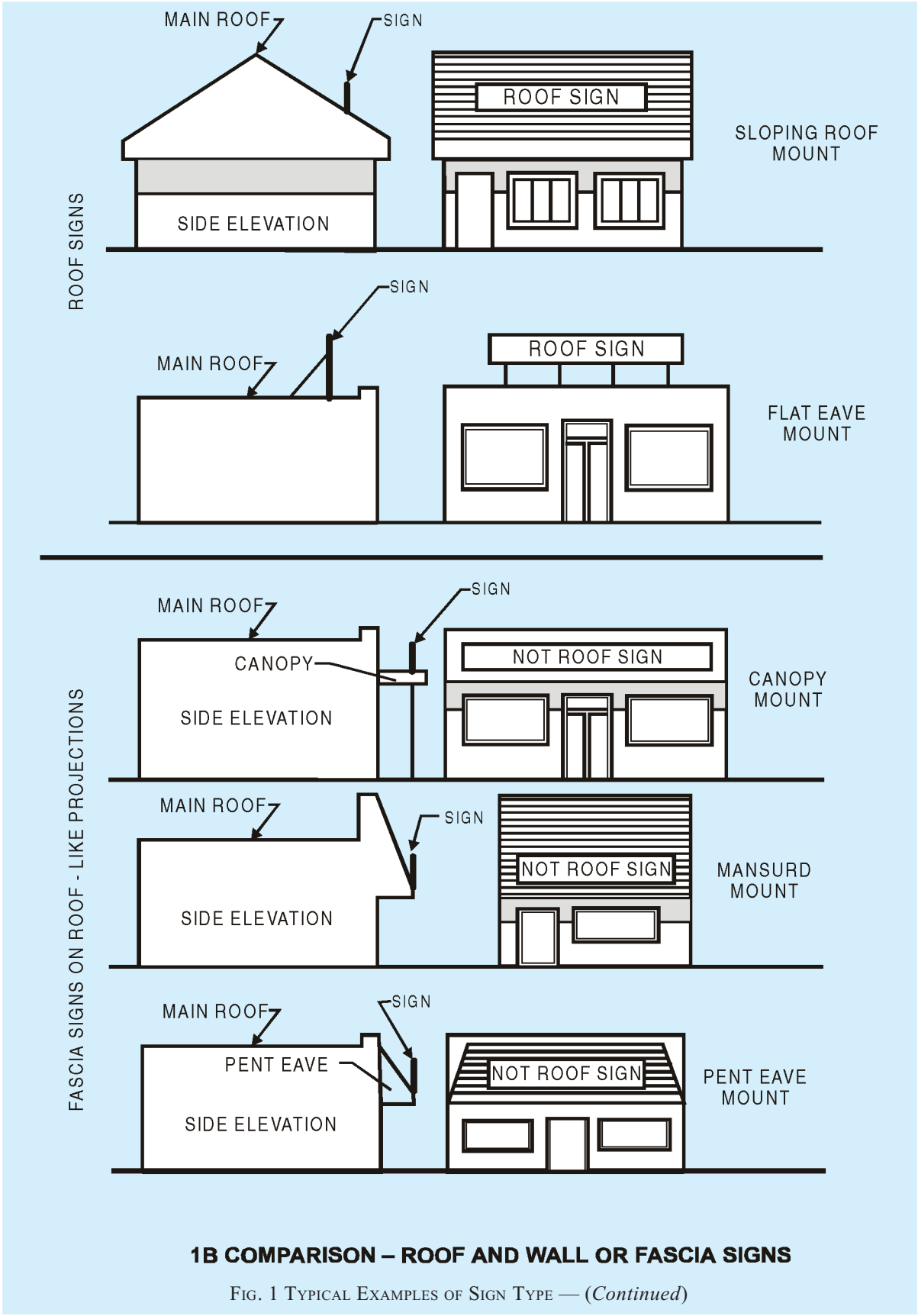


FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — (*Continued*)

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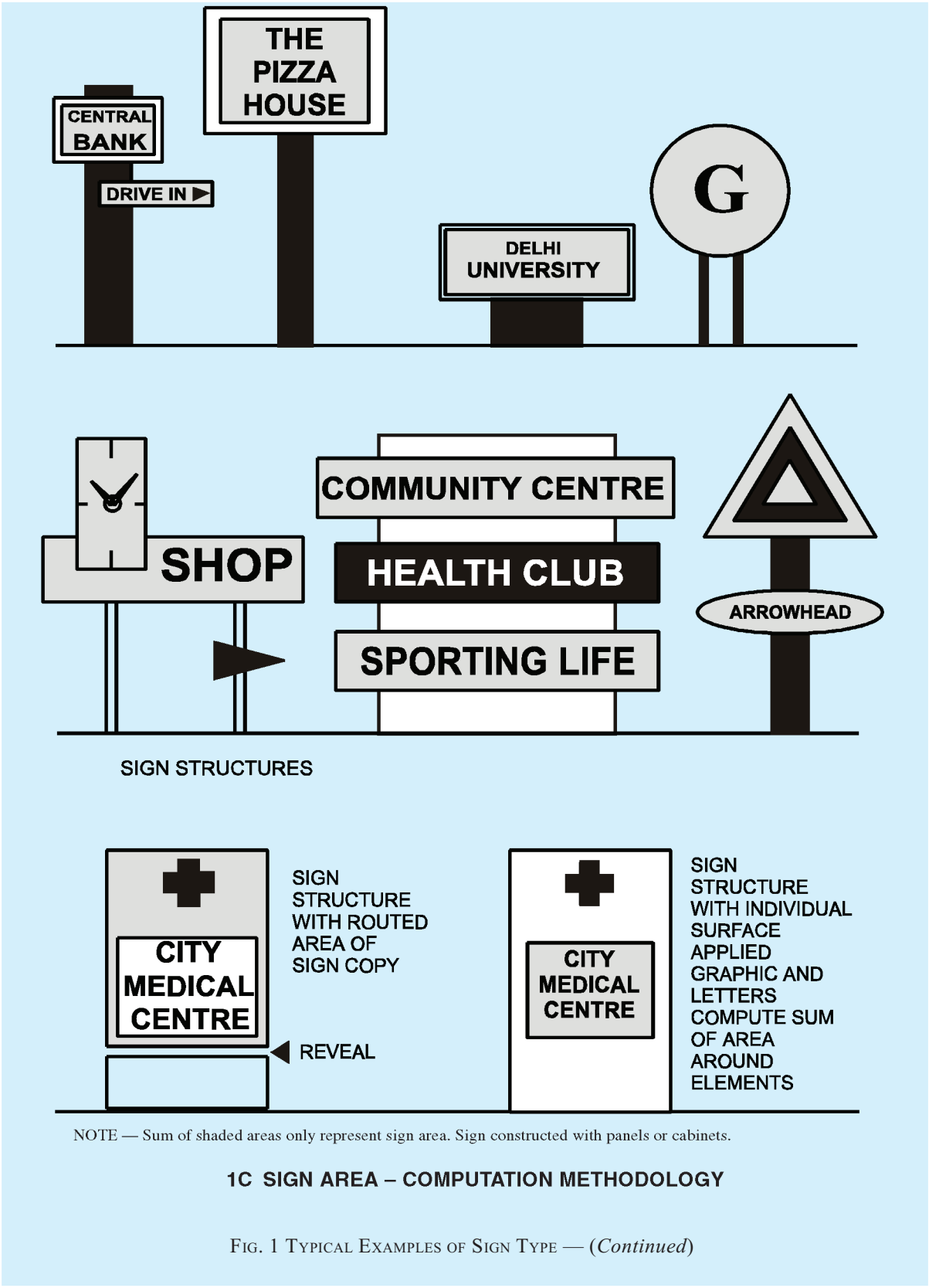
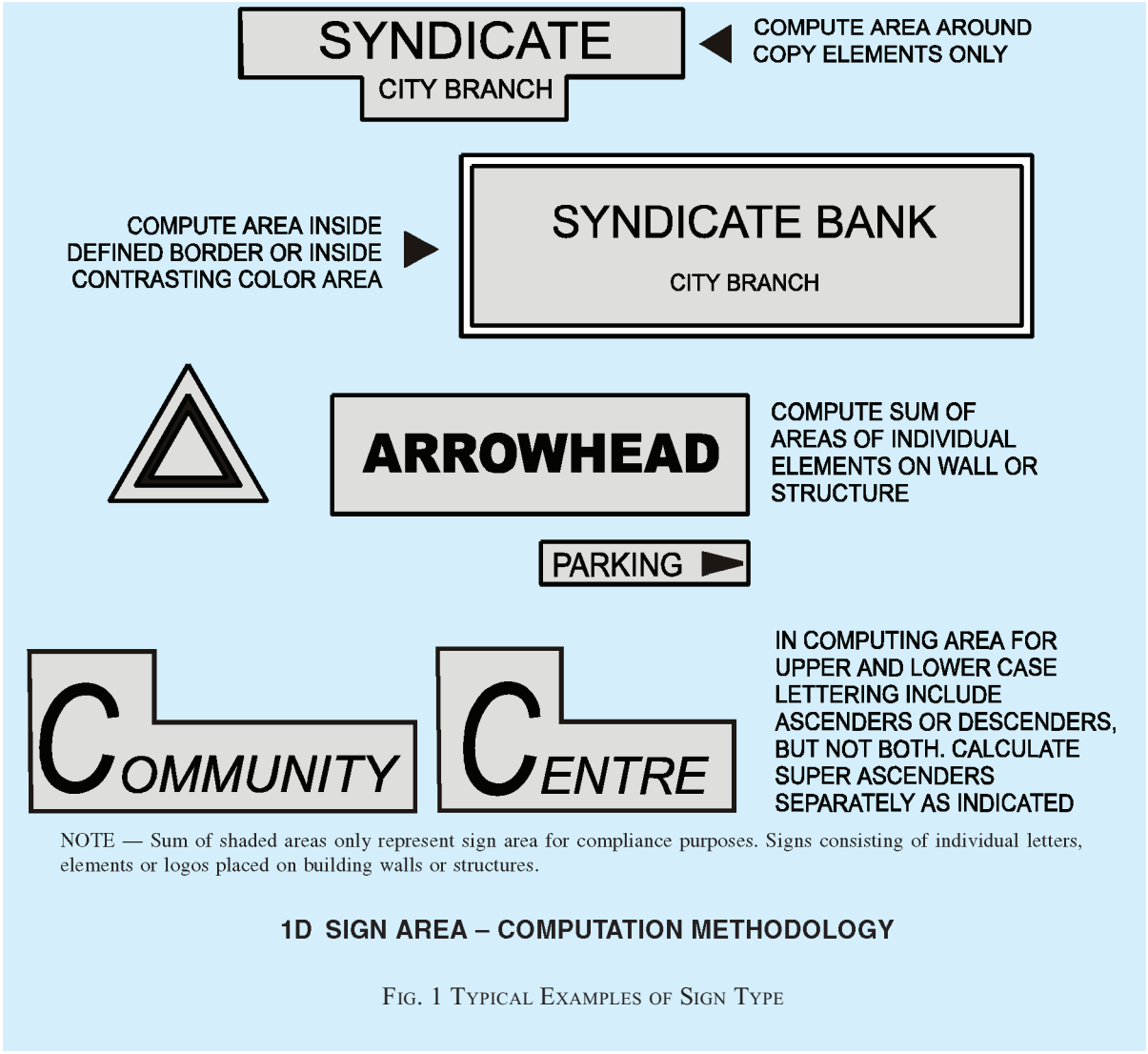


FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE — (*Continued*)

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NOTE — Sum of shaded areas only represent sign area for compliance purposes. Signs consisting of individual letters, elements or logos placed on building walls or structures.

1D SIGN AREA – COMPUTATION METHODOLOGY

FIG. 1 TYPICAL EXAMPLES OF SIGN TYPE

6.3 Design and Location of Advertising Signs

a) Sign should not obstruct any pedestrian movement, fire escape, door or window, opening used as a means for egress or fire fighting purposes.

b) No sign shall in any form or manner interfere with openings required for light and ventilation.

c) When possible, signs should be gathered together into unified systems. Sign clutter should be avoided in the landscape.

d) Signs should be combined with lighting fixture to reduce unnecessary posts and for ease of illuminating the signs.

e) Information signs should be placed at natural gathering spots and included in the design of sight furniture.

f) Placement of sign should be avoided where they may conflict with pedestrian traffic.

g) Sign should be placed to allow safe pedestrian clearance vertically and latterly.

h) Braille strips may be placed along sign edges or raised letters may be used for readability for the blind and partially sighted.

j) No sign shall be attached in anyway to a tree or shrub.

6.4 Use of Combustibles

6.4.1 *Ornamental Features*

Wood or plastic or other materials of combustible characteristics similar to wood may be used for mouldings, cappings, nailing blocks, letters and latticing where permitted and for other purely ornamental features of signs.

6.4.2 *Sign Facings*

Sign facings may be made of approved combustible

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materials provided the area of each face is not more than 10 m^2 and the wiring for electric lighting is entirely enclosed in metal conduit and installed with a clearance of not less than 5 cm from the facing material.

6.5 Damage or Defacement by Removal of Advertising Signs

Whenever any advertising sign is removed, whether in consequence of a notice or order under the Code or otherwise, any damage or defacement to the building or site on or from which such sign was displayed, shall be made good to the satisfaction of the Authority.

6.6 Alteration to Ground Level

Whenever any alteration is made to the ground level adjacent to any advertising sign, the owner of the site on which sign is erected, shall be responsible for the alteration of the height of such sign so as to conform to the requirements of this Section.

6.7 Traffic Control Interference

No advertising sign shall be erected or maintained which interferes with or is likely to interfere with any sign or signal for the control of traffic. No advertising sign shall be placed particularly in bends and curves so as to obstruct the view of traffic at intersecting streets.

6.8 Draining of Signs

Adequate provision for drainage shall be made in every advertising sign, where the possibility of collection of moisture exists.

6.9 Glass in Signs

All glass used in advertising signs, other than glass tubing used in gas discharge or similar signs, shall be of safety glass conforming to accepted standards [10-2(2)], at least 3 mm thick. Glass panels in advertising signs shall not exceed 6 m^2 in area, each panel being securely fixed in the body of the sign independently of all other panels. Glass signs shall be properly protected from the possibility of damage by falling objects by the provisions of suitable protecting metal canopies, or by other approved means. Use of glass may be discouraged or avoided wherever possible for signs placed overhead.

6.10 Interference to Fire Hydrants

Advertising signs shall be so placed as not to obstruct the use of the hydrants or other fire fighting appliances.

6.11 Serving Devices

Ladders, platforms, hooks, rings and all other devices for the use of servicing personnel shall have safety devices and suitable design loadings (reference may also be made to Part 7 'Construction Management, Practices and Safety' of the Code).

6.12 Animated Devices

Signs which contain moving section or ornaments shall have fail-safe provisions to prevent the section or ornaments from releasing and falling or shifting its center of gravity more than 450 mm. The fail-safe device shall be in addition to the mechanism and its housing which operate the movable section or ornament. The fail-safe device shall be capable of supporting the full dead weight of the section or ornament when moving mechanism releases.

7 ELECTRIC SIGNS AND ILLUMINATED SIGNS

7.1 Material for Electric Signs

Every electric sign shall be constructed of non-combustible material except where the sign is purely a flood-lit sign.

7.2 Installation of Electric Signs and Illuminated Signs

Every electric sign and illuminated sign shall be installed in accordance with Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code.

7.3 No illuminated sign in red, amber or green colour shall be erected or maintained within a horizontal distance of 10 m of any illuminated traffic sign.

7.4 All advertising signs illuminated by light other than a white light, at height of less than two storeys or 6 m above the footpath, whichever be the greater height, shall be suitably screened so as to satisfactorily prevent any interference with any sign or signal for the control of traffic.

7.5 Intense Illumination

No person shall erect any sign which is of such intense illumination as to disturb the residents in adjacent or nearby residential buildings. Notwithstanding any permission given for such erection, any such sign which after erection is, in the opinion of the Authority, of such intense illumination as to disturb the occupants of adjacent or nearby buildings shall, on the order of the Authority, be suitably altered or removed by the owner of the site concerned within such reasonable period as the Authority may specify.

7.6 Hours of Operation

No electric sign, other than those necessary in the opinion of the Authority in the interest of public amenity, health and safety, shall be operated between midnight and sunrise.

7.7 Flashing, Occulting and Animated Signs

No flashing, occulting or animated advertising signs, the periodicity of which exceeds 30 flashes to the

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minute, shall be erected so that the lowest point of such signs is less than 9 m above the ground level.

7.8 For illuminated signs in the vicinity of airports, the Directorate General of Civil Aviation should be consulted.

8 GROUND SIGNS

8.1 Material

Every ground sign exceeding 6 m in height together with frames, supports and braces shall be constructed of non-combustible material except as in **6.4**.

8.2 Dimensions

No ground sign shall be erected to a height exceeding 9 m above the ground. Lighting reflectors may extend beyond the top or face of the sign.

8.3 Supports and Anchorage

Every ground sign shall be firmly supported and anchored to the ground. Supports and anchors shall be of treated timber in accordance with good practice [10-2(3)], or metal treated for corrosion resistance or masonry or concrete.

8.4 Site Cleaning

The owner of any site on which a ground sign is erected shall be responsible for keeping such part of the site as is visible from the street, clean, sanitary, inoffensive and free of all obnoxious substances and unsightly conditions to the approval of the Authority.

8.5 Obstruction to Traffic

No ground sign shall be erected so as to obstruct free access to or egress from any building.

8.6 Set Back

No ground sign shall be set nearer to the street line than the established building line.

8.7 Bottom Clearance

The bottom line of all ground signs shall be at least 0.6 m above the ground, but the intervening space may be filled with open lattice work or platform decorative trim.

8.8 Ground painted signs shall conform to the requirements of **6** and **7**, where applicable.

9 ROOF SIGNS

9.1 Material

Every roof sign together with its frames, supports and braces, shall be constructed of non-combustible material, except as in **6.4**. Provision shall be made for electric grounding of all metallic parts; and where combustible materials are permitted in letters or other ornamental features, all wiring and tubing shall be kept free and insulated therefrom.

9.2 Dimensions

No roof sign shall exceed the following heights on buildings of heights:

Sl No.	*Height of Building*	*Height of Sign Max*
i)	Not exceeding four storeys or 18 m	2 m
ii)	Five to eight storeys or exceeding 18 m but not exceeding 36 m	3 m
iii)	Exceeding eight storeys or 36 m, provided that in calculating the height of such signs, signs placed one above the other, or on planes at different levels of the same building shall be deemed to be one sign, whether or not such signs belong to different owners	5 m

9.3 Location

a) No roof sign shall be so placed on the roof of any building as to prevent free passage from one part of the roof to another.

b) No roof sign shall be placed on or over the roof of any building unless the entire roof construction is of non-combustible material.

9.4 Projection

No roof sign shall project beyond the existing building line of the building of which it is erected or shall extend beyond the roof in any direction.

9.5 Supports and Anchorage

Every roof sign shall be thoroughly secured and anchored to the building on or over which it is erected. All loads shall be safely distributed to the structural members of the building.

9.6 For roof signs near the airports, the Directorate General of Civil Aviation should be consulted.

9.7 Painted roof signs shall conform to the requirements of **6** and **7**, where applicable.

10 *VERANDAH* SIGNS

10.1 Material

Every *Verandah* sign shall be constructed entirely of non-combustible material except as in **6.4**.

10.2 Dimensions

No *Verandah* sign exceed 1 m in height. No *Verandah* sign hanging from a *Verandah* shall exceed 2.5 m in length and 50 mm in thickness, except that *Verandah* box signs measuring not more than 200 mm in

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thickness, measured between the principal faces of the sign and constructed entirely of metal wired glass may be erected.

10.3 Alignment

Every *Verandah* sign shall be set parallel to the building line, except that any such sign hanging from a *Verandah* shall be set at right angles to the building line.

10.4 Location

Verandah signs, other than hanging signs only, shall be placed in the following locations:

a) Immediately above the eaves of the *Verandah* roof in such a manner as not to project beyond the rear of the roof gutter;
b) Against but not above or below the *Verandah* parapet or balustrade provided such parapet or balustrade is solid and the sign does not project more than 20 cm from the outside face of such parapet or balustrade; or
c) On the *Verandah* beams or parapets in the case of painted signs.

10.5 Height of Hanging *Verandah* Signs

Every *Verandah* sign hanging from a *Verandah* shall be fixed in such a manner that the lowest point of such sign is not less than 2.5 m above the pavement.

10.6 Projection

Except as provided for in **10.4**, no *Verandah* sign shall extend outside the line of the *Verandah* to which it is attached.

11 WALL SIGNS

11.1 Material

Every wall sign exceeding 4 m^2 in area shall be constructed of non-combustible material except as in **6.4**.

11.2 Dimensions

a) The total area of any wall sign shall not exceed 20 m^2 for every 15 m of building frontage to the street to which such sign faces; except that in the case of a wall sign, consisting only of the name of a theatre or cinema, the total area of such sign shall not exceed 200 m^2.
b) No wall sign which exceeds 30 m^2 in area shall be located on any wall not directly facing the road; provided that any such sign or signs shall not exceed 25 percent of the side wall area visible from the street.

11.3 Projection

No wall sign shall extend above the top of the wall or beyond the ends of the wall to which it is attached. At any place where pedestrians may pass along a wall, any wall sign attached thereto shall not project more than 7.5 cm therefrom within a height of 2.5 m measured from the level of such place.

11.4 Supports and Attachment

Every wall sign attached to walls shall be securely attached. Wooden blocks or anchorage with wood used in connection with screws, staples or nails shall not be considered proper anchorage, except in the case of wall signs attached to walls of wood.

12 PROJECTING SIGNS

12.1 Material

Every projecting sign and its support and framework shall be constructed entirely of non-combustible material.

12.2 Projection and Height

No projecting sign or any part of its supports or frame work shall project more than 2 m beyond the building; however it shall not project beyond the plot line facing the street; when it projects into the street it shall be at clear height of 2.5 m from the road (*see* Part 3 'Development Control Rules and General Building Requirements' of the Code):

a) The axes of all projecting signs shall be at right angles to the main face of the building. Where a V-construction is employed for the faces, the base of the sign against the building shall not exceed the amount of the overall projection.
b) No projecting signs shall extend above the eaves of a roof or above the part of the building face to which it is attached.
c) The maximum height of a projecting sign shall be related to the height of the building to which it is attached in the following manners:

Sl No.	*Height of Building*	*Height of Sign Max*
i)	Not exceeding four storeys or 18 m	9 m
ii)	Five to eight storeys or not exceeding 36 m	12 m
iii)	Exceeding eight storeys or 36 m	15 m

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12.3 Supports and Attachment

Every projecting sign shall be securely attached to a building so that movement in any direction is prevented by corrosion-resistant metal brackets, rods, anchors, supports, chains or wire ropes so designed and arranged that half the number of such fixing devices may safely support the sign under all circumstances.

12.3.1 Staples or nails shall not be used to secure any projecting sign to any building.

12.4 Additional Loads

Projecting sign structures which could be used to support an individual on a ladder or other servicing device whether or not specifically designed for the servicing device shall be capable of supporting the anticipated additional load but in no case less than 500 kg concentrated horizontal load and 1 500 kg vertical concentrated load applied at the point of assumed loading or point of most eccentric loading. The building component to which the projecting sign is attached shall also be designed to support the additional loads.

13 MARQUEE SIGNS

13.1 Materials

Marquee signs shall be constructed entirely of metal or other approved non-combustible materials.

13.2 Height

Such sign shall not exceed 2 m in height, nor shall they project below the fascia of the marquee, nor lower than 2.5 m above the footpath.

13.3 Length

Marquee signs may extend the full length but in no case shall they project beyond the ends of the marquee.

14 SKY SIGNS

In the case of the sky signs, the regulations laid down by the Authority concerned shall apply.

15 TEMPORARY ADVERTISING SIGNS, TRAVELLING CIRCUS SIGNS, FAIR SIGNS AND DECORATIONS DURING PUBLIC REJOICING

15.1 Types

None of the following advertising signs shall be erected or maintained, other than as temporary signs erected in accordance with **15.2**:

a) Any advertising sign which is painted on or fixed on to or between the columns of a *Verandah*;

b) Any advertising sign which projects above or below any fascia, bearer, beam or balustrade of a *Verandah* or balcony;

c) Any advertising sign which is luminous or illuminated and which is fixed to any fascia bearer, beam or balustrade of any splayed or rounded corner of a *Verandah* or balcony;

d) Any streamer sign erected across a road;

e) Any sign not securely fixed so as to prevent the sign swinging from side to side;

f) Any advertising sign made of cloth, paper mache, or similar or like material but excluding licensed paper signs on hoardings or fences;

g) Any advertising sign on a plot used or intended to be used exclusively for residential purposes, other than a brass plate or board preferably not exceeding 600 mm x 450 mm in size, affixed to the fence or entrance door or gate of a dwelling, and in the case of a block of flats, affixed to the wall of the entrance hall or entrance door of any flat; and

h) Any sign on trees, rocks, hillsides and similar natural features.

15.2 Requirements for Temporary Signs

15.2.1 All temporary advertising, travelling circus and fair signs and decorations during public rejoicing shall be subject to the approval of the Authority and shall be subjected to the approval of the Authority, and shall be erected so as not to obstruct any opening and to minimize fire risk.

15.2.2 The advertisement contained on any such sign shall pertain only to the business, industry or other pursuit conducted on or within the premises on which such sign is erected or maintained. Temporary advertising signs shall be removed as soon as torn or damaged and in any case within 14 days after erection unless extended.

15.2.3 The Authority shall be empowered to order the immediate removal of any temporary advertising sign or decoration, where, in its opinion such action is necessary in the interests of public amenity and safety.

15.2.4 *Pole Signs*

Pole signs shall be constructed entirely of non-combustible materials and shall conform to the requirements for ground or roof signs as the case may be (*see* **8** and **9**). Such signs may extend beyond the street line if they comply with the provisions for projecting signs (*see* **12**).

15.2.5 *Banner and Cloth Signs*

Temporary signs and banners attached to or suspended

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from a building, constructed of cloth or other combustible material shall be strongly constructed and shall be securely attached to their supports. They shall be removed as soon as torn or damaged, and in no case later than 14 days after erection; except, that permits for temporary signs suspended from or attached to a canopy or marquee shall be limited to a period of 10 days.

15.2.6 *Maximum Size*

Temporary signs shall not exceed 10 m^2 in area.

15.2.7 *Projection*

Temporary signs of cloth and similar combustible construction shall not extend more than 300 mm over or into a street or other public space except that such signs when constructed without a frame may be supported flat against the face of a canopy or marquee or may be suspended from the lower fascia thereof but shall not extend closer to the footpath than 2.5 m.

15.2.8 *Special Permits*

All temporary banners suspended from building or hung on poles, which extend across streets or other public spaces shall be subject to special approval of the Authority.

15.2.9 Bill boards set up by the Authority shall be used for temporary signs, symbols, bills for entertainment, etc, so that other walls of the city are not defaced.

15.2.9.1 Bills for entertainment and other functions shall not be affixed on to building walls other than the bill boards (*see* **15.2.9**). The organization responsible for such bills and posters shall be held responsible for any such defacement and non-removal of signs.

16 ADDITIONAL GUIDELINES FOR SIGNS IN URBAN AND RURAL AREAS

16.1 Erecting maintaining and owning signs in rural areas shall be encouraged so as to boost the information and economic status of the rural population.

16.2 The tolerance criteria for the permission granted towards putting up any signs for any urban area shall be as given in **16.2.1** to **16.2.4**.

16.2.1 *Small Towns*

The traffic hazards in small towns are few and the defacement due to excessive advertising signs has not occurred. Therefore, orderly development of signs may enliven the town environment and boost the economy. The tolerance here may be high. The following guidelines may be followed for signage:

a) *Advertising sign* — Electric sign, ground sign, building sign, illuminated sign, sky sign and temporary sign are permissible.

b) *Directional sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

c) *Informational sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

d) *Identification sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory sign* — Electric sign, ground sign, illuminated sign and temporary sign are permissible while building sign and sky sign are not permissible.

16.2.2 *Medium Towns*

The traffic hazards in medium towns are few and the defacement due to excessive advertising signs has not occurred. Proper design, erection and maintenance of the signs shall be encouraged. The following guidelines may be followed for signage:

a) *Advertising sign* — Electric sign, ground sign, building sign, illuminated sign, sky sign and temporary sign are permissible.

b) *Directional sign* — Electric sign, ground sign, illuminated sign are permissible while building sign, sky sign and temporary sign are not permissible.

c) *Informational sign* — Electric sign, ground sign, illuminated sign, and temporary sign are permissible while building sign and sky sign are not permissible.

d) *Identification sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory sign* — Electric sign, ground sign, illuminated sign and temporary sign are permissible while building sign and sky sign are not permissible.

16.2.3 *Large Cities*

The traffic is high and hazards of accidents are many in large cities. Defacement of buildings, roads and the urban spaces due to advertisements has to be checked. Therefore, the permissivity and tolerance for erecting signs is very low. The following guidelines may be followed for signage:

a) *Advertising sign* — Electric sign, ground sign, illuminated sign and sky sign are permissible while building sign and temporary sign are not permissible.

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b) *Directional sign* — Ground sign, illuminated sign are permissible while electric sign, building sign, sky sign and temporary sign are not permissible.

c) *Informational sign* — Ground sign, illuminated sign, building sign and temporary sign are permissible while electric sign and sky sign are not permissible.

d) *Identification sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

16.2.4 *Mega and Metro Cities*

The traffic hazards in mega and metro cities are many and the defacement due to excessive advertising signs has marred the urban environment. The density of population is very high and the danger of greater loss of life due to disasters is self evident. Therefore, the permissivity for erecting signs is very low and no tolerance exists for law breakers. The following guidelines may be followed for signage:

a) *Advertising sign* — Electric sign, ground sign, illuminated sign and sky sign are permissible while building sign and temporary sign are not permissible.

b) *Directional sign* — Ground sign, illuminated sign are permissible while electric sign, building sign, sky sign and temporary sign are not permissible.

c) *Informational sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

d) *Identification sign* — Electric sign, ground sign, building sign, illuminated sign and temporary sign are permissible while sky sign is not permissible.

e) *Regulatory sign* — Ground sign, illuminated sign and temporary sign are permissible while electric sign, building sign and sky sign are not permissible.

17 ENVIRONMENTAL GRAPHICS FOR CITYSCAPE

The urban environment may be susceptible to confusion and chaos due to improper graphics, hoardings and advertisements. Therefore, the signage should be installed following requisite guidelines laid down keeping the functional, safety and aesthetic aspects in view.

The scale of the project should also be considered for implementing signage design. In urban design/planning projects and landscape projects on a large scale, the following criteria should be followed for signs and outdoor display structures:

a) Aesthetic and harmonious development of the visual environment.

b) Signage for the persons with disabilities at all level/grade changes, entry points to buildings and public conveniences and facilities; including braille and tactile signage used for the benefit of the visually impaired at all important nodes, entrances and routes (see Part 3 'Development Control Rules and General Building Requirements' of the Code).

c) Environmental graphics should be creatively designed to cater to the basic function of information, identity and way finding, with the objective of improvement of urban scape.

d) Safety aspects.

e) Protection of trees and other vegetation from harm due to signs.

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ANNEX A

(*Clause* 3.1.2)

SPECIMEN FORM FOR APPLICATION FOR PERMIT TO ERECT, RE-ERECT OR ALTER ADVERTISING SIGN

1. Type of sign _____
2. Location[1)] : _____
   a) Building/premises _____
   b) Location of building/premises with respect to neighbouring streets _____
   _____
3. Dimensions and details of the sign[1)] _____
4. Materials used for different parts _____
5. Electrical and lighting details[1)] _____
6. Structural details showing also supporting framework and anchorages[1)] _____
   _____
7. Mode of operation _____

Name and address of the applicant	Name and address of the owner of the building/premises
_____	_____
_____	_____
_____	_____
Signature _____	Signature _____
Date _____	Date _____

[1)] Plans as desired in **3.1.2** (b) are enclosed.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of this Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Section.

	IS No.	*Title*
(1)	3808 : 1979	Method of test for non-combustibility of building materials (*first revision*)
(2)	2553	Specification for safety glass
	(Part 1) : 1990	General purpose (*third revision*)
	(Part 2) : 1992	For road transport
(3)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 11 APPROACH TO SUSTAINABILITY

BUREAU OF INDIAN STANDARDS

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FOREWORD

This Code (Part 11) covers the parameters required to be considered for planning, design, construction, operation and maintenance of buildings and those relating to land development, from the point of view of sustainability.

From the dawn of civilization, our ancestors were concerned with preservation and sustenance of environment. The ancient *Vedas* have several references in them on environmental protection, ecological balance, weather cycle, rainfall phenomenon, hydrological cycle and related subjects. Seers, even at those times, recognized that changes caused due to indiscreet human activities could result in imbalances in seasons, rainfall patterns, crops and atmosphere and degrade the quality of water, air, and earth resources. Basham, in 'The Wonder that was India', describes how palaces in Mauryan dynasty in second century B.C., were exquisitely built from carved wood of local deodars. In later years the monasteries, temples and *dharmashalas* were built with locally available stones and these have withstood the ravages of time. Edwin Arnold, in 'The Light of Asia', describes *Vishramvan*, the palace built with local marble and alabaster for prince Siddharth. The epic Mahabharata describes palace built by Vishwakarma. *Kashi Vishwanath* Temple in Varanasi was built more than a thousand years ago. Many other ancient monuments in various parts of India are classic examples of sustainable buildings.

The *Taj Mahal*, built more than four hundred years ago, can accommodate hundreds of people with no suffocation, as the stone *jalis* in the facia induce air movement and enable natural ventilation. The fort in *Mandu* has elaborate rainwater harvesting techniques. *Havelis* in northern India were invariably built around a central courtyard, which brought daylight to all nooks and corners, but the heat was kept out. Many forts and *havelis* have elaborate provision for evaporative cooling, using *khas*-screens and rainwater stored at higher plateaus. Sustainability and sustainable buildings have been the way of life in India.

It was not just palaces, monasteries and temples that were built on the platform of sustainable practices. The awareness was innate and intuitive, guided by a clear understanding of nature and driven by total alignment with environment, with the resolve not to harm nature but to respect and revere it, and to live in harmony with it. A reflection of this is visible in the locally evolved climate-responsive architecture that blended with social and cultural mores, leaving behind lasting concepts of building forms and human settlements. These buildings provided comfort to the occupants. They were passive in approach with no external intervention, which in modern times have become quite desirable. Diverse climatic conditions in our country resulted in evolution of different fabrics of built form, with the commonality being the focus on harmony with nature. It becomes obvious to see why all the scriptures, literature, life styles and cultural ethos made reference to the *Panchabhoothas*, which represent five elements of nature, thus blending the architecture and habitats with nature. Thus, sustainability, and sustainable buildings have been the way of life in India.

Less than a hundred years ago, industrial revolution came to India and changed many of these traditional sustainable practices in Indian buildings. The insatiable thirst for progress and comfort at any cost, altered the equation with nature forever. Concrete, steel, glass and later plastics became the dominant construction materials, beyond stone and wood of yesteryears. Power supply, artificial lighting, water supply and disposal, and thermal environmental control within built environment, were desired and obtained.

The new civilizations grew along the river banks, always regarding rivers as sacred. With the industrial revolution, untreated water, effluents from chemical industries and organic waste were discharged into rivers and water bodies, destroying our precious sources of water for domestic use. In addition, the unsustainable development and usage of buildings have led to huge construction and demolition waste, and municipal solid waste during their operation, which today have become a major problem.

Modern buildings in India consume about 25 to 30 percent of total energy, and up to 30 percent of fresh potable water, and generate approximately 40 percent of total waste. India is now entering the phase of rapid urbanization. Various studies indicate that by 2050, the built up area of India may become four times the current mass, which may pose a major challenge in preserving our fragile environment. Although the present energy consumption per

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capita in India is a fraction of that of most developed nations, but with its projected growth, unless enough measures are taken, it may lead to acceleration of environment degradation, contributing to increased carbon footprint leading to global warming and climate change, resource scarcity and inequitable development.

Sustainable buildings have demonstrated reduction in energy and water consumption to less than half of the present consumption in conventional buildings and complete elimination of the construction and operational waste through recycling. The Indian way of life is *Aparigraha* (minimum possession), conservation (minimum consumption) and recycling (minimum waste). These three attributes are the guiding principles for sustainable buildings as well. With these attributes and its rich heritage, India can make a substantial contribution in this field and eventually lead the world on the path of sustainability.

Developed nations' approach to sustainability generally concentrates on energy efficiency through high technology innovations, and use of products, materials and designs with lower embodied energy. Their green ratings are based on intent, which implies expert inputs and simulation which often can be counter intuitive such as the envisaged load and effective use of energy efficient appliance. Indian construction industry will do better through use of products, materials and designs with lower embodied energy and our traditional wisdom and practices, building in harmony with nature through regional common knowledge, consuming as little as necessary, applying low cost technology innovations, using recycled materials, and recognizing performance (not intent) through easily measurable parameters, wherever feasible. If required, the above approach may be supplemented with an appropriate blend of the emerging and sustainable technology innovations. It is particularly emphasized that the hazard of construction and demolition waste should be properly attended to in view of increased construction and redevelopment activities in the country anticipated in future. This would require that such waste is preferably used at site and the balance, if any, may be sent to recycling plant which is closest to the site.

The Sectional Committee, reviewed the contents of the 2005 version of the Code and observed that due consideration had been given to these important dimensions in building planning, design and construction and during operation through provisions of effective utilization of natural light and ventilation; increased use of renewable energy, material selection including recyclability and reusability aspects; use of low gestation plantations and agriculture and industrial wastes; design approach; proper management practices; efficient electrical and other building services and plumbing services; energy conservation; rainwater harvesting, etc. All these have been duly interwoven throughout the Code addressing both the embodied energy and the operational energy involved, as also showing sensitivity towards the concerns such as ozone depletion, global warming, etc. The Committee, however, felt that in keeping with the present needs as well as likely future scenario, it might be appropriate to completely review all such aspects and give them a special and separate identity in the form of Part of the Code covering approach to sustainability relating to buildings and built environment. Aiming towards such objectives, the Sectional Committee first formulated this Part and incorporated in the 2005 version of the Code through Amendment No. 1 to the Code.

This revision has been taken up to further review this Part and update it particularly in view of the modifications being incorporated in other Parts/Sections in this revision of the Code, to bring coherence among the provisions of this Part and other revised Parts/Sections. The significant modifications incorporated in this revision are:

a) Inclusion of definitions of a number of additional terms such as surface coefficient, surface resistance, thermal transmission and total thermal resistance.
b) Greater emphasis on ensuring barrier free design for universal accessibility, as part of approach to sustainability.
c) Review of provisions on materials and technologies for sustainability and their updating, wherever required.
d) Inclusion of guidelines for selection of window types.
e) Modification of the clause on refrigerants for air conditioning to include refrigerants, considering sustainability aspects.
f) Inclusion of provision for preparation of overall water balance chart, as part of water and waste management.

This Part of the Code provides a comprehensive set of requirements, intended to reduce the negative impact of buildings on the natural environment. It can be readily used by the owners, developers/builders, architects, engineers, building services engineers and other building professionals as well as by manufacturers of building materials apart from the Authorities concerning land and building development, government and private construction agencies and academic and research institutions. The intent of this Part of the Code is to highlight sustainability measures including those referred to in different Parts/Sections of the Code as may be required as well as to define

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comprehensive sustainability standards for the building construction and related built environment.

The approach to sustainability is founded on principles consistent with this Code, to adequately protect public health, safety and welfare and to provide requirements that do not unnecessarily increase construction cost nor restrict the use of new / innovative materials, products or methods of construction. The benefits of incorporating measures listed in this Part are not only environment friendly, but also result in much better health and productivity of occupants, at minimal additional initial cost over the cost of conventional buildings, while substantially reducing the life cycle cost. This minimal additional cost is offset during a few years usage of the buildings, and vast advantage in cost is accrued during the life cycle of the building.

The measures of sustainable buildings described in this Part, set performance thresholds and incorporate features that allow Authority to customize requirements according to local geographical conditions, environmental priorities and agenda. These are not specific to any rating system and are not intended to provide a single metric indication of overall building performance. The flexibility of these provisions allows the practitioners to easily exercise their judgment in holistically and objectively applying the underlying principles of sustainability to a development or building facility, considering its functionality and required comfort level.

The provisions of this Part of the Code are without prejudice to the concerned statutory provisions including those given in various Acts and Rules and Regulations framed thereunder.

The information contained in this Part of the Code has been brought in coherence with the provisions contained in other parts of the Code, as also with the concerned Indian Standards on various areas. In the formulation of this Part, efforts have been made to take into cognizance the various latest applicable practices followed in the country and abroad, relevant to sustainability in buildings. This has been done by taking into consideration the publications of the American Society for Heating, Refrigeration, Air conditioning Engineers; American Society for Testing and Materials; Bureau of Energy Efficiency, India; Indian Green Building Council; Indian Society for Heating, Refrigeration, Air conditioning Engineers; International Organisation for Standardisation; and The Energy and Resources Institute, India.

All standards cross-referred to in the main text of this Part, are subject to the revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Part is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 ‘Rules for rounding off numerical values (*revised*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part of the Code.

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NATIONAL BUILDING CODE OF INDIA

PART 11 APPROACH TO SUSTAINABILITY

1 SCOPE

1.1 This Part 11 covers the parameters required to be considered for planning, design, construction, operation and maintenance of buildings and those relating to land development, from sustainability point of view.

1.2 This Part of the Code is a supplement to all other Parts/Sections of the Code and shall be read along with the same.

1.3 For all buildings and facilities open to and used by the public, including all forms of public housing by the government/civic bodies and private developers, barrier free access and movement within and around buildings, for persons with disabilities and of different age groups, shall be ensured in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

2 TERMINOLOGY

2.0 For the purpose of this Part of the Code, the definitions given below shall apply.

2.1 Adaptive Thermal Comfort — The comfort that relates indoor design temperatures or acceptable temperature ranges to outdoor meteorological and climatological parameters.

NOTE — The adaptive thermal comfort model refers to the concept of specifying indoor comfort temperature set points based on the physiological, behavioural and psychological measures that the occupants take, voluntarily or involuntarily, to adapt themselves to the thermal environment and achieve comfort.

2.2 Authority Having Jurisdiction — The Authority which has been created by a statute and which, for the purpose of the Code/Part, may authorize a committee or an official or an agency to act on its behalf; herein after called the 'Authority'.

2.3 Biodiversity — The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species, and of ecosystems.

2.4 Building Environment — The surrounding in which a building operates, including air, water, land, natural resources, flora, fauna, human beings and their inter-relations.

2.5 Building Performance — The ability of a building to fulfil required functions under intended use conditions or behaviour when in use.

2.6 Built Environment — The collection of man-made or induced physical objects located in a particular area or region.

NOTE — When treated as a whole, the built environment typically is taken to include buildings, external works (landscape areas), infrastructure and other construction works within the area under consideration.

2.7 Disaster — It is a catastrophe, mishap, calamity or grave occurrence in any area, arising from natural or man-made causes, or by accident or negligence which results in substantial loss of life, or human suffering or damage to, and destruction of, property or damage to or degradation of environment, and is of such a nature of magnitude as to be beyond the coping capacity of the community of the affected area.

2.8 Ecological Footprint — The impact of a person or community, expressed as the amount of land required to sustain their use of natural resources.

2.9 Ecosystem — The community of biological organisms and their physical environment, functioning together as an interdependent unit within a defined area.

NOTE — For the purpose of this definition, humans, animals, plants, and microorganisms are individually all considered biological organisms.

2.10 Embodied Energy — The sum total of energy that is used to extract, process, package, transport, and install the material in the building.

NOTE — Embodied energy data is often collected using input and output analysis.

2.11 Emissivity(E) — The ratio of rate of heat emitted by a surface as compared to that of an absolutely black surface under similar conditions. It varies with the temperature of the emitting surface.

2.12 Environmental Impact — Any change to the environment, whether adverse or beneficial, wholly or partially, resulting from environmental aspects of a built environment.

2.13 Green Roof System — An assembly that supports an area of planting/landscaping, built up on a waterproofed substrate at any level that is separated from the natural ground by a human made structure.

2.14 Heat Island Effect — A phenomenon in which air and surface temperature of an area are higher than nearby areas due to the replacement of natural land cover with pavement, building, and other infrastructure.

2.15 Horizontal Sun Angle (HSA) — The horizontal angle between the normal of the window and the sun azimuth angle at a given time (*see* Fig. 1).

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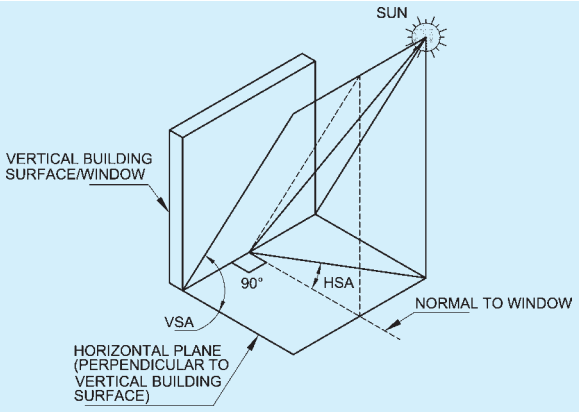


FIG. 1 HORIZONTAL AND VERTICAL SOLAR ANGLE FORMULATION

2.16 Indoor Air Quality (IAQ) — The nature of indoor air that affects the health and well-being of building occupants.

2.17 Indoor Environment Quality (IEQ) — The condition or state of the indoor environment.

2.18 Life Cycle Assessment (LCA) — A method of evaluating a product by reviewing the ecological impact over the life of the product.

NOTE — At each stage, the product and its components are evaluated based upon the materials and energy consumed, and the pollution and waste produced. Life stages include extraction of raw materials, processing and fabrication, transportation, installation, use and maintenance, and reuse/recycling/disposal.

2.19 Light Shelf — An architectural element that allows daylight penetration in a building. It is usually a horizontal light-reflecting overhang on a window or opening and is placed above eye-level and has a high-reflectance upper surface. This surface reflects daylight onto the ceiling and deeper into a space.

2.20 Non-renewable Resource — A resource that exists in a fixed quantity that cannot be replenished on a human time scale.

NOTE — Non-renewable resources have the potential for renewal only by the geological, physical and chemical processes taking place over hundreds of millions of years. Non-renewable resources exist in various places in the earth's crust. Examples include iron ore, coal, and oil.

2.21 Renewable Resource — A resource that is available naturally, harnessed, and can be replenished.

NOTE — Sustainable use of renewable resource implies that the rate of replenishment, or cleansing takes place at a rate equal to or greater than the current rate of depletion of that resource. Examples include trees in forest, grasses in grassland, and fertile soil.

2.22 Reuse — Using a material, product or component of the waste stream in its original form more than once.

2.23 Recycling — A process to convert discarded materials that would otherwise become waste, into valuable resources.

2.24 Skylight Roof Ratio (SRR) — The ratio of the total skylight area of the roof, measured to the outside of the frame, to the gross exterior roof.

2.25 Solar Heat Gain Coefficient (SHGC) — The fraction of incident solar radiation admitted through a fenestration, both directly transmitted, and absorbed and subsequently released inward through conduction, convection and radiation (*see* Fig. 2).

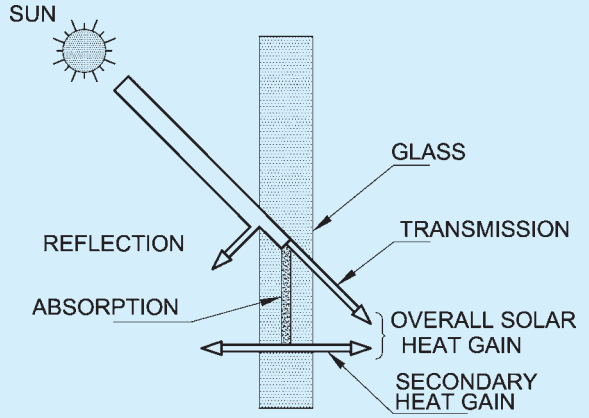


FIG. 2 MECHANISM OF SOLAR HEAT GAIN

2.26 Solar Reflectance Index (SRI) — A measure of material's ability to reject solar radiation, as shown by a small temperature rise.

NOTE — SRI of standard black surface (having reflectance of 0.05 and emittance of 0.9) and a standard white surface (of reflectance 0.8 and emittance 0.9) are taken as 0 and 100, respectively.

2.27 Surface Coefficient (*f*) — The thermal transmission by convection, conduction and radiation from unit area of the surface, for unit temperature difference between the surface and the surrounding medium. It is expressed in $W/m^2 K$.

NOTE — The value of *f* depends on many factors, such as, air or fluid movement in contact with the surface, roughness and emissivity of the surface and upon the temperature and nature of surroundings.

2.28 Surface Resistance (1/*f*) — The reciprocal of surface coefficient. It is expressed in m^2K/W.

2.29 Sustainability — The state in which components of ecosystem and their functions are maintained for the present and future generations.

NOTES

1 Sustainability is the goal of sustainable development and can result from the application of the concept of sustainable development.

2 In building construction, it relates to how the attributes of the activities, materials/products or services used in construction work, or the use of construction works, contribute to the

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maintenance of ecosystem components and functions for future generations.

3 While the challenge of sustainability is global, the strategies for sustainability in building construction are local and may differ in context and content from region to region.

4 'Components of ecosystem' includes plants and animals, as well as humans and their physical environment. For humans, this includes a balancing of key elements of human needs namely the economic, environmental, social and cultural conditions for societies' existence.

2.30 Sustainable Buildings — A building that meets the specified building performance requirements while minimizing disturbance to and improving the functioning of local, regional, and global ecosystem both during and after its construction and specified service life.

NOTE — A sustainable building optimizes efficiencies in resource management and operational performance; and, minimises risks to human health safety and the environment.

2.31 Sustainable Development — The development that meets the need of the present without compromising the ability of future generations to meet their own.

2.32 Thermal Absorptivity — A factor indicating the relative amount of radiation absorbed by a surface as compared to an absorbing black body under the same conditions. Its value is dependent upon the temperature of the source and of the receiving surface.

2.33 Thermal Capacity — The amount of heat necessary to raise the temperature of a given mass by 1°C. Numerically, the thermal capacity per unit area of surface is the sum of the products of the mass per unit area of each individual material in the roof, wall or floor surface multiplied by its individual specific heat.

2.34 Thermal Conductance (*R*) — The thermal transmission of a single layer structure per unit area divided by the temperature difference between the hot and cold faces. It is expressed in W/m^2 K.

NOTE — Thermal conductance is a measure of the thermal transmission per unit area through the total thickness of the structure under consideration. Thermal conductivity on the other hand refers to unit thickness of material. Further, this term applies only to a single layer of material and not to a composite insulation or to a structure made up of several layers of materials or medium.

2.35 Thermal Conductivity (*k*) — The quantity of heat in the steady state conditions flowing in unit time through a unit area of a slab of uniform material thickness of infinite extent and of unit thickness, when unit difference of temperature is established between its faces. Its unit is W/mK.

NOTE — Thermal conductivity is a characteristic property of a material and its value may vary with a number of factors, including density, porosity, moisture content, fibre diameter, pore size, type of gas in the material, mean temperature and outside temperature range. The conductivity value varies from 0.03 W/mK for insulators to 400 W/mK for metals. Materials with lower conductivity are preferred, as they are better insulators and reduce the external heat gains from the envelope or loss of internal heat to outside cold environment.

2.36 Thermal Comfort — That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

2.37 Thermal Reflectivity — The ratio of the reflected heat to that of the total heat incident on a surface at a certain mean temperature range.

2.38 Thermal Resistance (*R*) — The reciprocal of thermal conductance. For a structure having plane parallel faces, thermal resistance is equal to thickness (L) of the structure divided by thermal conductivity (k).

$$R = \frac{L}{k}$$

NOTE — The usefulness of the quantity is that when heat passes in succession through two or more components of the building units, the resistance may be added together to get the total resistance of the structure.

2.39 Thermal Resistivity (*1/k*) — The reciprocal of thermal conductivity. It is expressed in mK/W.

2.40 Thermal Transmission or Rate of Heat Flow (*q*) — The quantity of heat flowing in unit time under the conditions prevailing at that time. Its unit is W.

2.41 Thermal Transmittance (*U*) — Thermal transmission through unit area of the given building unit divided by the temperature difference between the air or other fluid on either side of the building unit in steady state conditions. It is also called as *U*-value. Its unit is W/m^{2}K.

NOTE — Thermal transmittance differs from thermal conductance in so far as temperatures are measured on the two surfaces of a material or structure or building unit in the latter case and in the surrounding air or other fluid in the former case. Thermal conductance is a characteristic of the structure or building unit whereas thermal transmittance depends on conductance and surface coefficients of the structure or building unit under the conditions of use.

2.42 Total Thermal Resistance (R_T) — It is the sum of the surface resistances and the thermal resistance of the building unit itself. It is expressed in m^{2}K/W.

2.43 Tropical Summer Index (TSI) — The temperature of calm air at 50 percent relative humidity which imparts the same thermal sensation as the given environment. TSI (in °C) is expressed as:

$$TSI = 0.745t_g + 0.308t_w - 2.06\sqrt{v} + 0.841$$

where

t_g = globe temperature, °C;
t_w = wet bulb temperature, °C; and
v = wind speed, m/s

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2.44 Vertical Solar Angle (VSA) — The angle that a plane containing the bottom two points of the window and the centre of the sun makes with the ground when measured normal to the shaded surface (*see* Fig. 1).

2.45 Visual Light Transmittance (VLT) — The ratio of total transmitted light to total incident light.

2.46 Volatile Organic Compound (VOC) — The carbon compounds (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) which participate in atmospheric photochemical reactions. The compounds vapourize at normal room temperatures.

2.47 Waste — Substances or objects which the holder intends or is required to dispose of.

3 APPROACH TO SUSTAINABILITY

3.1 Need for Sustainable Development

Building construction, occupancy and additions/ alterations including preventive and remedial maintenance are always energy and material intensive. Large amount of primary form of natural materials, water, air, energy, etc, are consumed. The energy and material resources required for a building can be categorised as embodied energy, recurring operation energy, refurbishment energy, and end of life disposal. These elements and their use are inter-dependent. There is need for integrated approach of considering them all together in general design development and construction practice. However, conventional approach towards utilizing them is independent of each other and results in very low efficiency in material and resource use.

With increasing urbanization and rapid rise in people's economic level and consumption pattern in many parts of the country, there is an increasing trend to consume more natural resources per capita. This is evident from the aspirational lifestyles and resulting changing tastes and expenditure patterns of individuals and societies. This is equally witnessed from modern construction trends and changing sky lines of cities that bear no resemblance to local climate and resource availability. This is constantly putting tremendous pressure on fragile ecosystem by over-exploitation of natural resources adversely affecting biodiversity of our planet. Realizing this fact, there are efforts for a changing approach towards nature from 'humanization of nature' to 'naturization of human' and more recently towards sustainable development. The concept is to ensure that every living being on earth have equal opportunity to utilize the natural resources for survival and mutual sustenance.

To achieve this, it is important to accept the major challenge in controlling and judiciously using natural resources to shrink ecological footprint. The way to achieve this is by holistically planning our growth needs, one of which is construction and combining them with need based economy, but at the same time without compromising on functionality and essential comforts.

The basic components of building facility, their inter-relation, tradeoffs and effect on surrounding micro-climatic conditions have to be estimated, to achieve the harmony between buildings and ecological surroundings. Ideally a building should symbiotically fit within prevalent natural cycles. It is necessary to assess the association of various factors involved, rationalizing the impact of construction on neighbourhood and/or building micro-climatic conditions to discern sustainability in the built environment.

3.2 Elements of Sustainability

The generalized design process towards sustainability should creatively address the following considerations:

a) Set the design parameters to be implemented to be equal to or higher than benchmarking standards given in this Code.

b) Make the basic performance requirements and set standards, applicable/ selectively adaptable to the climatic zone and geological conditions in which the construction is proposed.

c) Have deep understanding of requirements of performance and human comfort in a building and its surroundings, considering building type and use, quality of building and plumbing services as desired, needs of persons with disabilities and of different age groups, and other parameters.

d) Question the need, identify their optimum levels in long term scenario, and take the design provisions to that level only.

e) Ensure what is sustainable today, remains that way in decades to come, and ensure the required performance levels of systems designed. If required extensive damages done could also be rectified/reversed in course of time.

f) Ensure that sustainability is not only in parts, but also a holistic effort and local action should contribute to sustainability.

g) Make efforts to maximize the use of traditional wisdom in design, wherever applicable, as it represents the knowledge about the long-term behaviour of materials and technology and their strengths as well as weaknesses.

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h) While having an open approach, assess new materials and technologies for their long-term impact in the context of the country and its development priorities, before accepting them for use.

j) Take decision making processes to measurable levels wherever feasible, in order to make informed choices. Also by willing to accept limitations of decisions made.

k) Take the savings' benchmark targets closer to the minimum consumption standards; undertake value engineering exercises for deciding among the options.

This process emphasizes the requirement of bottom up approach which invariably considers microclimatic and cultural conditions around.

NOTE — The 'bottom up approach' concentrates more on how little is consumed; pursue deep understanding of sustainability; uses low technology innovations, materials and practices; recognizes performance to be more important than intent; and necessitates the use of common knowledge and common sense in design decisions. On the contrast, the 'top down approach' concentrates more on how much energy is saved; accepts the understanding of sustainability, may not be developed indigenously, more readily; uses high technology innovations, materials and practices; is driven by green brand and accompanying recognitions based on intent; and necessitates expert inputs and simulations.

The design process itself can play a significant role in creating built environment respecting all principles of sustainable development. This has to take into account various climatic zones (like hot-dry, warm-humid, composite, temperate and cold climates) as well as sun path movements, location (prone to tsunami, hurricane, etc), annual wind directions and geological conditions in the design of building, its orientations, wall and roof materials combinations, space layout, fenestrations and landscape. A solar passive architecture that places minimum energy demand in maintaining thermal comfort should be explored foremost.

The sustainable design process should be based on the principles of universal design as per Part 3 'Development Control Rules and General Building Requirements' of the Code, so as to address accessibility needs of persons with disabilities and persons of different age groups.

Functional requirements of buildings have to also measure up to the required comfort levels demanded for all types of user requirements.

3.3 Life Cycle Sustenance

The process flow from concept, design, construction, commissioning, operation and maintenance, and also decommissioning and disposal at the end of useful life of structure, should be planned and important steps chalked out for sustainable development. This should also take care of possible reuse/recycle of materials/components/structure or parts thereof. Ideally close the loop (cradle to grave) with regards to resources originally used.

3.4 Technology Options

The consequential building envelope to create harmonious development and productive living environment with neighbourhood and building environments poses one of the biggest challenges in selection of building materials, technologies and practices. It may be a combination of natural and manmade materials with least embodied energy and also leading to use of rapidly renewable resources. The trade-off between choice of the materials and technologies and their effect on environment has to be balanced with the aim of a closed-loop system. As a holistic approach, all efforts should be made towards,

a) encouraging and harnessing building materials out of agricultural, industrial and bio-wastes, which have an enormous scope for regeneration.

b) encouraging indigenous environment-friendly and acceptable cost-effective technologies and practices in identifying and pursuing sustainable developments amenable to local, cultural and resource diversity.

c) identifying and encouraging appropriate technologies for more research and development applications.

d) making building construction more indigenous, more adaptable to local climatic zone and executable to achieve the basic provisions for sustainable development to ensure sustained availability of building resources through regeneration and/or reuse/recycle.

e) encouraging use of traditional materials, technologies, vernacular design and construction practices, which have stood the test of time and which may be blended with the modern technology applications.

3.5 Energy Efficient Design and Processes

All efforts need to be made towards optimum and efficient use of energy sources for life sustenance. The increasing thrust on using non-fossil fuel energy for all needs have to be given priority consideration. The tapping of renewable sources of energy for lighting, heating, cooling and ventilation needs, deserve special attention. For example, an improved day light factor will reduce the day lighting needs by means of

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supplementary lighting with added health benefits such as reduced eye strain (associated with constant elimination conditions). India with over 95 percent of the clear design sky available, the design has to fully utilize the associated benefits. While deciding on the energy choices, life cycle cost analysis including tangible and intangible benefits should be made and not look at the onetime initial capital expenditure alone. The end of life options should also be perceived.

3.6 Reduced Embodied and Operational Energy

All designs, materials and technologies, construction practices should be selected and employed, aimed at reducing the overall embodied and operational energy involved in construction and operation of the built facility. The construction should promote sustainability through adoption of local resources (natural and man-made) and skills.

3.7 Integrated Water Management

Considering an ever increasing demand for water for a growing population, efforts are needed to substantially reduce per capita water consumption in buildings. Integrated and sustainable water management focusing on least anthropogenic water discharge from human activities should be pursued. The use of water conserving fixtures, landscaping, rainwater harvesting, aquifer recharging and waste water recycling need to be given due priority consideration.

3.8 Operation and Maintenance of Services

This should involve use of efficient building and plumbing services components and fixtures tailor-made to meet sustainability objectives and creating sufficient awareness among the users of building facility and its services, during the occupancy stage.

3.9 Monitoring Compliances

The measures adopted during design, construction and occupancy stages should be monitored against norms as per this Code at periodic time interval to ensure sustainability.

3.10 Corporate Governance

The concerned top management should ensure association of all stakeholders including the training and awareness in pursuing and achieving needs for sustainable development at all stages of building lifecycle (from design to end of life). The environmental impact assessment should be carried out and remedial measures based on the findings should be taken during the life cycle of the buildings.

3.11 Disaster Preparedness

3.11.1 *General*

Disaster preparedness as part of approach to sustainability is in addition to the normal considerations of structural safety, health safety, fire safety and public safety taken into account in the building planning, design, construction, use and occupancy, and end of life. The disasters may be natural disasters such as earthquake, floods, cyclone, tsunami, landslides and avalanches; and man-made disasters such as nuclear, chemical, and biological disasters, explosions, act of sabotage and terrorism. Consequence of such disasters could be life threatening and debilitating in the long run.

Also man-made or natural disasters can trigger combined form of progressive disasters. The severity index is another important factor which will be governed by geomorphology, wind flows and cyclonic vulnerability, and climatic zone wherein the construction is proposed. *See* Part 6 'Structural Design' of the Code for structural design of buildings for various loads, forces and effects using various building material options and structure systems.

3.11.2 *Approach*

The approach to disaster mitigation and management should be holistic and integrated with emphasis on prevention, mitigation and preparedness rather than being relief centric. The approach should emphasize on preparedness through planning, protection, training and partnership measures with associated stakeholders.

These efforts are aimed to protect and conserve existing development and also to minimise losses to lives, livelihood and property with clear cut focus on protection of environment. The approach shall be towards integrating disaster management as a part of design development, construction practices and management, operation and maintenance and end of life strategies. The required awareness should be achieved through multi stakeholder based planning, awareness, displays, mock drills and adequate training to both aged and young.

The disaster mitigation should also comprise identification of risks during construction, risks during occupancy stages/operations and preparing disaster preparedness plan by decommissioning. The occupancy type, density of occupancy and any specific/strategic aspects should be considered while working out disaster preparedness plan to achieve minimum damages and/or losses to lives, livelihood, properties and environment for the sustainable buildings for least damages or losses.

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3.11.3 *Disaster Risk Assessment and Mitigation*

The formulation of disaster preparedness plan for any location should comprise the following steps:

a) *Step 1* — Identify the geomorphology; river, coastal and cyclonic proximity; and climatic zone related disasters risks.

b) *Step 2* — Identify population, business related disasters and vulnerabilities.

c) *Step 3* — Carry out risk assessment through hazard analysis and vulnerability analysis including possible combining effects of multiple hazards. Also include the effect on micro-climate and environment biodiversity. Coastal zones which are falling in high cyclonic flood zone, tsunami, and seismic zones of high intensity and landslide sensitive areas should receive special attention.

d) *Step 4* — Identify the socio-economic, socio-political hazards and vulnerabilities attributed to man-made disasters.

e) *Step 5* — Prepare a disaster risk mitigation plan supported with sufficient budgetary provisions.

f) *Step 6* — The disaster resistant building construction and infrastructure development features shall form part of the submittal to the Authority for statutory approvals.

g) *Step 7* — Establish/nominate a responsible senior person/safety officer as controller for regulating, planning and monitoring disaster preparedness plan for whole project. Carry out all constructions, installations and operations in line with the disaster resistant features for each of the vulnerabilities.

h) *Step 8* — Prepare and have mock drills at regular intervals for creating awareness and response preparation amongst stakeholder involved.

j) *Step 9* — Prepare operation manual for post-construction operation and up keep of disaster resistant features and equipment.

The basic action plan should focus on capacity building amongst stakeholders involved, communication, co-ordination, role of information technology, role of every individual working at site and role of emergency response cell of building in conjunction with the mitigation plans of local/state level authorities. The possible after-effects on human and natural habitats and mitigation plan should form integral part of disaster preparedness plan for least damage to human life, built environment and related ecosystems.

4 APPLICABILITY OF THIS PART

4.1 Where a building is erected, this Part of the Code shall be applicable to such building.

In case of renovation or addition and/or alteration to an existing building, this Part of the Code shall apply to such parts of the building. However, owner shall have opportunity to get an existing building or part thereof evaluated under the provisions of this Part of the Code.

4.2 This Part of the Code may also be applied to the development projects.

5 IMPLEMENTATION OF THIS PART

Provisions for building planning, design including material selection and structural design, construction, operation and maintenance have been covered in National Building Code of India: Part 0 to Part 10. These also allow various options to be exercised, for example while various building materials have been listed therein along with their quality requirements for compliance, the choice may rest with the owner/ building professionals, say for walling or masonry units, the options could be: use of common burnt clay bricks, perforated clay bricks, hollow clay bricks, fly ash lime bricks, fly ash clay bricks, calcium silicate bricks, solid/ hollow concrete blocks, light weight concrete blocks, autoclaved aerated concrete blocks, preformed foam concrete blocks or any other alternative specified. This Part of the Code discusses such options from sustainability point of view for guiding in their appropriate selection. Similar explanation applies to other materials as also other aspects in planning, design, construction, operation and maintenance. However, once a choice of material, design methodology, construction technique/methodology, operation and maintenance related options, etc, is made, the provisions given in this Part of the Code for the same shall be complied with. This Part also prescribes provisions to be necessarily complied with so as to help achieve the objective of sustainability.

This Part should, therefore, be implemented in light of the above while following the approach given in **3**. The Authority may require submission and verification of relevant documents while applying for building permit, to demonstrate compliance to the requirements of various provisions under this Part.

6 SITING, FORM AND DESIGN

6.1 General

Before initiating the formal design process, it is critical to evaluate all the passive design options to take advantage of local site and climatic conditions,

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acceptable thermal comfort conditions and other occupant requirements. Passive techniques are very cost effective, climate responsive and energy efficient and help a building integrate better with its immediate environment and most importantly do not create any negative impact on the environment unlike active systems that may cause various negative impacts including ozone depletion, global warming and environmental disruptions. The objective, therefore, is to encourage passive design strategies for every building as a means to reducing overall energy demand before pursuing active and mechanical means in an effort to not only save energy but also to minimise the overall negative impact on the environment.

The requirements for the development of buildings and building sites that encourages sustainable building practices including siting, form and architectural approach towards sustainable development, are given in **6.2**. The purpose includes providing guidelines that establish objectives for siting and form of residential, mercantile, industrial or other building occupancy developments early in the design stage so as to address sustainability through design. These objectives include, but are not limited to, energy conservation, water conservation and reduced greenhouse gas emissions.

6.2 Site Design and Development

6.2.1 *Site Assessment Prior to Design*

The responsible design professional shall prepare an assessment of the onsite natural resources and pre-site conditions. The person shall,

a) establish, if there are any protected areas such as floodplains; forest department areas; water bodies such as sea, lakes, rivers, wetlands, tributaries and/or streams; coastal regulation protected areas; defence areas; public parks and recreation areas (unless otherwise used for the purpose of the park); natural contours/ terrain requiring protection and agricultural land (unless serving an agriculturally related purpose such as storage, processing, transport, etc) and demonstrate that no critical natural resource is impacted by the project and/or dredging operations;

b) establish the degree to which the existing soil at site and hydrology has been disturbed prior to development and demonstrate various site erosion protection measures taken including measures to preserve natural stormwater drainage system, top soil and existing vegetation, minimise soil disturbance as specified in Part 10 'Landscape Development, Signs and Outdoor Display Structures Section 1 Landscape Planning, Design and Development' of the Code;

c) identify and ensure diversion, avoidance of existing water, power, communication, sewerage lines, saving/replanting of old trees, removal of existing invasive vegetation on site and that no invasive vegetation is planted post completion; and

d) identify and ascertain the natural resources available onsite and surrounding areas and ensure optimum utilization of the same in construction and post occupancy.

A site assessment report for the building/development project shall be prepared.

6.2.2 *Building Form, Orientation and Shading*

The development shall plan on locating, orienting and shading the building so that,

a) there is adequate provision for external shading of the facades during the peak summer season;

b) there is adequate provision for vertical shading to prevent direct solar radiation and glare due to low altitude sun angles, specifically on the eastern and western facades;

c) the building is oriented optimally based on sun-path and engineering analysis; and

d) there is adequate protection for the building envelope against thermal losses, drafts and degradation by natural elements such as wind, dust, sand, snow, rainwater, hail, etc.

The above strategies shall be implemented based on the climatic conditions of the location. Specifically, the designs should be based on the heating degree days and cooling degree days of the actual location of the building. In the absence of this data, a more generalist approach based on the five climatic zones of the country may be used.

The responsible design professional shall carry out building orientation and shading studies and establish the optimal building orientation for the project and ensure appropriate shading design such that the facades are shaded for more than 50 percent of the summer solstice. A solar path analysis shall be done as an aid in arriving at optimum form and orientation for the building. Appropriate shading design can be arrived at either through simulation approach or by using the prescriptive shading norms as indicated in the SP 41 : 1987 'Handbook on the Functional Requirements of Buildings (other than industrial buildings)'. A design report showing both the optimum orientation and shading design strategies along with justification for the selection of the same shall be prepared.

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6.2.3 *Thermal Massing*

The responsible design professional shall carry out building thermal massing studies to evaluate the impact on thermal mass on the consequent thermal transmittance and energy performance of the building based on the sun-path analysis and local/equivalent weather data. A report showing both the optimal thermal massing and the choice and justification of the proposed wall material of the building together with the design approach for decision making shall be prepared, together with other documents while applying for the building permit.

6.2.4 *Reduced Building Footprint in Multi-Storeyed Building Designs*

The requirements for open spaces (within a plot) as specified in **8** of Part 3 'Development Control Rules and General Building Requirements' of the Code shall be complied with. In any case, at least 30 percent of the open spaces shall be maintained as softscapes (permeable surface on ground). For areas where the calculated softscape area requirement is less than 10 percent of the total plot area, a minimum of 10 percent softscape area shall be provided.

6.2.5 *Optimum Building Volume*

For air conditioned buildings, efforts shall be made in design to reduce building volume by reducing floor to floor and floor to ceiling height without compromising the utility and functional efficiency of the building. For natural ventilated buildings or mixed mode ventilated building, the optimum building volume and floor to floor heights to be ascertained and a report on the design and justification of the same shall be prepared.

6.2.6 *Building Form Development Plan*

A report shall be prepared on the evolution of the form of the building based on science of architecture, climatology and building physics. The plan shall be in line with the decision making process of the project team and a narrative shall be prepared briefly mentioning the justification behind the selected building form and orientation of the building and shading devices to ensure that the final design meets with the intent of this Part.

6.2.7 *Natural Ventilation, Cooling and Wind Effects*

A report illustrating the evaluation of the various natural ventilation and cooling studies to maximize natural ventilation or mixed mode ventilation based on adaptive thermal comfort criteria for the project, shall be prepared. In addition, for high rise buildings, wind analysis shall be carried out to evaluate the impact of wind movement and natural air flow changes because of the new building proposed to be erected. Strategies may include application of cross-ventilation and thermal comfort, factoring prevalent wind patterns, seasonality, stack effect and other principles. A narrative on how these aspects have been factored in the design shall be prepared.

6.2.8 *Optimal Daylighting*

A day lighting analysis study based on the proposed form of the building for the project shall be carried out and a report thereof prepared. It shall be demonstrated that at least 25 percent of the regularly occupied areas of the building achieve sufficient day lighting with a minimum day lighting factor of 2 percent or as described in SP 41:1987 'Handbook on the Functional Requirements of Buildings (Other than Industrial Building)'. For details of day lighting harvesting methods and calculations (*see* **8.1.3.2**).

6.2.9 *Defining Building Service Life in Terms of Minimum Component Service Life*

A building service life plan shall be prepared along with the design and construction documents. The plan shall clearly indicate the design service life and the minimum design service life shall be not less than 60 years for the structure itself and not less than 10 years for various service components, equipment and systems within the building. All plan shall include dismantling, de-mounting and re-use plan.

6.2.10 *Life Cycle Assessment (Optional)*

The materials and assemblies may be selected based on their carbon footprint (GHG emission potentials) and/or a life cycle assessment of the embodied energy of the product. For more details on LCA analysis of building materials (*see* **9.1.4**).

7 EXTERNAL DEVELOPMENT AND LANDSCAPE

7.1 Landscape Planning and Design

The landscape planning and design shall be in accordance with Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 1 Landscape Planning, Design and Development' of the Code. In addition, the provisions given in **7.1.1** to **7.1.3** shall be followed.

7.1.1 *Landscape Design*

Proper landscaping helps in maintaining natural capacity of site for stormwater management, filtration, groundwater recharge and maintenance of soil structure thereby contributing to soil organic matter, and preventing erosion. It helps in moderating microclimate through evaporation, transpiration and the uptake and storage of carbon in trees and other vegetation.

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7.1.1.1 *Microclimatic conditions*

Microclimatic conditions play an important role in landscape design and in working out irrigation requirements, as it accounts for the environmental conditions specific to the landscape, including temperature, wind and humidity. For example, a water body can increase the humidity and a wind funnel can increase the evapotranspiration rate and hence the irrigation requirement. The microclimatic conditions may be taken into account in landscape irrigation calculations by applying a microclimate factor.

The average microclimate factor is 1.0 and this refers to conditions where the landscape evapotranspiration rate is unaffected by buildings, pavements, reflective surfaces and slopes. Higher microclimate factor conditions occur where evaporative potential is increased due to landscapes surrounded by heat absorbing and reflective surfaces or due to exposure to particularly windy conditions. Examples of high microclimate factor areas include parking lots, west sides of buildings, west and south sides of slopes, medians, and areas experiencing wind funnel effects. Areas with low microclimate factor include shaded areas and areas protected from wind. North sides of buildings, courtyards, areas under wide building overhangs and north sides of slopes.

7.1.1.2 *External noise reduction/mitigation practices*

Need for reducing the noise at site shall be assessed. If so required, appropriate measures may be taken for noise abatement, such as quieter pavement or road surfacing, dense foliage, earth berms, barriers or screens, and scheduling maintenance activities when site users are not present. Walls, fences and vegetation may also be used to break, guide, deflect or filter the wind and thereby alter its effects. Noise may be reduced with use broad-leaved trees more than with the conifers and this further improves when foliage extends close to the ground. The best location for a noise barrier is either very close to the source or very close to the receiver while the worst position for attenuation is halfway between them. Provisions of Part 8 'Building Services, Section 4 Acoustics, Sound Insulation and Noise Control' of the Code shall be followed.

7.1.1.3 *Building shadow considerations on landscape*

Vegetation provides climate moderating benefits as well as benefits to human health. Most vegetation requires sunlight in varying degrees for their growth and maintenance. The buildings by their design, shade certain parts of the external areas for some part of the day or other. External landscapes shall be designed taking the shading pattern of the buildings into consideration. For instance the northern side external areas of the building tend to be shaded for large parts of the day, while the southern side has access to sunlight for most times of the day, the choice of vegetation should be based on the availability of sunlight along different solar exposures and the requirement of various species of vegetation. Vegetation also has the potential to reduce the energy consumption of a building by providing shading and a cool microclimate. Vegetation and/or vegetated structures shall be kept in strategic locations around buildings to reduce energy consumption and costs associated with indoor climate control.

7.1.2 *Hard Landscape Design*

7.1.2.1 *Pervious paving design*

Pervious paving helps in holding rainwater, reducing the rate of storm water flow, infiltrating storm water into the ground for reuse and also helps in filtering the rainwater. Besides helping in storm water management, pervious paving helps in reducing the heat island effect. For sustainable site planning, perviousness in the paved areas of the site may be maximized.

However, the rainwater harvesting potential of pervious paving is subject to local geo-morphological formations and the use of the same should be assessed based on local conditions. For example, in coastal areas, where the water table may be high and the water absorptive capacity is low, pervious paving may not be as effective.

7.1.2.2 *Heat island effect and parking design*

The heat island effect raises the localized temperature, impacting local climate/microclimate. Plants and animals that are sensitive to large fluctuations in day time and night time temperatures may not thrive in areas affected by heat island. Heat islands also exacerbate air pollution as smog is produced faster at higher temperatures and as rising temperatures lead to increased cooling requirements, requiring energy and causing associated emissions.

Open parking areas consisting of concrete and asphalt absorb heat and contribute substantially to the heat island effect. Shading and/or use of light-coloured/high-albedo materials and/or open grid pavement for the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc, shall be made to help in reducing the heat island effect.

The solar energy should instead be utilized for generation of renewable energy, thus serving the dual purpose of dampening the heat island effect and reduction in use of fossil fuel for energy generation (*see* **11.16**).

7.1.2.3 *Post-occupancy maintenance*

A site maintenance plan shall be developed that outlines the long term strategies and identifies short-term actions

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to achieve sustainable maintenance goals. The plan should address issues such as plant maintenance, integrated pest management, soil management, fertilizer use, rainwater harvesting, reducing freshwater consumption, site safety, and irrigation allotment and schedule.

7.1.3 *Soft Landscape Design*

7.1.3.1 *Preserving top soil*

Healthy soils allow rainwater to penetrate, preventing excess runoff, sedimentation, erosion, and flooding. Soils also help clean and store water, and recharge groundwater. By storing water and slowing the delivery of water to plants, healthy soils play a significant role in vegetation health. In areas of previously disturbed soils, soil function shall be restored to rebuild ability of soils to support healthy plants, biological communities, and water storage and infiltration. In existing soils, depending upon the requirement, the need of soil compaction, organic matter levels, and the balance of soil organisms shall be addressed. It shall be ensured that adequate soil volume is made available for proper plant growth. In order to protect soil horizons and maintain soil structure, existing hydrology, organic matter, and nutrients stored in soils, the disturbance to healthy soil shall be limited. Typically, the first 200 mm soil depth is most conducive for plant growth, and is considered as top soil. Where healthy top soil is being disturbed due to construction activities like excavation, the top soil should be stripped and stacked on one side till further use. Use of excessive chemicals such as fertilizers may result in lasting damage to the soil ecology and shall, therefore, be avoided. *See* Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 1 Landscape Planning, Design and Development' of the Code, for further details regarding protection of landscape during construction.

7.1.3.2 *Ecological design/conserving biodiversity*

A diverse range of species, especially native plants can provide habitat for native fauna, including important pollinator species (for example, insects, birds and bats) that are necessary for plant reproduction, including cultivation of crops. Also, biodiversity in landscapes helps in retaining soil nutrients and is more resistant to attacks by pests. The following considerations shall be used:

a) *Protection and use of existing vegetation* — Such sites shall be selected that do not include habitat for threatened or endangered species. Site may be designed to minimise disruption to existing habitats. Trees designated as important by concerned local, state or central authorities shall be preserved. Mature trees are significant community resources because of their cultural, aesthetic, or historic relevance and shall be preserved. Transplantation for mature trees within the site or to another site shall be explored, where vegetation clearing is necessary for construction.

b) *Use of vegetation that promotes a regional identity and a sense of place* — Native plants which are endemic to the location and appropriate non-native plants adapted to site conditions, climate, and design which support biodiversity, reduced pesticide use and water conservation, shall be used. Only non-invasive plants that are nursery grown, legally harvested or salvaged for reuse from on or off-site shall be used.

c) *Conservation of native endangered species* — Native vegetation that is endangered in the locality may be planted to conserve/enhance the gene pool of native vegetation and promote biodiversity.

7.1.3.3 *Landscape design for controlling solar gain*

Vegetation placed in strategic locations around buildings provides an opportunity to reduce energy consumption and costs associated with indoor climate control for cooling. Trees, shaded trellises, green roofs, green facades and green walls may be used individually or in conjunction with other measures to increase shading both on the ground and on the building surface. Deciduous trees allow access to the sun in winter and provide shade in summer. Vegetation provides significant opportunities in conserving building energy consumption, especially if the west, south-west, south-east and east facades of the building are shaded. For buildings with natural ventilation, the vegetation species shall be carefully chosen such that they provide shade, but do not significantly block cool breezes or any convective air currents.

7.1.3.4 *Vertical landscaping and roof gardens*

Roof garden and/or green walls or vertical landscaping may be provided as it helps in conserving energy by providing shading, reduces heat island effect, helps (specially in dense areas) in maintaining a certain biomass critical for human health and also helps in reducing storm water flow rates through bio-retention. Required caution shall be observed in respect of water proofing requirement for the above.

7.1.3.5 *Urban agricultural practices/social forestry*

Growth of cities puts a significant pressure on natural resources resulting in drastic reduction of green open spaces, depletion of trees, heat island effects, and floods and other natural disasters, further aggravated by the effects of climate change. Proper attention may be given

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to the potentials of urban forestry and agriculture for contributing towards urban greening, heat reduction, storage of excess storm water and maintaining flood plains free from construction. Large scale developments that exceed 10 hectare should be encouraged to fulfil minimum 5 percent bio-capacity required to sustain themselves.

7.2 Rainwater Harvesting — Surface Runoff

7.2.1 *Rainwater Harvesting*

Rainwater harvesting refers to collection and storage of rainwater and also other activities aimed at harvesting surface and groundwater, prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions, aimed at conservation and efficient utilization of the limited water endowment of physiographic unit such as watershed. In general, rainwater harvesting is the activity of direct collection of rainwater. The rainwater collected can be stored for direct use or can be recharged into the groundwater. While enough measures should be taken voluntary, the Authority should encourage and appropriately provide for ensuring rainwater harvesting in outdoor built environment.

The system of collection of rainwater and its conservation for future needs has traditionally been practiced in the country, such as through *Baoris*, step wells, lakes, tanks, roof top collection systems, etc, to meet the domestic and irrigation demands. This also helps to arrest groundwater decline and augment groundwater table, beneficiate water quality in aquifers, conserve surface water runoff during monsoon, reduce soil erosion and inculcate a culture of water conservation.

Two broad approaches to rainwater harvesting are:

a) *Storing rainwater for direct use* — Under this approach, for domestic and irrigation purposes, the rainwater is directly collected either in the natural or man-made structures such as *Nadi, Tanka, Kund,* sand filter bed, pond, rooftop rainwater collection structure, etc.

   Roof rainwater collection system augments the water demands by collecting rainwater from the roof and diverting it to specially designed storage or recharge tanks, as per the requirement. On sloping roofs, evaporation losses are small, so collection efficiency may be of the order of 85 percent. Rainwater may be collected from any kind of roof. Tiled or metal roofs are easier to use for the purpose and a smooth surface for the roof will help in water flow and collection.

   To reduce contamination of rooftop rainwater, the necessary actions and precautions as given below shall be followed:

   1) Avoid overhanging of trees above the roof to prevent leaves and bird droppings falling on the roof.
   2) Do not allow the first rainfall to enter the tank by diverting it away from tank; although human or animal coliforms are not involved, bird droppings or lizard faeces, and other air borne dirt are also to be washed away from the roof.
   3) Filter the water on entering the tank by suitable filter and also cleaning the filter and tank regularly.
   4) Seal tanks to keep out sunlight (to prevent algae growth), mosquitoes, lizards, birds, etc.
   5) Disinfect tanks once in a year with bleaching powder.

b) *Recharging groundwater aquifers* — This approach involves use of various kinds of recharge structures, which not only arrest the water but also promote water percolation through soil strata to recharge the depleting aquifers. Structures like percolation tank, anicut, gabion, etc, facilitate the recharge of underground aquifers. However, meteorological and hydrological investigations along with geo-technical investigations shall be carried out before selecting the best suited method for groundwater recharge. Direct injection of rainwater through deep bore wells should be avoided for quality control reasons.

For rainwater harvesting a reference to **4.5.12** of Part 9 'Plumbing Services, Section 2 Drainage and Sanitation' of the Code may be made. For further details, reference may also made to good practice [11(1)].

7.3 Water Elements and Irrigation Practices

7.3.1 *Design and Post Occupancy Maintenance of Water Features*

The site maintenance plan (*see* **7.1.2.3**) shall include appropriate maintenance activities for the water features taking care of the following considerations:

a) Use of chemicals likely to harm aquatic life, such as chlorine and bromine shall be avoided.
b) Maintenance activities to ensure that the water features do not create habitat for mosquitoes, shall be included.
c) Water features shall be designed such that they match or mimic water in the natural

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environment; and water features that are incompatible with the local ecological context (for example, a lake in a desert) shall be avoided.

d) Volumes of rainwater or water from other non-potable sources available on site for use in water features shall be estimated, and water features shall be so designed that these are integrated with the site so as to utilize this water on site, and not require additional water from potable water sources.

e) Non-potable water from sources such as gray water, reclaimed water or storm-water basins shall be collected and used for non-potable applications.

f) Design and maintain water features as natural ecosystems with water source(s), plants and aquatic organisms appropriate for local conditions.

g) Water quality may be enhanced in created water features with biologically-based water treatment including with the use of certain enzymes, mineral, and oxygen-based additives, especially during initial establishment.

h) Natural swimming pools or other water features intended for human contact may require additional treatment methods such as ozonation or thermal treatment.

7.3.2 *Water Conservation and Irrigation Practices*

Selecting efficient irrigation systems, planting vegetation appropriate for site conditions and climate, and using captured rainwater or gray-water can reduce water waste and conserve sources of potable water. Typically, half of irrigation water may get wasted as a result of evaporation, wind, improper system design, and over-watering requiring the following considerations which may be followed:

a) Low water demand vegetation (xeriscape) and high-efficiency equipment (for example, drip irrigation) and/or climate based controllers for irrigation systems should be used.

b) If turf grasses are to be used, they should be selected, to be regionally appropriate and to minimise post-establishment requirements for irrigation. The turf area should not exceed 30 percent of the total landscaped area.

c) Reuse gray-water, captured rainwater and/or condensate water for irrigation to decrease potable water use for irrigation as well as to create a net benefit to the local watershed by making the landscape part of the natural water-treatment process.

d) If gray-water or wastewater is to be recycled for landscape irrigation, tests should be conducted to determine suitability for reuse.

e) Irrigation systems should be so designed that trees, shrubs and ground cover are irrigated in separate hydrazones such that watering can be discontinued zone by zone as plants become established.

f) A sub-surface drainage system shall be planned in areas covered with turf to collect excess water for reuse.

7.4 External Access Design

7.4.1 *Reduced Environmental Impacts from Parking Facilities*

Open parking areas, if largely made of concrete and asphalt, absorb heat and contribute substantially to the heat island effect. This shall be mitigated by following the considerations given below:

a) Rendering these areas white or light in colour instead of black, so that they may reflect a lot of sunlight back to space rather than absorbing it.

b) Providing shade and/or using light-coloured/ high-albedo materials and/or open grid pavement for the site's non-roof impervious surfaces, including parking lots, walkways, plazas, etc.

c) Limiting the net paved area of the site under parking, roads, paths, or any other use so as not to exceed 25 percent of the site area or net imperviousness of the site not to exceed the imperviousness factor as prescribed in **4.5.11.2.1** of Part 9 'Plumbing Services, Section 2 Drainage and Sanitation' of the Code, whichever is more stringent.

Additionally, the following shall be complied with:

1) More than 50 percent of the total paved area shall have pervious paving/open grid pavement/grass pavers, or

2) A minimum 50 percent of the total paved area (including parking) shall have shading by vegetated roof/pergola with planters, or

3) A minimum 50 percent of the total impervious paving area (including parking) shall be topped with finish having solar reflectance of 0.5 or higher.

The external access, including pedestrian walkways/ pathways shall be designed and developed in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

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7.4.2 *Long term Public and Private Transportation Plan*

The long term public and private transportation plan shall take care of the following considerations:

a) Incorporating urban transportation as an important parameter at the urban planning stage rather than being a consequential requirement;
b) Encouraging integrated land use and transport planning in cities so that travel distances are minimised and access to livelihoods, education, and other social needs, especially for the marginal segments of the urban population is improved;
c) Improving access of business to markets and the various factors of production;
d) Bringing about a more equitable allocation of road space with people, rather than vehicles, as its main focus;
e) Encouraging greater use of public transport and non-motorized modes;
f) Enabling the establishment of quality focussed multi-modal public transport systems that are well integrated, providing seamless travel across modes;
g) Establishing enforcement mechanisms to ensure efficiency and enhanced safety for the transport system users;
h) Establishing institutional mechanisms for enhanced coordination in the planning and management of transport systems;
j) Introducing intelligent transport systems for traffic management;
k) Addressing concerns of road safety and trauma response;
m) Reducing pollution levels through appropriate travelling practices, better enforcement, stricter norms, technological improvements, use of electrically operated vehicles etc; and
n) Building capacity (institutional and manpower) to plan for sustainable urban transport and establishing knowledge management system.

7.4.3 *Bicycle Lanes and Pedestrian Access — Safety and Comfort*

Construction of cycle tracks and pedestrian paths in cities enhances safety and thereby enhances use of non-motorized modes. The safety concern of cyclists and pedestrians should be addressed by encouraging the construction of segregated rights of way for bicycles and pedestrians. Apart from improving safety, the segregation of vehicles moving at different speeds helps improve traffic flow, increase the average speed of traffic and reduce emissions resulting from sub-optimal speeds. Such segregated paths are useful not only along arterials, to enable full trips using non motorist transport but also as a means of improving access to major public transport stations. Such access paths, coupled with safe bicycle parking places, may be provided for promoting an increased use of public transport. Creative facilities like shade giving landscaping, provision of drinking water and resting stations along bicycle corridors should also be encouraged to help mitigate, the effect due to adverse weather conditions. The use of the central verge along many roads, along with innovatively designed road crossings, may be considered for developing as cycle tracks. At busy intersections and high traffic corridors, pedestrian crossing shall be constructed.

Following are some of the features which should be considered while designing pedestrian and cycle/cycle-rickshaw friendly environment:

a) Design and construction ensuring safety and comfort of all the users.
b) Use of following climatic design features for streets and public spaces to make them comfortable for pedestrians, cyclists and public transport users, based on local climate:
    1) Planting of deciduous trees all along the pedestrian/cycling path to provide adequate shade in summer and allow solar access in winter.
    2) Considerations to overhangs, arcades and closely built buildings providing shading and comfort in summer to the public realm.
    3) Orientation of streets to allow the desirable directional wind flow through streets and public spaces in summer and block undesirable winds in winter, to ensure comfort in the public use areas.
c) Signalization of junctions and mid-block crossings on roads to allow safe crossings at grade.
d) Multimodal interchange and provision of good para-transport options and walkability at the neighbourhood level as the most important factor in reducing use of private modes and also reducing transportation demand; and the following to be provided so that people can walk or cycle easily for short trips as well as for accessing mass transport stations:
    1) Fast and convenient interchange between modes (distances between modal changes to be as per multimodal integration and connectivity requirements).
    2) Closest convenient interchange access at

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stations for pedestrians, non-motorized modes and public/paratransport modes, preferably within 50 m of station exits.

e) Proper street grid density as a critical requirement in urban design to ensure small blocks and an interconnected street network to provide a walkable, public transport friendly neighbourhood as per the following:
   1) Street grid density of 7-10 km centre-to-centre/km^2 for residential-mixed use neighbourhoods and 13-20 km centre-to-centre/km^2 for commercial-mixed use neighbourhoods to provide adequate connectivity and frequent directional changes for pedestrians.
   2) Direct and shortest route/access to station through provision of cut-throughs for pedestrians and non-motorized transport through blocks above 200 m in length with a view to making smaller block sizes.
   3) Signalization of junctions and mid-block crossings on roads to allow safe crossings at grade at a maximum frequency of 200 m.

f) Provisions of dedicated lanes and signal prioritization for pedestrians, non-motorized transport and public transport on major corridors so as to provide priority and congestion-free movement for these modes.

g) Adequate street lighting for pedestrians and bicycles to ensure their safety; minimum illuminance being 30 lux for non-shopping areas and 20 lux for shopping areas, bus stops and signalized crossings.

h) Commercial/hawking zones at regular intervals in accordance with the local byelaws/ masterplan (within 5 min walk from every home in the city) to encourage walkability and increased street activity and to provide safety.

j) Amenities for public transport users:
   1) Amenities at-grade crosswalks (and overpasses on highways) at intervals of 80-200 m, aligning with location of transit stops, type of street/land use activities and neighbouring building entries and destinations.
   2) Dustbins, letter-boxes, signages and other public amenities at street corners for high usability.
   3) Accessible public toilets at every 500 m to 800 m distance, preferably located close to bus stops for easy access by pedestrians and public transport users.

k) Barrier free environment to make public streets and crosswalks fully navigable by all persons including the persons with disability and the elderly.

m) Vertical mixing of uses such that all non-work trips are reduced to be under 500 m walking distance such that vehicular trips may be eliminated for daily errands; for example through mixed convenient/community shopping uses with residential uses to reduce dependency on private vehicle and shifting all short trips from private vehicle to walking, cycle-rickshaw or public transport.

7.4.4 *Off Street Parking*

The off street parking shall be planned taking care of the following objectives as per Part 3 'Development Control Rules and General Building Requirements' of the Code:

a) To relieve congestion on streets by providing convenient off-street parking and loading facilities in proportion to the demand created by the use;

b) To provide for the safe and orderly movement of traffic through proper design and location of adequate parking, loading, and manoeuvring areas;

c) To protect neighbourhoods and surrounding land uses from vehicular parking, loading and traffic congestion, noise and dust, through proper aesthetic design and location of entries, parking areas, and landscaping;

d) To promote businesses, industries and commercial activities by providing safe, convenient, attractive parking facilities and environments; and

e) To encourage the use of efficient forms of transportation.

7.4.5 *Discouraging Subsidized Parking in Public Realm*

Subsidized parking in public roads and spaces, especially in urban areas with high traffic density or having likely projected high traffic density should be discouraged to reduce private vehicle usage and inducing a modal shift towards public transport. Parking management may be used as a demand management tool rather than a supply based tool, with the following considerations:

a) Discouragement to the use of car as a feeder or a general mode of transport, with park and ride facilities being only at stations of mass rapid transport system (MRTS).

b) Providing parking only for servicing rather

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than for access, and only emergency vehicle access to be provided which can be done through provision of mountable kerbs, etc, on pedestrian dominated streets.

c) No free or subsidized parking in public space and actual parking cost to be defined by market forces.

d) Enforcement of parking caps in areas with mass rapid transport access.

e) Park once-and-walk facilities in busy markets and residential/mixed use areas.

f) Strict enforcement of parking through self-regulating design.

7.4.6 *Providing Neighbourhood Connectivity, Walkability and Safety*

At the site design and block design level, several measures should be taken for reducing transportation demand and promoting walkability, and ensuring that the neighbourhood is a safe walkable place. These measures should include the following:

a) Vertical mixing of housing and community based uses to ensure vibrancy and safety.

b) Based on local climate, minimum 2 h daylight access to neighbouring buildings to be ensured through provision of required street width-to-height ratios, in accordance with Part 3 'Development Control Rules and General Building Requirements' of the Code.

c) *Block sizes and paseos* — For blocks where any one side is greater than 200 m in length, a public access cut-through for pedestrians and non-motorized transport (NMT) shall be provided. This ensures connectivity and walkability in the neighbourhood enabling short local trips to be made on foot.

d) The setbacks and boundary wall for commercial properties should be designed so as to also promote safety and encourage pedestrian communication.

7.4.7 *Ecology of Streets*

As streets constitute about 20 to 25 percent of the impervious cover of the city, they have a large detrimental effect on the heat island effect and ecological character of a city. The following design components should be integrated in street design:

a) Planting of trees as an essential component for all streets to provide shade to pedestrians and reduce solar gain.

b) Use of high albedo (diffused reflectivity) materials for paving and increasing greenery around to reduce heat island effect.

c) Decreasing impervious surfaces through permeable paving, tree planting zones, etc, to increase groundwater infiltration and prevent seasonal flooding.

d) Integrate natural storm water filtration and absorption into street design through bio-filtration beds, bio-swales and detention ponds.

7.5 External Lighting Design

7.5.1 *Landscape Lighting Design — Allowable Lighting Power Density (LPD)*

Light pollution can disrupt circadian rhythms and melatonin production, which has been linked to serious health concerns. Reasonable use of outdoor lighting restores dark night skies and preserves the ambiance of the night. Whether outdoor light is directly adjacent to a species habitat or located at some distance is an important consideration, as through sky glow, the combined effects of artificial lighting on vast numbers of nocturnal species have the potential to disrupt the functioning of entire ecosystems by disturbing balances in competition and predation. The landscape lighting should be designed such that light fixtures emit minimum light as per the specified total fixed lumens and only light the areas as required for safety and comfort. In addition, the lighting shall be efficient complying with the requirements of maximum LPD given in Table 1.

7.5.2 *External Signage Design*

External signage may be designed to address the following main issues related to overall sustainability:

a) The signage shall be classified as external lit and internal lit and further classified based on functional requirements such as emergency, way finding, etc. The requirements of each type of signage are different and should be evaluated based on the same. The recommended lighting power density is 130 W/m^2, maximum for internally illuminated signage, and 25 W/m^2, maximum for externally illuminated signage.

b) Illuminated signage forms a substantial part of upward directed lighting. Efforts should be made to shield the lighting.

c) Paints, adhesives, etc, used in the signage should be of low VOC.

d) Fabrication of the signage should be using materials locally available and having a recycled content.

7.5.3 *External Lighting*

The facades may be lit with fixtures that are shielded,

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Table 1 Maximum Lighting Power Densities for Building Exteriors

(*Clauses* 7.5.1 *and* 7.5.3)

Sl No.	Area to be Lit	LPDs *Max*
(1)	(2)	(3)
i)	*Uncovered parking areas:*	
	a) Parking lots and drives	1.6 W/m^2
ii)	*Building grounds:*	
	a) Walkways less than 3 m wide	3.28 W/linear metre
	b) 1) Walkways 3 m wide or greater 2) Plaza areas 3) Special feature areas	2.15 W/m^2
	c) Stairways	10.76 W/m^2
iii)	*Building entrances and exits:*	
	a) Main entries	98.52 W/linear metre of door width
	b) Other doors	65.68 W/linear metre of door width
iv)	*Canopies and overhangs:*	
	a) Canopies (free standing and attached and overhangs)	13.45 W/m^2
v)	*Outdoor sales:*	
	a) Open areas (including vehicle sales lots)	5.38 W/m^2
	b) Street frontage for vehicle sales lots in addition to open areas allowance	65.68 W/linear metre
vi)	Building facades	2.15 W/m^2 for each illuminated wall or surface or 16.42 W/linear metre for each illuminated wall or surface length
vii)	Automated teller machines (ATMs) and night depositories	270 W per location plus 90 W per additional ATM per location
viii)	Entrances and gatehouse inspection stations at guarded facilities	13.45 W/m^2 of uncovered areas covered areas are included under the canopies and overhangs
ix)	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	5.38 W/m^2 of uncovered areas covered areas are included in the canopies and overhangs
x)	Drive-up windows at fast food restaurants	400 W per drive-through
xi)	Parking near 24 h retail entrance	800 W per main entry
xii)	Landscaped areas, including individual house courtyards, terraces	2.15 W/m^2

with less than 10 percent lumens above 90° from the nadir (*see* Fig. 3) and the lighting power density of the facade lighting may be as given in Table 1.

7.5.4 *Light Trespass Allowance*

The light trespass allowance may vary for different site surroundings, and a light should also vary for different settings depending upon the requirements. The site settings may be kept as,

a) *Dark* — For rural setting.
b) *Low lighting setting* — For residential areas/ sub-urban areas and townships.
c) *Medium lighting setting* — For medium rise buildings, high rise buildings, commercial/ office areas and high density for non-commercial area.
d) *High lighting setting* — For malls, entertainment areas and city centre areas.

8 ENVELOPE OPTIMIZATION

8.1 Building Envelope

The building envelope acts as the interface between indoor and external climatic conditions. It potentially regulates the building climatic response. The building envelope should be designed to conserve energy substantially. Well designed building envelope maximizes daylight, natural ventilation (access to fresh air) and views to the exterior, and enables to modulate solar heat gain and control/reduce noise. The building envelope may also be designed to integrate systems for renewable energy and rainwater harvesting. In general, the design strategies drawn from long experience in the country in its various climatic zones may be taken into account (*see* Annex A for guidance).

Building envelope components and their configuration largely determine the amount of heat gain or loss and wind that enters inside the building and extent of natural ventilation in the building. The primary components of building envelope which affect the performance of a building are,

a) walls,
b) roof (including skylights and clerestories),
c) fenestration (openings with or without glazing),
d) floor, and
e) surface finishes.

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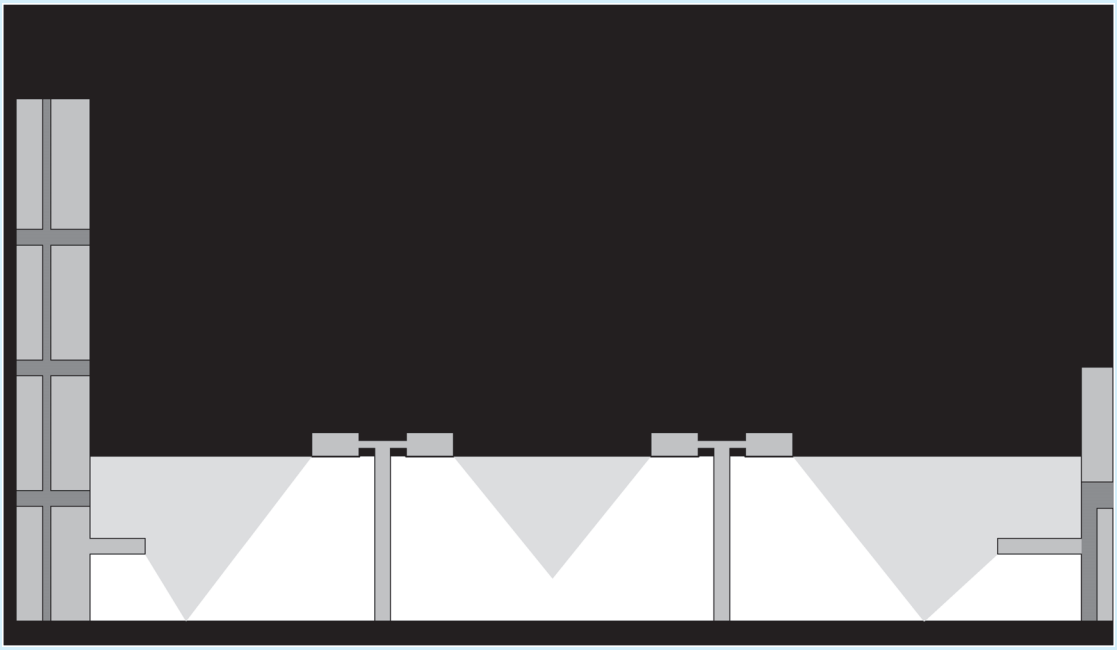


FIG. 3 FACADE LIGHTING USING SHIELDED FIXTURES

8.1.1 *Walls*

Walls are a major part of the building envelope, which are exposed to external environment conditions such as solar radiation, outside air temperature, wind and precipitation. The construction of wall and thereby its heat storing capacity and heat conduction property has a major impact on indoor thermal comfort in naturally ventilated buildings and on cooling loads in air conditioned buildings. The wall material, thickness, finishes should be selected according to climate zone and building's comfort requirement. Wall properties that determine heat transfer are thermal conductivity, thermal resistivity, thermal absorptivity, emissivity, thermal reflectivity and thermal capacity (*see* **2**).

8.1.1.1 *Enhancement of thermal performance of walls*

Thermal performance of walls can be improved by following ways:

a) *Thermal insulation* (*applying insulation on wall surface*) — Thermal insulation plays an important role in reducing the thermal conductance or *U*-value of walls. The effect of insulation is to reduce heat gain and heat loss. Insulation should always be placed on the hotter side of the surface. In hot climate zone, insulation should be placed on the external side of wall composition. Insulation also controls the interior mean radiant temperature (MRT) by isolating the interior surfaces from the impacts of exterior conditions. Insulation along with infiltration control is important for reducing heating and cooling loads in simple occupancy (skin) load dominated buildings such as residences. In buildings, that are internal load dominated such as offices with high equipment load, the insulation thickness and properties should be determined based on thermal performance analysis including the role of insulation in reducing cooling energy consumption, particularly in hot and dry, composite and warm humid climates. Thermal insulation may be made from a variety of materials and in several forms. Broadly they may be divided into following five categories:

1) Rigid or semi rigid blocks and boards (such as, mineral wool, expanded polystyrene boards);
2) Boards with impact or weather resistant surfaces suitable as exterior grade material;
3) Loose fill (such as, cellulose, fibre glass);
4) Foam and dry spray (such as, polyurethane or polyisocyanurate); and
5) Blankets, felts or sheets (such as, fibre glass, mineral wool, closed cell flexible elastomeric foam).

When specifying insulation, its key properties such as thickness, density, thermal resistivity/ thermal conductivity value at specified

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temperature, long term thermal retention, fire resistance, moisture resistance (structure open/ closed cell), water vapour diffusion resistance, etc, should be specified. Insulation should be applied as per manufacturers' recommendations and in a manner so that it achieves rated insulation in terms of thermal resistance or *R*-value. Damaging or compressing the insulation reduces the effective *R*-value and compromises thermal performance of the construction assembly.

b) *Thermal mass (increasing wall thickness)* — Thermal mass in walls enables time delay in impact of external environment on internal conditions. Thermally massive walls have high thermal capacity, and thermal storage capacity increases with increasing compactness, density and specific heat capacity of the materials. Walls (and other building elements such as roof and floor) can be used for thermal storage. The effectiveness of storing heat or coolness can be increased by creating a flow of fluid through the storage media.

   Thermal mass is particularly effective in hot-dry climate with larger diurnal range. The building mass stores heat during daytime when outside temperature is high, and releases it to the inside space during night when outdoor temperature is cooler. Thermal mass is also used in storing heat during daytime in cold climates, to release it into the space during night, to warm it up when outdoor conditions are colder. Materials such as concrete, brick and water have high thermal storage capacity and can be used for such application. Storage mass exposed to direct sunlight should be dark in colour to allow larger absorption. It is generally more efficient to have thicker rather than thinner storage mass. The optimum thickness varies between 100 mm and 200 mm.

   NOTE — There are ongoing developments based on research, regarding use of improvised materials with special properties such as phase changing characteristics which may be considered in future along with their implications from sustainability point of view.

c) *Air cavities (Providing air cavities in walls)* — Air cavities in wall reduces heat gain factor. Performance is improved if the cavity is ventilated. Heat is transmitted through air cavity by convection and radiation. Cavity represents resistance that is not proportional to the thickness of the cavity. For thicknesses greater than 20 mm, the resistance to heat flow is nearly constant. Air cavity, however, may not be treated as replacement for higher insulation, where needed as per the design requirements.

d) *Surface finishes (Applying light coloured paints on walls)* — Surface colour and finish plays an important role in heat gain and loss from a structure. If external surface of a building is painted with light colour, it will reflect solar radiation. But if the emissivity of the surface colour in the long wave region is also high, the heat flux into the building is considerably reduced. For example, whitewash has a lower reflectivity than aluminium, but will stay cooler when exposed to high solar radiation, due to its high emissivity at low temperatures. The effect of colour on external surfaces is more evident in lighter structure, which offers low resistance to heat flow, and because of low thermal capacity. Ongoing research has made possible paints that are dark but reflect most off infrared (IR) radiation, thereby preventing excessive heat gain.

8.1.2 *Roofs*

The roofs of buildings receive most of heat throughout the day. Predominantly used construction practices in the country especially in urban areas, mainly involve reinforced cement concrete (RCC) as the roofing element, which has high thermal conductivity. If the roof is exposed to solar heat, the temperature inside will also rise as the day progresses. When buildings are air conditioned, the purpose of the system is to maintain inside the building, a lower temperature than the ambient. If the roof slab is exposed to solar heat, it will allow continuous heat inside the building which in turn will add to the air conditioning load. If the roof is protected from heat incidence by suitably insulating the roof from the heat, the conditions inside can be controlled to a large extent so that the living environment inside the building remains below the ambient temperature throughout the day. The function of roof insulation is to insulate the building against heat inflow from outside during the day. The options for roof insulation are given in **8.1.2.1** to **8.1.2.2**. The overall thermal transmittance from the exposed roof should be kept as minimum as possible and under normal conditions, the desirable value should not exceed 0.58 W/(m^2°C). The ceiling surface of floors which are not to be air conditioned may be suitably insulated to give an overall thermal transmittance not exceeding 1.16 W/(m^2°C). Some traditionally adopted methods of roof construction like stone *Patti* and jack-arched roof may be used after evaluating their thermal performance. Mechanism to shade the roof with vegetation will help a great deal in lowering solar exposures.

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8.1.2.1 *Over-deck and under-deck insulation*

In this system a thermal barrier or insulation is provided over RCC roof, so that the amount of heat of the sun reaching the RCC slab of the roof is substantially reduced to prevent the slab from getting excessively heated up. In contrast, if the thermal barrier is provided under RCC roof, as in under-deck insulation, some heat passes through it and heats up the ambience of the room. This decreases the comfort level of the room and if the building is air conditioned, increases the air conditioning load. Over-deck insulation is, therefore, considered advantageous over under-deck insulation in hot climates. Over-deck insulation also protects waterproofing system from damage due to thermal stress caused by continuous variation in diurnal and seasonal temperatures. It also acts as a protection against mechanical damage to water proofing systems. Over-deck insulation material should have adequate compression resistance, low water absorption, resistance to high ambient temperature and low thermal conductivity. Over-deck insulation applications may be carried out by either of the following methodologies:

a) *Use of preformed insulation materials* — Preformed insulation materials used are classified as given below which may be laid, over the roof surface as per the manufacturers' recommendations:
   1) Expanded polystyrene sheet.
   2) Extruded polystyrene sheet.
   3) Polyurethane/polyisocyanurate sheet.
   4) Perlite board.

b) *In-situ application using spray applied polyurethane* — This is applied directly over the roof by spraying. This insulation has advantage of non-interference with internal constructional/operational activities of a building, jointless adhesion to the roof surface due to seamless and monolithic nature of spray, and speedy application. *In-situ* spray application involves a mixture of atmospheric air leading to open cell formation and may affect insulation performance over time. Therefore, it is preferable in complex locations where use of rigid boards is difficult or not possible. This insulation needs to be treated with proper water proofing treatment ensuring no water ingress into the insulation, as in case of the waterproofing treatment getting damaged, the water ingress into the insulation may lead to deterioration and adversely affecting the insulation properties.

c) *Conventional roof insulation practices* — There are a number of traditional roof insulation practices followed in the country which have been effectively employed. These may include mud *phuska* and brick bat *coba*.

d) *Other traditional practices of roof insulation* — Inverted earthen pots may also be used for roof insulation. In this system burnt clay pots are placed in inverted positions and covered with filler material. The air trapped inside the pots act as insulator and renders insulating property to roof. Suitable water proofing treatment needs to be additionally applied [*see also* **9.2.4.1.1** (m)].

   Cellular concrete may also be used depending on the thermal insulation requirement.

   The thermo-physical properties of different roof constructions are given in Table 2 and Table 3 for flat roof and sloped roof, respectively.

   NOTE — Thermal conductivity values are indicative and many other/traditional practices may be employed for achieving desired thermal properties.

   Thermal properties of some commonly used insulating materials and building materials are given in Table 4.

   For thermal performance of flat and sloped roofs with use of various other considerations of materials and for thermal properties of building and insulating materials, refer to good practice [11(2)] and SP41 'Handbook on Functional Requirements of Buildings'.

e) *Other over-deck systems that minimise heat gains* — There are other systems employing use of highly reflective and emissivity coatings that stay cooler in the summer thereby reducing energy costs, improving occupant comfort, cutting maintenance costs, increasing the life of the roof, and contributing to the reduction of heat island effect. Roofs with slopes less than 20Ú slope have a minimum initial solar reflectance of 0.70 and minimum emittance of 0.75. Cool roofs should be designed to have a minimum solar reflectance of 0.70 and a minimum thermal emittance of 0.75 or alternatively should achieve a minimum solar reflective index (SRI) of 82. Various types of cool roof systems are:
   1) *Roof coatings* — These may be field applied or factory applied. Field applied roof coatings are applied directly onto the roof surface and may require an appropriate primer. Factory applied coatings are applied in factory and include coatings applied to metal sheets. Specialized white elastomeric coatings may be used for sloped roofs and cool colour polymer coatings may be used for

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Table 2 Typical Thermal Performance of Flat Roof Constructions

(*Clause* 8.1.2.1)

Sl No. (1)	Specification of Roof (2)	U-Values W/(m^2.K) (3)
i)	100 mm RCC	3.59
ii)	100 mm RCC + 100 mm lime concrete	2.78
iii)	100 mm RCC + 50 mm foam concrete + waterproofing	1.08
iv)	50 mm RCC + 25 mm expanded polystyrene	1.08
v)	50 mm expanded polystyrene + 50 mm RCC + waterproofing	0.62
vi)	25 mm expanded polystyrene + 50 mm RCC	1.09
vii)	100 mm RCC + 50 mm cinder concrete + 50 mm brick tile	2.07
viii)	100 mm RCC + 75 mm cinder concrete + 50 mm brick tile	1.76
ix)	115 mm RCC + 50 mm mud *phuska* + 50 mm brick tile	2.31
x)	115 mm RCC + 75 mm mud *phuska*+ 50 mm brick tile	2.01
xi)	150 mm clay unit	3.15
xii)	137.5 mm clay unit	2.99
xiii)	150 mm clay unit + 100 mm lime concrete	2.21
xiv)	137.5 mm clay unit + 100 mm lime concrete	2.14
xv)	100 mm cellular unit + 85 mm lime concrete	2.27
xvi)	125 mm cord unit + 85 mm lime concrete	2.13
xvii)	154 mm lime concrete using stone aggregate + 76 mm stone slab	3.07
xviii)	88.9 mm concrete using brick aggregate + 25.4 mm kota stone slab on each side	3.65
xix)	50.8 mm lime concrete using ballast aggregate + 114 mm reinforced brick and bitumen wash on top	2.45
xx)	50.8 mm lime concrete using brick ballast aggregate + 50.8 mm RCC slab + bitumen wash on top surface	4.02
xxi)	100 mm RCC + Inverted clay pots with mud *phuska*	2.344
xxii)	100 mm RCC + Extruded polystyrene 25 mm-36 kg/m^3	0.749
xxiii)	100 mm RCC + Extruded polystyrene 30 mm-36 kg/m^3	0.658
xxiv)	100 mm RCC + Extruded polystyrene 40 mm-36 kg/m^3	0.528
xxv)	100 mm RCC + Extruded polystyrene 60 mm-36 kg/m^3	0.380
xxvi)	100 mm RCC + Extruded polystyrene 75 mm-36 kg/m^3	0.312
xxvii)	100 mm RCC + Expanded polystyrene 25 mm-24 kg/m^3	0.931
xxviii)	100 mm RCC + Expanded polystyrene 30 mm-24 kg/m^3	0.823
xxix)	100 mm RCC + Expanded polystyrene 40 mm-24 kg/m^3	0.670
xxx)	100 mm RCC + Expanded polystyrene 60 mm-24 kg/m^3	0.482
xxxi)	100 mm RCC + Expanded polystyrene 75 mm- 24 kg/m^3	0.409
xxxii)	100 mm RCC + Phenolic foam 25 mm-32 kg/m^3	0.725
xxxiii)	100 mm RCC + Phenolic foam 30 mm-32 kg/m^3	0.641
xxxiv)	100 mm RCC + Phenolic foam 40 mm-32 kg/m^3	0.511
xxxv)	100 mm RCC + Phenolic foam 60 mm-32 kg/m^3	0.363
xxxvi)	100 mm RCC + Phenolic foam 75 mm-32 kg/m^3	0.301
xxxvii)	100 mm RCC + Polyurethane spray 25 mm-42 + 2 kg/m^3	0.664
xxxviii)	100 mm RCC + Polyurethane spray 30 mm-42 + 2 kg/m^3	0.579
xxxix)	100 mm RCC + Polyurethane spray 40 mm-42 + 2 kg/m^3	0.460
xl)	100 mm RCC + Polyurethane spray 60 mm-42 + 2 kg/m^3	0.319
xli)	100 mm RCC + Polyurethane spray 75 mm-42 + 2 kg/m^3	0.259
xlii)	100 mm RCC + Polyisocyanurate spray 25 mm-42 + 2 kg/m^3	0.664
xliii)	100 mm RCC + Polyisocyanurate spray 30 mm-42 + 2 kg/m^3	0.579
xliv)	100 mm RCC + Polyisocyanurate spray 25 mm-42 + 2 kg/m^3	0.460
xlv)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 43 mm polyurethane of 36 kg/m^3 + brick tiling	0.409
xlvi)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 71 mm expanded polyurethane of 24 kg/m^3 +brick tiling	0.409
xlvii)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 58 mm extruded polyurethane of 29 kg/m^3 +brick tiling	0.409
xlviii)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 140 mm exfoliated vermiculite of 264 kg/m^3 +brick tiling	0.409
xlix)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 43 mm polyisocynuarate of 32 kg/m^3 +brick tiling	0.409
l)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 73 mm polyurethane of 36 kg/m^3 +brick tiling	0.261
li)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 122 mm expanded polystyrene of 24 kg/m^3 +brick tiling	0.261
lii)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 98 mm extruded polystyrene of 29 kg/m^3 +brick tiling	0.261
liii)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 240 mm exfoliated vermiculite of 264 kg/m^3 +brick tiling	0.261
liv)	15 mm cement plaster + 150 mm RCC + 100 mm brick bat coba + 73 mm polyisocynurate of 32 kg/m^3 +brick tiling	0.261

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Table 3 Typical Thermal Performance of Sloped Roof Constructions

(*Clause* 8.1.2.1)

Sl No. (1)	Specification of Sloped Roof (2)	*U*-Values W/(m^2.K) (3)
i)	0.625 cm AC sheet	5.47
ii)	0.625 cm AC sheet + 2.5 cm air space + insulating board	2.44
iii)	0.625 cm AC sheet + air space + 5 cm fibre glass + 0.625 hard board	1.40
iv)	0.625 cm AC sheet + air space + 5 cm sandwich of fibreboard/ expanded polystyrene	0.65
v)	0.625 cm AC sheet + air space + 2.5 cm sandwich of fibreboard/ expanded polystyrene	1.22
vi)	0.3 cm GI sheet	6.16
vii)	2.5 cm tile + 2.5 cm bamboo reinforcement	3.56
viii)	5 cm tile + 2.5 cm bamboo reinforcement	3.20
ix)	2.5 cm thatch roof + 2.5 cm bamboo reinforcement	2.38
x)	5 cm thatch roof + 2.5 cm bamboo reinforcement	1.69
xi)	Mangalore tiles on wooden rafters	4.07

roof tiles, and these can be sprayed on existing roofs.

2) *Broken china mosaic terracing* — Properly sized broken pieces of glossy glazed tiles may be used as a cost effective cool roofing option.

3) *Cool colours* — Cool colour roofing materials are created by integrating pigments that reflect infrared energy, even though their colour may still absorb some of the visible spectrum. In this way, roofing products can be dark coloured and still be cool.

4) *Traditional methods* — Lime wash also renders similar property but has limited life and has to be reapplied.

Issues of excessive glare do arise with white roof coatings.

Table 4 Thermal Properties of Building and Insulating Materials at Mean Temperature of 50°C

(*Clause* 8.1.2.1)

Sl No. (1)	Type of Material (2)	Density kg/m^3 (3)	Thermal Conductivity W/mK (4)	Specific Heat Capacity kJ/kgK (5)
i)	Building materials:			
1)	Burnt brick	1 820	0.811	0.88
2)	Mud brick	1 731	0.750	0.88
3)	Dense concrete	2 410	1.74	0.88
4)	RCC	2 288	1.58	0.88
5)	Limestone	2 420	1.80	0.84
6)	Stale	2 750	1.72	0.84
7)	Reinforced brick	1 920	1.10	0.84
8)	Brick tile	1 892	0.798	0.88
9)	Lime concrete	1 646	0.730	0.88
10)	Mud *phuska*	1 622	0.519	0.88
11)	Cement mortar	1 648	0.719	0.92
12)	Cement plaster	1 762	0.721	0.84
13)	Cinder concrete	1 406	0.686	0.84
14)	Foam slag concrete	1 320	0.285	0.88
15)	Gypsum plaster	1 120	0.512	0.96
16)	Cellular concrete	704	0.188	1.05
17)	AC sheet	1 520	0.245	0.84
18)	GI sheet	7 520	61.06	0.50
19)	Timber	480	0.072	1.68
20)	Timber	720	0.144	1.68
21)	Plywood	640	0.174	1.76
22)	Glass	2 350	0.814	0.88
23)	Alluvial clay (40 percent sands)	1 958	1.211	0.84
24)	Sand	2 240	1.74	0.84
25)	Black cotton clay (Madras)	1 899	0.735	0.88
26)	Black cotton clay (Indore)	1 683	0.606	0.88
27)	Tar felt (2.3 kg/m^2)		0.479	0.88
28)	AAC block of 200 mm	749.6	0.089	1.0
29)	Fly ash clay brick	1 240	0.44	
30)	Sand lime brick	1 820	0.90	
31)	Vermiculite tiles	1 254	0.432	
32)	Perlite concrete	1 000	0.261	
33)	Expanded polystyrene concrete	932	0.231	

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Table 4 — (*Concluded*)

(1)	(2)	(3)	(4)	(5)
ii)	Insulating materials:			
1)	Expanded polystyrene	16.0	0.038	1.34
2)	Expanded polystyrene	24.0	0.035	1.34
3)	Expanded polystyrene	34.0	0.035	1.34
4)	Foam glass	127.0	0.056	0.75
5)	Foam glass	160.0	0.055	0.75
6)	Foam concrete	320.0	0.070	0.92
7)	Foam concrete	400.0	0.084	0.92
8)	Foam concrete	704.0	0.149	0.92
9)	Cork slab	164.0	0.043	0.96
10)	Cork slab	192.0	0.044	0.96
11)	Cork slab	304.0	0.055	0.96
12)	Rock wool (unbonded)	92.0	0.047	0.84
13)	Rock wool (unbonded)	150.0	0.043	0.84
14)	Mineral wool (unbonded)	73.5	0.030	0.92
15)	Glass wool (unbonded)	69.0	0.043	0.92
16)	Glass wool (unbonded)	189.0	0.040	0.92
17)	Resin bonded mineral wool	48.0	0.042	1.00
18)	Resin bonded mineral wool	64.0	0.038	1.00
19)	Resin bonded mineral wool	99.0	0.036	1.00
20)	Resin bonded mineral wool	16.0	0.040	1.00
21)	Resin bonded mineral wool	24.0	0.036	1.00
22)	Exfoliated vermiculite (loose)	264.0	0.069	0.88
23)	Asbestos mill board	1 397.0	0.249	0.84
24)	Hard board	979.0	0.279	1.42
25)	Straw board	310.0	0.057	1.30
26)	Soft board	320.0	0.066	1.30
27)	Soft board	249.0	0.047	1.30
28)	Wall board	262.0	0.047	1.26
29)	Chip board	432.0	0.067	1.26
30)	Chip board (perforated)	352.0	0.066	1.26
31)	Particle board	750.0	0.098	1.30
32)	Coconut pith insulation board	520.0	0.060	1.09
33)	Jute fibre	329.0	0.067	1.09
34)	Wood wool board (bonded with cement)	398.0	0.081	1.13
35)	Wood wool board (bonded with cement)	674.0	0.108	1.13
36)	Coir board	97.0	0.038	1.00
37)	Saw dust	188.0	0.051	1.00
38)	Rice husk	120.0	0.051	1.00
39)	Jute felt	291.0	0.042	0.88
40)	Asbestos fibre (loose)	640.0	0.060	0.84
41)	Closed cell flexible elastomeric foam - NBR	40-55	0.043	1.20

8.1.2.2 *Green roof system*

Green roofs have the potential to improve the thermal performance of a roofing system through shading, insulation, evapotranspiration and thermal mass, thus reducing energy demand of building for space conditioning. The green roof moderates the heat flow through the roofing system and helps in reducing the temperature fluctuations due to changing outside environment. If widely used, green roofs can reduce the problem of heat island effect which in turn reduces the energy consumption in urban areas. Green roof systems comprise a lightweight growing medium, plants and a root repellent layer in addition to the regular components of a roof. The additional components and thickness of the growing medium provides thermal insulation, while the green cover lowers ambient temperatures through evapotranspiration. Issues related to dead weight and water proofing should be considered while designing roof. There are three types of green roofs, as follows:

a) *Intensive green roof* — It is like a conventional garden or park with almost no limit on the type of available plants including trees and shrubs.

b) *Extensive green roof* — It is designed for little maintenance or human intervention once it is established.

c) *Modular block green roof* — It is designed in modular units which interlock and each module contains drainage systems and plants.

Use of photovoltaic panels for renewable energy (*see* **8.3.2**) can also be advantageously used for their effect on shading of roof top.

8.1.3 *Fenestration*

8.1.3.1 Of all the elements of building envelope, windows and glazed areas are most vulnerable to heat gains. Windows are required to bring inside natural daylight and wind, however, with light it also bring in heat. Proper location, sizing and detailing of windows

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and shading form is therefore a very important aspect in a solar passive building design. Primary factors/ components of a window which have significant impact on energy and cost of the building are window size and placement, glazing, frame, shading (external and internal), and screens or *Jalis*.

8.1.3.1.1 *Window size and placement*

The following may be taken into consideration:

a) *Height of window head* — The higher the window head or lintel, the deeper the penetration of daylight.

b) *Sill height (height from floor to the bottom of the window)* — The optimum sill for good illumination as well for good ventilation should be between the workspace and head level of a person. For carrying out any task, the suitable work plane levels shall be in accordance with **4.1.3.3** of Part 8 'Building Service, Section 1 Lighting and Natural Ventilation' of the Code. Strip windows provide more uniform daylight. Punched windows should be paired with work areas to avoid creating contrasts of light and dark areas. Windows close to task areas should be with optimum visual transmission without glare with good insulation performance as they may be source of thermal discomfort. Small horizontal openings close to the floors and the ceiling are extremely effective in reducing the window area to reduce heat ingress and provide adequate daylight levels in the space. In case of larger windows, glazing selection and shading effectiveness are quite important to control glare and heat gain.

c) *Use of separate apertures for view and daylight* — For good day lighting and glare control, window should have clear glass with a partition for maximum daylight penetration and tinted glass below the clear glass for glare control. The structure in between the two provides a visual break and an opportunity to attach light shelf or shading device.

d) *Window wall ratio (WWR)* — Window to wall ratio is the net glazing area (window area minus mullions and frame or approximately 80 percent of opening) divided by gross exterior wall area. Gross wall area is the overall area of a wall including openings such as windows and doors, with measurement taken horizontally from outside surface to outside surface and measured vertically from top of the floor to the top of the roof (*see* Fig. 4).

NOTE — The above represents only one approach in the entire range of window to wall ratio. The issue is primarily of window to wall ratio, and not window to glazing ratio.

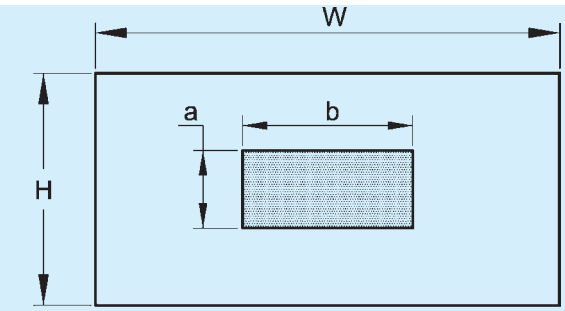


FIG. 4 WINDOW WALL-AREA

Screens make effective windows which reduce heat ingress and yet allow the air movement.

8.1.3.1.2 *Glazing*

The most commonly used glazing material in openings is glass, though recently polycarbonate sheets are being used for skylights. The primary properties of glazing that impact energy use in buildings are,

a) visible transmittance (affecting daylight),
b) visible reflectance (affecting heat and light reflection),
c) thermal transmittance or *U*-value (affecting conduction heat gains),
d) solar heat gain (affecting direct solar gain),
e) spectrum selectivity (affecting daylight and heat gain),
f) glazing material, and
g) glazing colour (affecting the thermal and visual properties of glazing systems).

Use of insulated glazing units (IGU) may be considered in appropriate cases. IGU are hermetically sealed, multiple pane assemblies consisting of two or more glazing layers held and bonded at their perimeter by a space bar typically containing a desiccant material. The glazing used in IGUs may be clear, tinted or coated or reflective. The spacer serves to separate the panes of glass and to provide a surface for primary and secondary sealant adhesion. As heat transfer at the edge of the IGU is greater than its centre, the choice of material for spacer is critical to the performance of IGU. The hermetically sealed space between glass panes may be filled with dry air or other alternatives such as argon and krypton.

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While selecting a glazing, attention should be given to the following:

1) Selecting between dual pane and single pane glazing.
2) Selecting a spectrally selective glazing (to keep off infra red and permit visible light).
3) Balancing the conflict between glare and light.
4) Trading off window size and glazing selection.
5) Dark or tinted glass may not necessarily provide good solar control.
6) Not depending on glazing alone to reduce heat gain and discomfort.
7) Selection of frame for glazing (*see* **8.1.3.1.3**).
8) Varying the selection and configuration of a glazed facade.

8.1.3.1.3 *Frame*

The type and quality of window frame affects air infiltration and heat gain/heat loss characteristics of windows. Window frames are usually made of aluminium, steel, wood, PVC, RCC, fibreglass or composites of these materials. Wood, fibreglass, RCC and vinyl frames are better insulators than metal. Some frames are designed with internal thermal breaks that reduce heat flow through the frame. These thermally broken frames can resist heat flow considerably better as compared to those without thermal breaks. The sealing between the openings and the window frames, and between the opening sashes of windows and fixed portions, are important as major heat loss happens from this area due to poor design of sealant material, and should be ensured. Adequate provision shall also be made to ensure that the frames are not susceptible to water ingress in case of driving rain.

For further details, reference may be made to **9.2.3.2**.

8.1.3.1.4 *Shading devices*

Direct sunlight can cause glare. Controls are therefore necessary to allow diffused natural light. Windows shading devices may be employed which help in keeping out the heat, block uncomfortable direct sun, and soften harsh daylight contrasts. Shading devices are also critical for visual and thermal comfort and for minimizing mechanical cooling loads. The three main ways of controlling direct sunlight are:

a) External shading and screens/*Jalis,*
b) Internal shading,
c) Use of solar control glass (spectrally selective), and
d) Horizontal/vertical or angled louvers.

8.1.3.2 *Design for windows in air conditioned and non air conditioned spaces/mixed mode ventilated spaces*

8.1.3.2.1 *Windows in air conditioned buildings*

Window (including both glazing and frame) affects the energy performance of an air conditioned space by impacting the HVAC energy consumption of the building and also the energy consumption for indoor lighting. Following are major types of energy flow which occur through a window impacting the HVAC energy consumption (*see also* Fig. 5):

a) *Non-solar heat losses and gains in the form of conduction, convection, and radiation* — The non-solar heat flow through a window occurs due to the temperature difference between the indoor and outdoor. Window loses heat to the outside during the winter season and gains heat from the outside during the summer season, adding to the heating/ cooling load in a building.
b) *Solar heat gains in the form of radiation* — The direct solar radiation entering into a conditioned space adds to the cooling load in summers and reduces heating load in winters in a building.
c) *Infiltration* — Infiltration is the unregulated exchange of air between indoors and outdoors through joints and cracks around window frame, sash and glazing. The air tightness of a window depends on both the characteristics of the window such as sash type and overall quality of window construction and the quality of the installation. These air exchanges can significantly influence indoor thermal comfort and consequent heating and cooling loads.

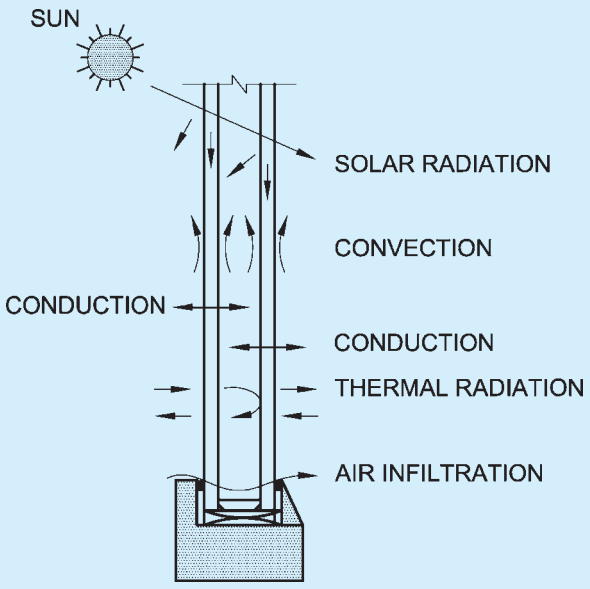


FIG. 5 TYPICAL FLOW OF SOLAR HEAT AND AIR INFILTRATION THROUGH A GLAZED WINDOW SECTION

Following are various parameters, related to the thermal performance of a window which should be considered to achieve energy efficiency in air conditioned building:

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1) *U-value of fenestration* — The *U*-value of a single pane window is mainly due to the thin films of still air on the interior and moving air on the external glazing surfaces. The glazing itself doesn't offer much resistance to heat flow. Double glazing units, help reduce the *U*-value by creating still air (insulated) spaces. In addition to the normal double glazed windows, other options aimed at decreasing *U*-values, such as low-emittance (low-E) coatings and gas fills, may also be available.

   A low-E coating is a microscopically thin, virtually invisible, metal or metallic oxide coating deposited on a glazing surface. The coating may be applied to one or more of the glazing surfaces facing an air space in a multiple-pane window. The coating limits radiative heat flow between panes by reflecting heat. In case of air filled panes, the air-gap between window panes can be filled with gases which have better thermal resistance property than air such as argon and krypton.

   For details regarding window frames and their thermal performance, reference may be made to **8.1.3.1.3**.

2) *Solar heat gain coefficient (SHGC) of fenestration* — Additional glazing layers provides more barriers to solar radiation, thus reducing the SHGC of a window. Tinted glazing, such as bronze and green, provide lower solar heat gain coefficients compared to the clear glass. Spectrally selective glazing, including some low-E coated glazing with low solar heat gain, block out part of the heat from the sun such as from infra-red radiations, while maintaining higher visible transmittances.

3) *Shading and adjusted SHGC* — Exterior or interior shading devices such as awnings, louvered screens, sunscreens, venetian blinds, roller shades, and drapes can complement and enhance the performance of windows with low SHGC. Many shading devices have an advantage that they can be adjusted to vary solar heat transmission with the time of day and season. Adjustable shades can also be integrated to permit some extra heat gain in the winter, if required.

   Exterior shading devices are more effective than interior devices in reducing solar heat gain because they block radiation before it passes through a window. Light-coloured shades are preferable to dark ones because they reflect more and absorb less, radiation.

4) *Projection factor (PF)* — The projection factor for horizontal overhang and vertical fins may be taken as follows:

   a) *For horizontal overhang* — Projection factor for overhang is calculated by measuring the depth of the overhang (*A*) and dividing that by the distance from the bottom of the window to the lowest point of the overhang (*B*) (*see* Fig. 6).

   b) SHGC for a window having an external shading device can be calculated by multiplying the SHGC value of the window with the *M* factor given in Table 5 for different projection factors for different orientations. The factor *M* is the relative reduction in the annual solar cooling load attributed to the overhangs and/or vertical fins for the given projection factor.

Table 5 *M* Factor for Different Projection Factors for Different Orientations

[*Clauses* 8.1.3.2.1(4)(b) *and* B-3]

Location	Orientation	Overhang *M* Factor for the Projection Factor				Vertical Fin *M* Factor for Projection Factor				Overhang + Vertical Fin *M* Factor for Projection Factors			
		0.25 to 0.49	0.50 to 0.74	0.75 to 0.99	More than 1.00	0.25 to 0.49	0.50 to 0.74	0.75 to 0.99	More than 1.00	0.25 to 0.49	0.50 to 0.74	0.75 to 0.99	More than 1.00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
15° North Latitude or greater	*N*	0.88	0.80	0.76	0.73	0.74	0.67	0.58	0.52	0.64	0.51	0.39	0.31
	E/W	0.79	0.65	0.56	0.50	0.80	0.72	0.65	0.60	0.60	0.39	0.24	0.16
	S	0.79	0.64	0.52	0.43	0.79	0.69	0.60	0.56	0.60	0.33	0.10	0.02
Less than 15° North Latitude	*N*	0.83	0.74	0.69	0.66	0.73	0.65	0.57	0.50	0.59	0.44	0.32	0.23
	E/W	0.80	0.67	0.59	0.53	0.80	0.72	0.63	0.58	0.61	0.41	0.26	0.16
	S	0.78	0.62	0.55	0.50	0.74	0.65	0.57	0.50	0.53	0.30	0.12	0.04

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c) *For vertical fins* — Projection factor for vertical fin is calculated by measuring depth of the vertical fin and dividing it by the distance from the window jamb to the farthest point of the external shading projection (*see* Fig. 7).

5) *Impact on lighting energy consumption* — During day time when natural light outside, is available in abundance, window can be utilized as a tool to harness natural light from Sun and sky to light the space. Buildings, in which artificial lighting is integrated with the day lighting, can reduce their energy consumption significantly. Good day lighting in a building depends upon the following factors:

a) *Window wall ratio (WWR) — See* **8.1.3.1.1**(d).

b) *Visible light transmittance (VLT) of glazing.*

c) *Day-lighting and window design* — Day lighting is utilization of light from the sun and sky to augment or replace electric light. Appropriate fenestration and lighting controls can be used to modulate daylight admittance and to reduce electric lighting, while meeting the occupants' visual comfort.

d) *Day-lit perimeter zone for vertical fenestration* — The day-lit zone associated to a window can be defined as an area having a depth which is twice the window height (measured from ground) and having the width which is equal to the window width plus 1.0 m on each of the vertical sides of window as indicated in the Fig. 8.

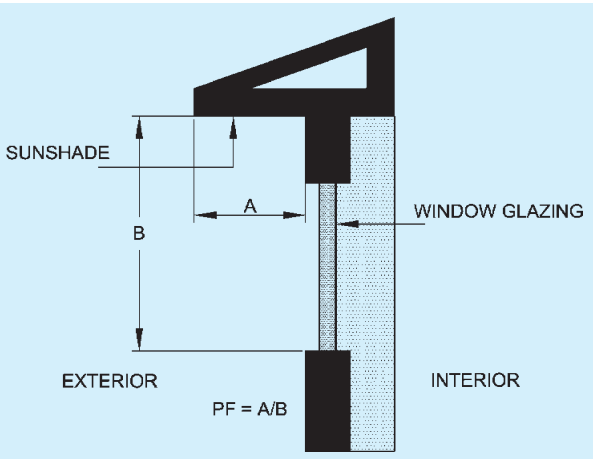


FIG. 6 PROJECTION FACTOR FOR HORIZONTAL OVERHANG FOR A TYPICAL WINDOW SECTION

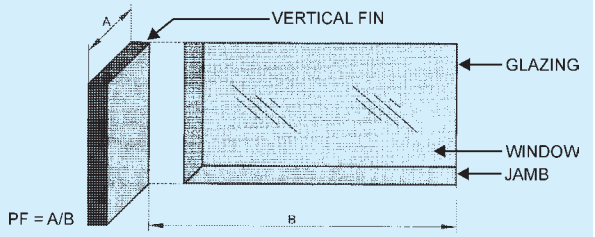
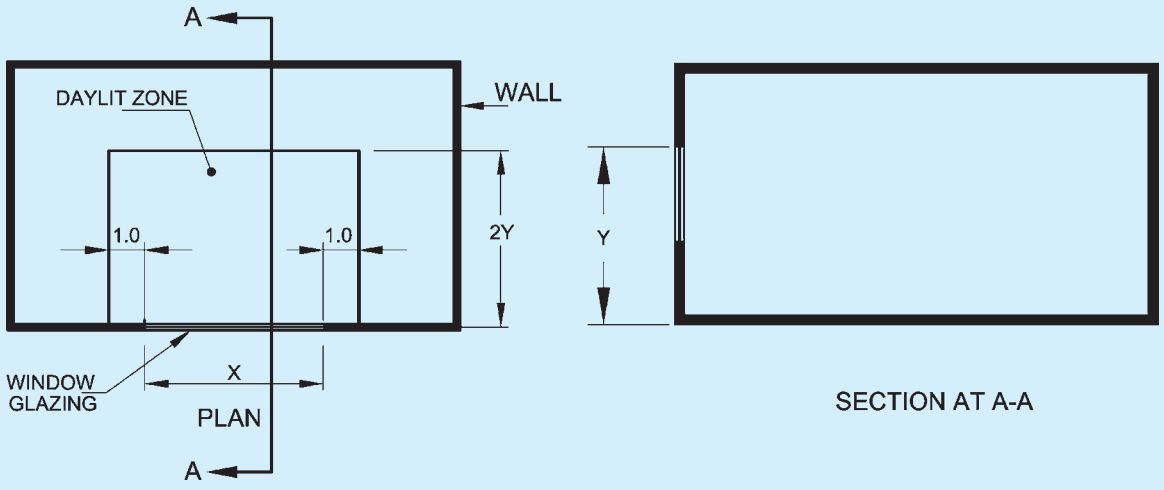


FIG. 7 PROJECTION FACTOR FOR VERTICAL FINS

The fenestration area, located above 1.0 m but below 2.2 m is considered as vision window area. The vision window area is usually provided with the glass with lower VLT in order to reduce glare.

The fenestration area located above 2.2 m is considered as daylight window area. Larger the daylight window



All dimensions in metre.

Dimension of day-lit perimeter: Depth (m) = 2 x *Y;* Width (m) = *X* + 1 + 1.

FIG. 8 DAY-LIT PERIMETER ZONE ASSOCIATED TO A WINDOW

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area more will be the daylight penetration into a space. The daylight window area is usually provided with glass with higher VLT so as to receive daylight to the greater depths of the space. The daylight window area can be designed in form of light shelves, as shown in Fig. 9, which enhance the penetration of daylight. The extent of natural light penetration into the room depends on the colour (reflectance) of the interior wall surfaces, the furnishing colour and partly the colour of the flooring.

The following should be determined and shall conform to the requirements of this Code:

i) *U*-value for a fenestration product (including the sash and frame).

ii) The SHGC for a fenestration product (including the sash and frame).

iii) Air leakage through fenestration, shall not exceed 2.0 litre /s.m^2.

iv) Window wall ratio on a facade, correlated to the visible light transmittance of the glazing which shall not exceed 60 percent.

NOTE — It may be noted that screens make effective windows which reduce heat ingress and yet permit natural ventilation.

8.1.3.2.2 *Window design guideline for non-conditioned/mixed mode buildings*

The following may be considered in selection of type of windows:

a) *Horizontal pivot windows* — These produce very effective ventilation because large open areas are created at a separation equivalent to the window height. Air will tend to enter at the lower level and exit *via* the top of the window. These are easily adjustable to provide control of the ventilation rate. These are often used in taller buildings, as both sides of glass can be cleaned from the inside of the building with ease. The main disadvantage of this type of window is that, when opened, the top of the sash interferes with the curtains.

b) *Vertical pivot windows* — These are less efficient than horizontal pivot windows because the open area is uniformly distributed throughout the height of the window rather than concentrated at the extremes; but these can work well in combinations. There is an advantage that these can be both opened and closed by pushing and are easy to clean from the inside. When fully open these offer a safe vertical barrier. The inward opening section may interfere with curtains when fully open.

c) *Casement windows* — These offer the same advantages as vertical pivot windows but are susceptible to gusts. The most commonly used are double sided hinged outward opening windows which have great versatility with respect to air flow control. Most casement windows are designed to open outwards, which poses a problem for installation of window air conditioners.

d) *Top/bottom hung windows* — These are less effective as ventilators than pivot windows as all the opening area is concentrated at one end, the top or bottom of the window.

e) *Sliding windows* — These have similar characteristics as horizontal or vertical pivot windows. Sliding windows are easy to open; these slide to the side instead of having to be pushed inside/outside. A good seal is important in reducing draughts and energy loss when closed. Cleaning the inside of slider windows is easy, but cleaning the outside may be difficult.

f) *Tilting top vents* — These provide smaller opening areas than the other systems as these occupy only a relatively small proportion of the window height. However, these can provide good draught-free ventilation, especially in cross-ventilation mode. The inward opening function of tilt and turn windows limit the available space.

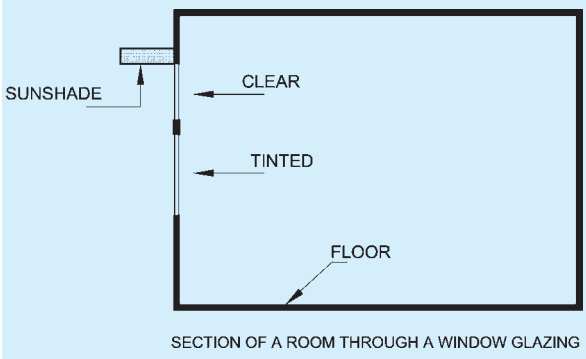


FIG. 9 ARRANGEMENT SHOWING VISION WINDOW AREA AND DAY LIGHT WINDOW AREA

The window may also be provided with fixed/sash/ sliding/roller insect screens to allow fresh air without the inlet of mosquitoes and other insects through openable windows.

As compared to air-conditioned spaces, the window design in non-conditioned/mixed mode buildings takes a different approach. The glazing system for windows in non-conditioned/mixed mode spaces is usually single pane/panel glazed units as the windows will be opened to allow ventilation. Thus there is less relevance to install double glazing units with low SHGC and *U*- values.

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However, in the non-conditioned/mixed mode buildings the shading device plays a crucial role in the thermal performance of a window. Windows on facades, for different orientations, should be provided by the shading devices which can cut the direct incident solar radiation for the critical solar angles.

In the non-conditioned buildings/mixed mode buildings, penetration of direct solar radiation needs to be regulated. The critical Horizontal Solar Angle (HSA) and Vertical Solar Angle (VSA) (*see* Fig.1) for fenestrations located on the cardinal directions should be regulated by designing appropriate shading devices. The horizontal solar angle at critical hours can be regulated by the vertical fins provided as external shading devices. The vertical solar angle at critical hours can be regulated by the horizontal fins provided as external shading devices.

The maximum permissible WWR on a facade should not exceed 60 percent. Window opening requirements for naturally ventilated low rise residential and office buildings include the following:

a) In order to allow outside air to enter the space, window openings should be oriented appropriately to optimize heat and solar heat gain.
b) In order to facilitate cross ventilation, location of window openings should be located opposite to each other on walls parallel to each other.
c) In order to achieve the required air change per hour in a given space, cross ventilation and stack ventilation mode of natural ventilation should be adopted.

The external shading devices can be designed in various ways to stop the solar radiation entering through the window. Figure 10 shows the commonly used shading devices.

Example to design shading device for a window

Design of shading device for a window of height 1.5 m and width 3.0 m to cut the HSA of 45° and VSA of 60°should be as follows:

a) *Design of shading device to cut the* VSA — The vertical solar angle of 60° can be cut by providing a single horizontal overhang of length 867 mm or it can be cut by providing two horizontal projections 60 mm thick each of length 415 mm placed at a distance of 720 mm as shown in Fig.11.

   The length and spacing can be calculated either by the drafting softwares by graphical method or by manually calculating using the following formula:

   Depth of shading device
   = Spacing between the shading device × tan (90° – VSA)

   For a given VSA, either of the values for depth or spacing between shading overhangs can be selected to get the value of the other.

b) *Design of shading device to cut the HAS* — The horizontal solar angle of 45° can be cut by providing a single vertical fin of length 3 000 mm or it can be cut by providing four vertical fins 60 mm thick each of length 705 mm placed at a distance of 705 mm as shown in Figure 12.

The length and spacing can be calculated either by the drafting softwares by graphical method or by manually calculating using the formula:

Depth of vertical fins = Spacing between the vertical fins × tan (90° – HSA)

For a given HSA either of the values for depth or spacing between vertical fins can be selected to get the value of the other.

It is desirable to break single overhang with larger depth into multiple overhangs of smaller length. It enhances the amount of (diffused) daylight penetration in the space. Figure 13 shows the comparison between amount of daylight penetration for two shading devices, one with single deep overhang and the other with multiple smaller overhangs. Another alternative is use of screens which make effective window/opening protection by reducing heat ingress and yet permitting air movement.

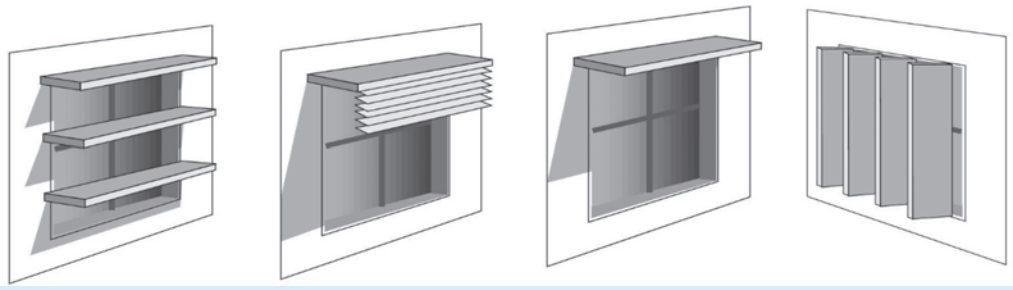
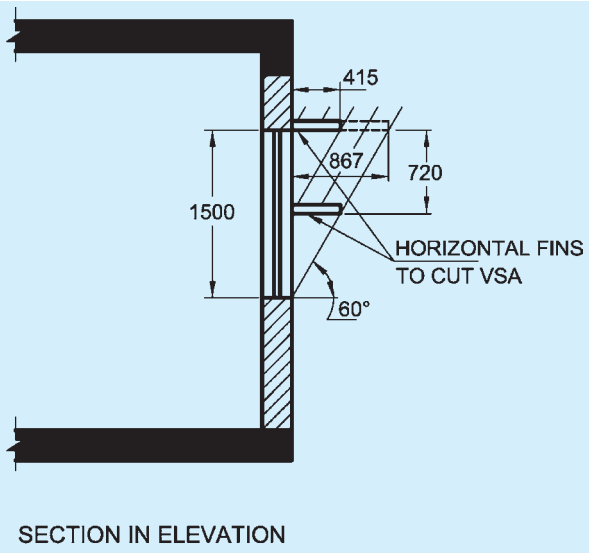


FIG. 10 COMMONLY USED SHADING DEVICES

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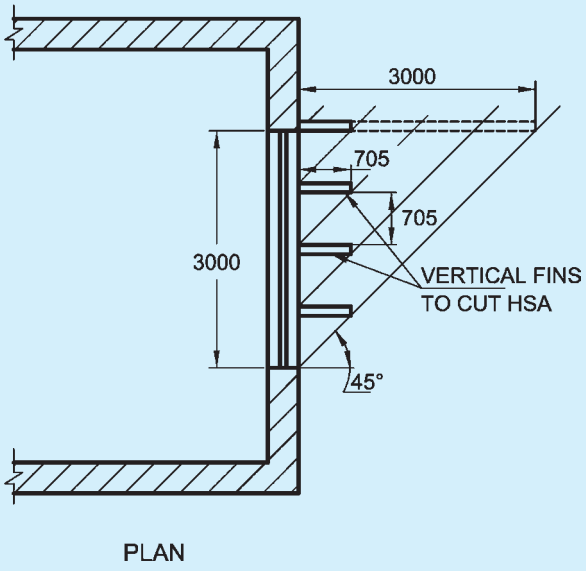


All dimensions in millimetres.

FIG. 11 DESIGN OF SHADING DEVICE TO CUT VSA

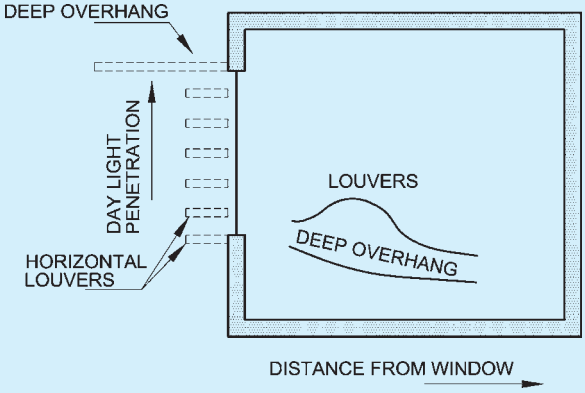
Window design for natural ventilation — Windows are required to provide natural cooling through ventilation. Optimized window design helps to achieve thermal comfort with no additional energy and/or financial investment. Optimized window design helps to reduce dependence on air conditioning where natural ventilation is possible and helps in reducing discomfort in naturally ventilated spaces. Following are the general guidelines for achieving effective natural ventilation:

1) Natural ventilated buildings should take advantage of the predominant wind originating from east and west directions to maximize cross ventilation. Stack ventilation can be enhanced by providing openings on the opposite side of the wall, where the inlet opening should be located at the bottom most part of the wall and outlet openings should be on the topmost part of the opposite wall in order to increase the height difference between the two (*see* Fig. 14).
2) Naturally ventilated buildings should have a narrow room width; and it is difficult to naturally ventilate buildings with room depth more than 15m.
3) For total area of openings (inlet and outlet) of 20 to 30 percent of floor area, the average indoor wind velocity that may be achieved is around 30 percent of outdoor wind velocity. Even on increasing the size of window further, the maximum indoor wind velocity does not exceed 40 percent of outside wind velocity.
4) To enhance physiological comfort through natural ventilation, the bottom side of the opening may be kept at 85 percent of the height of the room taken from ceiling or as per Table 6 for the corresponding occupant activity.



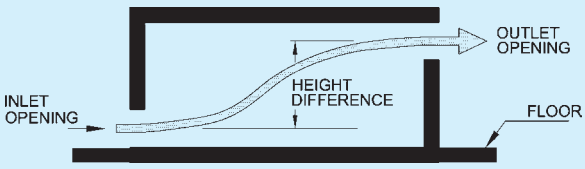
All dimensions in millimetres.

FIG. 12 DESIGN OF SHADING DEVICE TO CUT HSA



Section in Elevation

FIG. 13 COMPARISON OF DAYLIGHT PENETRATION WITH USE OF TWO SHADING DEVICES NAMELY DEEP OVERHANGS AND LOUVERS



Room Section

FIG. 14 ARRANGEMENT OF OPENINGS IN WALLS FOR ENHANCED VENTILATION

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Table 6 Critical Height Requirement for Physiological Cooling

[*Clause* 8.1.3.2.2(d)]

Sl No.	Pattern of Activities	Recommended Height of the Bottom Side of Opening
		m
(1)	(2)	(3)
i)	Sitting on chair	0.75
ii)	Sitting on bed	0.60
iii)	Sitting on floor	0.40

5) Clerestory or vented skylight provides an opening for vitiated air to escape through natural buoyant ventilation. The light well of the skylight may also act as a solar chimney to augment natural buoyant flows.

6) Openings in lower part of the structure, such as basement windows, should be provided to complete the ventilation system.

8.2 Envelope Optimization Methods for Energy Efficiency

Envelope optimization methods are important tools for optimizing the design of building envelope from energy efficiency point of view. Any of the following envelope optimization methods may be employed to achieve the objective:

a) *Prescriptive method* — This method specifies a set of prescriptive requirements for building systems and components. Compliance with these requirements can be achieved by meeting or exceeding the specific levels described for each individual element of the building systems. Envelope optimization using this method shall be carried out in accordance with Annex B.

b) *Trade-off method* — This is a systems-based approach, where the thermal performance of individual envelope components can be reduced, if compensated by higher efficiency in other building components (for example, using higher wall insulation could allow for a less stringent *U*-value requirement for windows, or *vice-versa*). These trade-offs typically occur within major building systems – roofs, walls, fenestrations, overhangs, etc. This method offers the designer more flexibility than strictly following the prescribed values for individual elements. The thermal performance of one envelope component such as the roof can fail to meet the prescriptive requirements as long as other components perform better than what is required to make necessary compensation. Trade-offs are permitted only between building envelope components. It is not permitted, for instance, to make trade-offs against improvements in the lighting or HVAC systems. However, this method makes using the envelope trade-off option more complicated than the prescriptive method. It is necessary to calculate the surface area of each exterior and semi-exterior surface; all areas are required to be calculated separately for each orientation. Envelope optimization using this method shall be carried out in accordance with Annex C.

c) *Whole building analysis method* — This method models the thermal, lighting, ventilation occupancy, and other energy-consuming processes taking place within the building to simulate and predict its energy performance. The simulation programme takes into account the building geometry and orientation, building materials, building facade design and characteristics, climate, indoor environmental conditions, occupant activities and schedules, HVAC and lighting system and other parameters to analyse and predict the energy performance of the building. This may be done using computer simulation models, which can be accomplished with a variety of proven software tools and in many cases may be the best method for guiding a building project to be energy-efficient. However, this approach does require considerable knowledge of building physics and building simulation tools and very close communication between members of the design team. Envelope optimization using this method shall be carried out in accordance with Annex D.

8.3 Renewable Energy Integration in Envelope

8.3.1 *Integration of Solar Thermal Technologies*

Solar collectors that harness the solar energy directly into usable heat can be aesthetically integrated with the building envelope or they may be mounted on the roof of building.

8.3.2 *Integration of Photovoltaic Technologies*

Building integrated photovoltaic (BIPV) system is the integration of photovoltaic (PV) and the building envelope. The PV modules can be designed and installed to serve the double purpose of both power generation and that of the building skin replacing conventional building envelope materials. By avoiding the cost of conventional materials, the incremental cost of photovoltaic is reduced and its life cycle cost is lower.

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A complete BIPV system includes the following:

a) PV modules (which may be thin-film poly or mono crystalline, amorphous with transparent, semi-transparent, or opaque backing);
b) Charge controller, to regulate the power into and out of the battery storage bank (in stand-alone systems);
c) Power storage system, generally comprising utility grid in utility-interactive systems or, a number of batteries in stand-alone systems;
d) Power conversion equipment including an inverter to convert the d.c. output of PV modules to a.c. compatible with the utility grid;
e) Backup power supplies such as diesel generators (optional), typically employed in stand-alone systems; and
f) Appropriate support and mounting hardware, wiring, and safety disconnects.

While photovoltaic panels as in (a) are considered as PV array, other components given in (b) to (f) are usually referred to as the balance of system (BoS). Not only solar photovoltaic technologies but other ways of producing renewable energy may also be integrated in to design, depending upon suitability to geo-morphological conditions, geo-thermal pumps, wind, etc.

9 MATERIALS

9.1 General

Building materials choices are important in sustainable design because of the extensive network of activities such as extraction, processing and transportation steps required for making a material, and activities involved thereafter till building construction and even thereafter. These activities may pollute the air, soil and water, as well as destroy natural habitats and deplete natural resources.

One of the most effective strategies for minimizing the environmental impacts of material usage is to reuse existing buildings. Rehabilitation of existing building, their shell and non-shell components, not only reduces the volume of solid waste generated and its subsequent diversion to landfills but also the environmental impacts associated with the production, delivery and use or installation of new building materials.

The use of rapidly renewable materials, recycled materials minimises the adverse impact of natural resource consumption in the manufacture of new building materials. The use of local materials supports the local economy and reduces the negative impact of transportation.

9.1.1 *Environmental Concerns and Human Health and Safety Aspects Related to Building Materials*

Increased demand for building materials creates a major and diversified impact on the environment. Excessive extraction of raw material diminishes non-renewable natural resources very rapidly. Even during some extraction process, waste is generated whose disposal may pose problems. Sometimes extraction processes may also affect the wildlife. Transportation of building materials from one place to another is also a major indirect factor leading to harmful effects. During manufacturing or processing of some materials like plastic, harmful gases are generated, which are dangerous for human health and environment. There are many frequently used building materials like reconstituted wood products, paints, glues, carpet and upholstery, which may release gases, fumes, etc, from the chemical components used, even long after the installation. These volatile organic compounds (VOCs) affect the environment and human health and may cause headaches, dizziness, respiratory problems and even major diseases in human and other living beings.

9.1.2 *Minimizing Green House Gas (GHG) Emission*

Construction sector in the country is a major consumer of energy resulting in the largest share of CO_2 emissions in the atmosphere. Cement, steel and bricks, the largest and bulk consumption items in the construction industry, are contributors of large CO_2 emissions. It is estimated that close to a tonne of CO_2 is emitted during the production of every tonne of cement, resulting in very high GHG emission. Similarly, bricks and concrete, which are very widely used construction material have very high GHG emission. Minimizing the consumption of such conventional materials which may contribute to substantial GHG emission, by using alternative materials and alternative methods and techniques can considerably reduce energy and CO_2 emissions.

9.1.3 *Building Material*

An ideal sustainable building material is not only environment friendly, causes no adverse impact on health of occupants, is readily available, can be reclaimed, can be recycled and is made from renewable raw material, but also uses predominantly renewable energy in its extraction, production, transportation, fixing and ultimate disposal. Practically, this kind of ideal material may not be available, hence when selecting sustainable materials, it may be best to choose materials which fulfill most of these criteria.

9.1.4 *Life Cycle Assessment (LCA) of Building Materials*

LCA of building materials intends to assess the potential environmental impacts at every stage in the life cycle

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of a material (*see* Fig. 15) right from the raw material sourcing, processing, manufacturing and finishing, up to the product installation, maintenance and ultimately reuse/recycle/demolition. It is a tool to determine the environmental suitability of any building material for a thorough understanding of the environmental impact and the improvement which can be employed at every stage of a material, so as to make a decision for its selection after evaluation of criteria such as embodied energy, performance and durability.

A description of life cycle analysis with respect to various relevant criteria is given below:

a) *Embodied energy* — It is an important factor to be considered in the life cycle assessment of a material. Minimizing embodied energy means minimizing the impact on the environment. In any building construction use of materials with low embodied energy should be considered.

   Table 7 gives classification of building materials based on their energy intensity and gives the comparative embodied energy for a few building materials.

b) *Resource reuse and upgradation* — It includes saving a material from disposal and utilizing it by renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product. Efforts should be made to reuse existing, previously occupied buildings – including the structure, envelope and elements, after removing or replacing the elements which have risk of failure/contamination during construction or occupancy. Upgradation of systems should be done in the areas of energy and water efficiency where the previously installed systems are not environment friendly or efficient.

c) *Recycled content* — To reduce the demand for virgin materials, effort should be made to use the products with identifiable recycled content, including from those coming from industrial and post-consumer utilization, with a preference for the later.

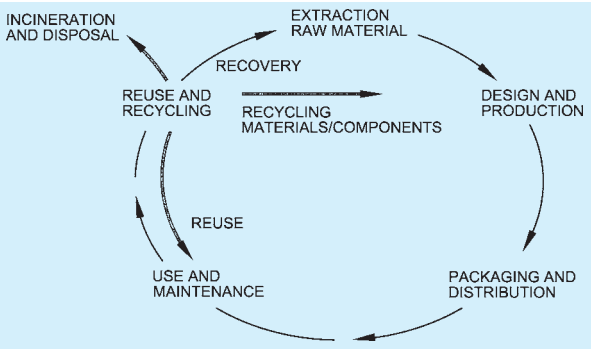


FIG. 15 LIFE CYCLE OF BUILDING MATERIALS

Table 7 Classification of Materials Based on Energy Intensity

[*Clause* 9.1.4 (a)]

Sl No.	Category of Material	Energy Intensity (Range) GJ/t	Examples
(1)	(2)	(3)	(4)
i)	Very high energy	>50	Aluminium, stainless steel, plastic, copper, zinc
ii)	High energy	5-50	Cement, steel, glass, bitumen, solvents, cardboard, paper and lead
iii)	Medium energy	1-5	Lime, gypsum plaster board, burnt clay brick, burnt clay brick from improved vertical shaft kiln, aerated block, hollow concrete block, gypsum plaster, concrete block, timber, wood products, particle board, medium density fibre board, cellulose insulation, *in-situ* concrete
iv)	Low energy	<1	Sand, aggregate, fly ash and fly ash based products, cement stabilized soil block, straw bale, bamboo, stone

NOTES

1 While comparing embodied energy of building materials, the total quantity by mass of the material times the embodied energy value per unit mass (energy intensity) of the material to be installed for same surface area of the building may be compared.

2 The values given in the table are comparative values, and in case of substantial difference in the transportation component of the materials in question, the same should also be taken into account while calculating the embodied energy.

d) *Reusable or recyclable* — Effort should be made to select materials that can be easily dismantled and reused or recycled at the end of their useful life. Consider installation techniques which allow easy dismantling and reuse of materials.

e) *Natural, plentiful* — Effort should be made to use materials which are bio-based and naturally harvested from sustainably managed sources.

f) *Bio-degradable* — Consider using materials which are bio-degradable so that they can be harmlessly disposed at the end of their life cycle.

g) *Indigenous or locally available* — Effort should be made to use building materials, components, and systems which are found locally or regionally, saving energy and resources for transportation of materials to the project site.

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h) *Rapidly renewable material* — Effort should be made to use materials which replenish substantially faster than traditional extraction demand (for example, timber which can be planted and harvested in less than a 10 year cycle) to reduce the demand for limited/finite resources.

j) *Materials compliant with clean air and clean water* — Effort should be made to select those materials that emit few or no carcinogens, reproductive toxicants, VOCs, etc. Such materials that enhance the indoor environment quality and consume less water, do not cause water contamination, pollution as well as help in reducing water consumption should be considered for use.

k) *Materials having low ozone depletion potential* — Efforts should be made to select materials which do not use in their manufacture, chemicals that have an ozone depleting potential (ODP).

9.2 Materials and Recommended Sustainable Alternatives

For quality requirements of building materials reference shall be made to National Building Code of India: Part 5 'Building Materials' of the Code. General guidelines and considerations for use of different structural and surface finishing materials and with alternatives for helping in sustainable construction, are given under **9.2.1** and **9.2.2**.

9.2.1 *Structural Materials*

9.2.1.1 *Cement concrete*

Concrete is a strong, durable material and provides good thermal mass to buildings. However, manufacture of cement used in it is a high energy-intensive process and source of pollution, requiring also high energy for its transportation due to centralized production. Extraction and mining of aggregates also result in natural habitat destruction or deforestations. Following are the recommended alternatives to conventional concrete:

a) *Use of pozzolanas and other mineral admixtures for cement replacement in cement concrete and other cement matrix products*:

1) *Use of fly ash and slag in cement concrete* — Pozzolanas like fly ash or ground slag may be used to replace certain percentage of ordinary Portland cement in cement concrete in accordance with the good practice [11(3)] or cement manufactured by using mineral admixtures like fly ash or ground slag may be used, in accordance with the good practice [11(3)].

2) *Rice husk ash (RHA)* — Rice husk ash, a waste from rice industry, is pozzolanic in nature and may be used for part replacement of cement in accordance with the good practice [11(3)].

3) *Ready mixed concrete (RMC)* — RMC provides opportunity for use of pozzolanas and slag in greater quantities while maintaining strict quality control. Also, there are advantages of RMC over conventional concrete such as reduction noise and dust pollution, apart from better quality control. Preference may be given to use of RMC, if the RMC manufacturing plant is nearby. The manufacture, quality control delivery, etc of RMC shall be done in accordance with the good practice [11(4)].

4) *Geopolymer concrete* — It is made with fly ash, ground granulated blast furnace slag (GGBS), fine aggregates and coarse aggregates and catalytic liquid system (CLS). This concrete uses no Portland cement and utilizes waste products. It has good resistance to chloride penetration and acid attack. However, geopolymer concrete is a future sustainable material option as it is in development stage. It could be designed and developed for a specific use in a project for which specialist literature may be referred.

5) *Other cement concrete mix and products/ cement matrix products/lime-pozzolana mixtures* — Various cement concrete mix and products, other cement matrix products, lime-pozzolana mixtures, etc, used in buildings having waste based/by-product mineral admixtures such as fly ash and slag may be produced or used. The requirements of such products and for their utilization shall be in accordance with accepted standards and good practice [11(5)] which also includes list of accepted standards for mineral admixtures for use in such products as may be applicable.

b) *Use of recycled aggregate* — Crushed concrete aggregate is most common form of recycled aggregate which should be considered for use in concrete. The recycled concrete aggregate should be intended to offer the same level of strength and durability as conventional aggregate from natural

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resources. In the concrete mix, both virgin aggregate from natural resources and recycled aggregate may be mixed with hydrated cement paste. Such mix may have reduced specific gravity and increased porosity compared to concrete using similar virgin aggregate from natural sources. It is recommended that recycled aggregate be batched in a pre-wetted and close-to-saturated surface dry condition. Recycled aggregate may be used in concrete for bulk fills, bank protection, base/fills of drainage structures, pavements, sidewalks, kerbs and gutters, etc. Up to 30 percent of natural crushed coarse aggregates can be replaced by the coarse recycled concrete aggregate, in fresh concrete. This percentage can be increased up to 50 percent for pavements and other areas which are under pure compression. Also refer good practices [11(3)]. For quality requirements for other/ artificial aggregates such as cinder as fine aggregate in lime, broken burnt clay bricks as coarse and fine aggregates, artificial light weight aggregates, etc, reference may be made to the accepted standards [11(6)].

c) *Precast/prefabricated/partially prefabricated concrete elements* — Precast concrete can be used in construction in the form of building elements which are assembled at site and made monolithic by pouring *in-situ* concrete. The products are manufactured by casting concrete in a reusable mould or form which is then cured in a controlled environment, transported to the construction site, and erected at place. Precast concrete elements break the structural elements into smaller segments resulting in ease and economy in construction. Precast concrete roofing techniques like plank and joist roofing system, ferrocement roofing channels, precast arch panels, precast waffle units, L-panels are among roofing systems which may have comparatively less embodied energy than conventional RCC roof.

d) *Use of light weight concrete:*

   1) *Preformed foam concrete* — Preformed foam concrete may be considered for use for the levelling of floors, sprayed onto horizontal surfaces or in hollow cavities as light weight filler.

   2) *Ferrocement* — Ferrocement is a thin cement mortar laid over wire mesh (which acts as reinforcement). It uses minimal material (particularly steel) which is reduced compared to conventional RCC.

e) *Use of light weight aggregates in concrete* — These are usually used in masonry blocks, slabs or floor beam units which are relatively strong. Light weight blocks help to reduce structural loading of building. These may be foamed blast furnace slag, bloated clay aggregate, sintered fly ash aggregate, cinder aggregate, etc. Mineral insulating aggregate in concrete like light expanded clay, pumice and expanded perlite have the lower moisture absorption coefficient, and are therefore best suited to products used for insulation. Fossil meal and exfoliated vermiculite, perlite or slag due to very high moisture absorption coefficient is preferred for high temperature equipment insulation. If artificial lightweight aggregate is used for making lightweight concrete, the same shall be in accordance with the accepted standard [11(7)].

f) *Commonly used masonry concrete blocks*:

   1) *Solid and hollow concrete blocks* — Hollow concrete block masonry uses lesser concrete as compared to solid concrete blocks and provides better thermal insulation due to cavity. Filling of the cores with concrete or concrete with steel reinforcement offers much greater tensile and lateral strength to structures, wherever required.

   2) *Autoclaved cellular (aerated) concrete blocks* — These are made by mixing fly-ash, lime, cement and gypsum, with foaming agent like aluminium powder which gives them the lightweight and good insulation property. These are lightweight blocks which can be useful to reduce dead load on structure, particularly of high rise buildings.

   3) *Lightweight concrete blocks* — These blocks are lightweight and manufactured like normal concrete blocks using light weight aggregates.

   4) *Preformed foam cellular concrete blocks* — These have considerably better thermal insulation properties than normal bricks or concrete.

   5) *Concrete stone masonry blocks* — Precast concrete stone block masonry which uses recycled stone is a viable option. It can be made with waste stone pieces which could be locally available, and lean cement concrete.

The design mix of concrete blocks can also be done using fly ash as replacement of certain percentage of cement by volume. The concrete blocks shall be in accordance with the

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accepted standards [11(8)] and masonry construction using these blocks shall be in accordance with good practice [11(9)].

9.2.1.2 *Burnt clay bricks and tiles*

Bricks are made of clay which is abundant and generally sourced locally. They are durable and provide thermal mass to buildings. They are used for applications such as wall masonry, cladding, flooring and roof tiling. In many cases bricks can improve the indoor climate by regulating and stabilizing moisture levels.

Clay building waste being inert, its disposal has no detrimental effects on the environment. Exceptions are coloured and pigmented brick and ceramic tiles containing heavy metals, fire proof bricks containing soluble chrome and bricks from chimneys which have absorbed large amount of aromatic hydrocarbons during their life span. These products have to be separated and disposed of by following special precautions.

The burnt clay products have high durability, and these have high potential for their reuse as the energy needed to remove and clean up old material only represents approximately 0.5 percent of the energy required for the manufacture of new bricks and tiles. However, the recovery for reuse of bricks is facilitated, if a weak or medium-strength mortar has been used. Ceramic tiles or expanded clay pellets cannot be recycled and have to be usually more down-graded for uses such as for use as fill. Clay tiles and bricks can be broken up and used as fill, and aggregate in concrete in accordance with the good practice [11(3)].

Brick and clay manufacturing is a medium to high energy intensive and polluting process depending on the firing temperatures and type of kilns used in firing. Preference should be given to locally manufactured bricks and tiles to reduce transportation energy. The vertical shaft brick kiln technology which substantially reduces both the embodied energy and resultant emissions from brick production may be used. The consumption of energy in the kilns can be reduced considerably by the use of bricks with different firing temperatures, in different parts of the building.

The following other types of bricks may also be used as sustainable alternatives:

1) *Hollow/perforated bricks* — These types of bricks save the amount of material used and provide better thermal insulation due to the presence of air cavities. These bricks when provided with reinforcements can be used for structural applications and also in the form of filler blocks to replace concrete in the tensile zone.
2) *Low and medium-fired bricks* — Clay bricks which are burnt between 350°C and 500°C are low-fired bricks, and bricks burnt at slightly higher temperature like 500°C to 800°C are medium-fired bricks. Low-fired bricks are highly absorbent and hence recommended for use in internal walls or inner layer of external cavity walls (where they act as a moisture regulator), etc. The medium-fired bricks although comparatively more durable, may be used in similar applications as above.
3) *Burnt clay flyash bricks* — They are lower in embodied energy, provide better thermal property as compared to conventional burnt clay bricks and also utilize flyash, an industrial waste product.
4) *Flyash lime bricks* — These are flyash based and use bricks lime as the binder, along with accelerator in required proportion. These have good thermal properties. These are mostly used as masonry units and as fillers in pre-fabricated floor slabs.
5) *Red mud burnt bricks* — Red mud is a waste product from aluminium extraction industry. It contains mainly oxides of aluminium, iron and titanium. Red mud and flyash partly replace clay in these bricks. The alumina content gives a nice red tone to the brick. They have high compressive strength and are suitable for all types of construction. The presence of 4 to 5 percent of alkali in red mud also results in better plasticity and better bonding in these bricks.
6) *Lato bricks* — These are strong bricks (south western region of India) made of laterite soil mixed with cement or lime, and are moulded under pressure instead of being fired.

For quality requirements of bricks, reference shall be made to Part 5 'Building Materials' of the Code.

9.2.1.3 *Traditional efficient building materials*

Each region in the country has developed unique ways of using locally available building material such as stone, timber, bamboo and soil. These building technologies have been developed over time, based on availability of natural materials, climatic considerations and culture. These techniques are not only environment friendly and energy efficient but are also cost effective as they involve the use of materials which are locally available reducing cost and energy on transportation.

9.2.1.3.1 *Earth construction*

Earthen buildings are easily recyclable, fire resistant, biodegradable, non-toxic, and have good thermal and sound absorption and moisture regulating properties.

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This type of construction can easily use onsite earth or locally available material depending on the quality of the earth available. Two main ways of making earthen buildings are ramming, where the earth is rammed between shuttering to make walls, and use of earth block (adobe), where the earth is first pressed into blocks and dried before use. Stabilizers such as cement or lime may be added to improve durability. Straw and sawdust act as reinforcement as well as increase the insulation value. Well mixed, homogeneous earth construction has structural properties. Various options/considerations in this area are:

a) *Adobe bricks* — These were made earlier with sand and clay mixed with a small proportion of water. Straw and/or grass are included as binder. Mixture is either poured into moulds or allowed to dry or it is pressed into blocks using hydraulic or lever press. Adobe can be made from wide range of soils but require plastering as they are not water-resistant. They have low structural strength but can be easily used for load bearing structures if, built between timber/concrete frames.

   Stabilized adobe block construction is a new improved system of construction in which stabilization is done by adding fibres (plant or animal fibres), binders (cement, lime, pozzolanas, etc) and sometimes water proofing agents (bitumen, natural and synthetic resins). This kind of construction is suitable for areas with higher rainfall, condensation, flooding, etc. Proportion of soil content in stabilized adobe blocks may be: coarse sand 40-75 percent; clay 10-25 percent; silt 15-25 percent; and fine gravel 0-10 percent.

b) *Adobe pouring construction* — In this system earth is compacted to an extent that the air gaps are eliminated, bulk density is considerably increased and the tendency of development of cracks and to absorb water is reduced. Adhesion of soil particles with one another increases the mechanical strength and improved water resistant, requiring no surface treatment. The ratio of wall thickness to the wall height should be between 1 : 8 and 1 : 12. Symmetrical and geometrical forms are preferred in use of this material.

c) *Compressed earth blocks (CEB)* — In this type of construction, blocks are manufactured by compacting raw earth using stabilizer such as cement or lime. Compressed earth blocks are generally cuboidal in shape and can be made in solid, hollow or interlocked pattern. Thickness to height ratio of walls constructed with CEB should not be greater than 1:16 and wall thickness not less than 200 mm. This kind of construction can bear load up to three stories. The appropriate particle size distribution of the soil is a critical factor in using these blocks and soil analysis is specially recommended before considering CEB construction. Natural earth plasters with natural additives can also be used on unstabilized walls. These blocks have high compressive strength and provide good thermal mass. CO_2 emission is nil in the production of these blocks, if produced by manual operated compression machines and very low in case of other machines.

d) *Soil based building blocks* — These blocks with appropriate combination of soil, cement, lime and possibly flyash (say 5 percent cement: 15 percent fly ash: 80 percent locally available soil) are cost effective and environmentally sustainable material. While in general building construction, soil based blocks may be used as a substitute for bricks, their use should be avoided in the case of isolated load bearing columns, piers and such other heavily loaded structures. These may be made in accordance with the accepted standard [11(10)].

9.2.1.3.2 *Cob walls*

Cob walls are a traditional system of wall construction done with soil along with sufficient clay, rough sand, small stones, straw and water. Cob when formed as one mass is called monolithic adobe. Cob is suitable for construction wherever there is sufficient clay in soil/ sand (preferably 30 percent). Dug out earth during construction can also be used for construction of cob walls. Unlike adobe brick buildings, cob walls do not require mortar joints, and therefore provide additional strength to the building. Plastering can be done in a 1 : 3 (lime : sand), for exterior and interior finishes.

Cob wall has good thermal mass properties, is fire resistant; can be integrated with other materials such as straw, light clay, timber frame, adobe, conventional wooden-framed structure; and can be easily moulded into any form.

9.2.1.4 *Stone*

Stone is a durable and abundant resource. It has much lower embodied energy as compared to brick and concrete as it is natural material and hence requires much less energy in processing. Stone is good in compressive strength but low in tensile strength. It is used as masonry, cladding, and flooring. Stone aggregates are used in concrete mixes. However, mining

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(quarrying) for stone may cause natural habitat destruction, deforestation and pollution.

Sustainable methodology should be the use of locally available (excavated) and undressed stone to the maximum possible extent subject to compliance to the environmental rules/regulations relating to its mining, etc.

For quality requirements of stones, reference shall be made to Part 5 'Building Materials' of the Code.

9.2.1.5 *Timber*

Timber is a building material which is used for structural as well as non-structural applications. It is a material with low embodied energy, is renewable, reusable, versatile, as well as varied in colour, pattern, grain, durability and strength. It is reusable and convertible into other sizes, and has a long life in indoor applications. Due to such properties of timber, its use may be desirable. However, over-harvesting of timber leads to adverse environmental effects such as natural habitat destruction, reduction in oxygen generation, soil erosion and silting of rivers. It is recommended to use timber harvested from sustainably managed forests or social/agro-forestry plantations or reclaimed (salvaged) timber. Secondary species of timber after proper treatment may be used for relevant applications. Timber should be properly seasoned and preservative treated. Timber is prone to fire, moisture ingress and termite and other insect attack. Therefore appropriate treatment is required with least amount of toxic and chemical content, depending upon the end applications. The seasoning and treatment of timber shall be done in accordance with the good practices [11(11)]. For structural timber small dimensional timber from saw milling waste and forestry waste can be utilised for the design of built-up structural components.

Reconstituted wood products are high in embodied energy (due to manufacturing process involved) as well as have toxic formaldehyde contents. However, these products can be considered due to high waste utilization benefits. Prefer using such products that have lower formaldehyde emission.

Use of techniques, like finger jointing which enables utilization of smaller sized timber jointed together through this technique to yield desired larger pieces, may be employed.

For interior applications, use of reconstituted wood or other lignocellulosic panel products made from agricultural or industrial wastes (such as phospho-gypsum, bagasse, cotton stalk, rice-husk, coir fibre, pine needles, sisal fibre and wood residues) should be preferred. For partitioning, panelling, cladding, false-ceiling applications and flooring, the appropriate reconstituted wood or other panel products such as plywood, block boards, particle boards, fibre boards, etc, made from secondary species of wood or plantation timber or from other lignocellulosic ingredients may be used. Reference may be made to accepted standards [11(12)] for compliance and for criteria for making such products eligible to apply for Eco-Mark Certification in accordance with the provisions laid down in these standards.

9.2.1.6 *Plastics*

Plastics are highly refined petroleum products. Plastics are materials with very high embodied energy, are non-biodegradable and may release harmful toxic gases during manufacturing processes or if burnt. Their disposal is a major problem yet, due to its light weight and flexibility, plastic has become a widely used material. It has various applications in the exteriors and interiors of buildings. The plastics are majorly used as insulation and as water proofing material [*see* **9.2.4.1.1**(e)]. UPVC (unplasticized polyvinyl chloride) window frames are also used for their light weight and thermal properties [*see* **9.2.3.2**]. The following recommendations may be considered from sustainability point of view:

a) Use of plastics should be limited as far as possible or preference given to plastic products made with recycled content or renewable resources.
b) Natural and renewable insulation materials should be preferred over plastic based insulation material.
c) If required to be used for interiors, flooring, furniture and partitions products made with recyclable plastics should be preferred.

   Other options where plastics may be used for appropriate applications, may be:

   1) *Rice husk plastic wood* — It may be used in door and window frames, furniture and structural supports as it is moisture and termite resistant, highly workable, and meets the requirements of structural timber.
   2) *Natural fibre composite panels and door shutters* — These are composites of natural fibres in laminate, faced on plastic wood.
   3) *Fibre-reinforced plastic (FRP)* — These are used to strengthen building components structural members for rehabilitation purposes.

9.2.1.7 *Metals*

Metals are recyclable, reusable, very durable, light-weight and can easily be moulded into any shape and form. Metals have limited reserves and very high

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embodied energy due to high consumption of energy to extract metals from its ore. All metals and metal alloys can in principle be recycled and reused. Through recycling of steel, copper, zinc and lead from waste, energy consumption can be reduced by substantially. The metal can be added to new processes in varying proportions, depending upon the end product and its quality requirements.

Steel and aluminium are the two maximum used materials in buildings, followed by brass as (building hardware), zinc and copper (cladding and electrical cables). Steel is used mainly as reinforcement material in concrete or as structural member in steel buildings. Steel building can be dismantled and reused easily unlike concrete. Steel buildings are more earthquake resistant and preferred in earthquake prone areas rather than concrete/masonry buildings. Steel sheets are used for roofing, walls and accessories. Aluminium is used in applications such as, door and window frames, cladding, and roofing sheets. The following recommendations may be considered from sustainability point of view:

a) Use salvaged metal sections as far as possible.
b) Use scrap steel and aluminium for non-structural applications.
c) Use metals with verified recycled content.

The recycled content of metals varies with the type of furnace used for processing. With electric arc furnace the recycled content can be as high as 90-100 percent, whereas with BOF (basic oxygen furnace) it is about 30 percent. Where feasible, bolted sections should be preferred instead of welded as it helps in reusing the metal sections later; and the sections used should be light-weight, efficient and well designed.

Iron, aluminium, magnesium and titanium can be considered abundant and relatively benign metals, with high recycle potential, even if the environmental consequences of their extraction and production are quite severe. Steel is easy to recover and recycle. Steel with zinc coating or zinc and aluminium alloy increase strength and life of the structure. Virgin chrome, nickel, copper and zinc, however, should be used very sparingly or not at all as natural resources are limited. Copper, nickel and tin can be reclaimed from alloys in which they are the main component. The use of mercury, cadmium and lead should be highly restricted because of their high toxicity. All metals in the long term should be kept within closed cycles, in order to minimise their loss during production or during the life cycle of the building.

9.2.1.8 *Bamboo*

As an enduring, versatile renewable resource having low embodied energy, bamboo can contribute to sustainable developments and poverty alleviations. It provides healthier environment by sequestration of carbon.

As a building material, it had been abundantly used in the country for traditional huts and hermitages for long besides as scaffolds. With the understanding of its physical and mechanical properties, it has been recognized as an engineering material with scope of designing and constructing moderate houses and other buildings and structures to sustain among others the lateral forces including earthquake forces, etc. Bamboo can be used as structural material in buildings in accordance with Part 6 'Structural Design, Section 3 Timber and Bamboo, Subsection 3B Bamboo' and Part 7 'Construction Management, Practices and Safety' of the Code. Bamboo can replace reinforced steel in tensile zone in certain applications and within limitations. Bamboo-jute composite panels, bamboo boards, bamboo lathe based partitions, flooring boards are also products which can be used for sustainable constructions.

9.2.1.9 *Mortar*

Mortar is a material used to bind as well as to fill the gaps between the bricks or blocks used in masonry construction. Mortar is a mixture of sand, a binder such as cement or lime, and water and is applied as a paste which then sets and hardens. The options available may be:

a) *Lime mortar* — Lime mortar is mixture of sand, slaked lime and water. This kind of lime mortar, sets very slowly .The speed of setting of mortar can be increased by using impure limestones in the kiln, or a pozzolanic material such as calcined clay. Bricks bonded with hydraulic lime can usually be re-used. Lime mortar is easily workable and when hardened is less brittle and rigid than cement mortar, minimizing the problems of cracks. Hydraulic lime mortar is porous, permeable and thus moisture regulating. Lime mortar is produced at lower temperatures than cement and therefore requires less energy resulting in 20 percent less CO_2 emission.
b) *Cement mortar* — Portland cement mortar is a mixture of Portland cement, with sand and water. Cement mortar is stronger and more impermeable than lime mortar and is therefore more commonly used for construction of load bearing masonry walls. However, manufacturing of cement is one of the major causes of the greenhouse gas emission. Such mortars having as large replacement of Portland cement as possible by alternative but effective materials, is desirable. For this, use of Portland pozzolana cement or Portland slag

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cement in place of Portland cement in the mortar shall be preferred.

c) *Mud mortar* — Mud mortar is prepared by simply mixing soil with water until it is in a plastic (workable) state. Once applied, a mud mortar sets quite rapidly on drying without the need for curing. The beneficial characteristics of mud mortars including good bond to compatible surfaces and ease of preparation allow them to be used in a range of applications such as cob walls, adobe blocks in wall construction, masonry, monolithic walls, and even in flat roofs. However, it has low tensile strength and is subject to shrinkage that causes large number of micro-cracks in the mortar reducing its bond strength and the strength of the whole structure. In addition, mud mortars are liable to increased erosion and loss in strength, if used in humid or wet conditions. Performance of mud mortars can be improved with various additives such as straw to reduce the shrinkage and cement to increase bond strength (but increases structural cracks which can be compensated for by inserting shrinkage joints).

d) *Lime sand mortar* — Lime sand mortars are a blend of sand and lime to which cement and water is added on site. Cement helps to give mortar early strength and durability, lime helps to achieve greater strength and elasticity over time, and sand acts as an inexpensive filler.

e) *Lime pozzolana mortar* — The pozzolana traditionally used in the country is *Surkhi* (made by burning clayey soils in a field kiln). Such mortar may be weaker than Portland cement mortar but has better waterproofing properties and has been widely used in dam construction. The use of reactive rice husk as super pozzolana is also a resource efficient option. Combination of burnt clay and rice husk can also be used as pozzolana. Flyash can also be used in the preparation of lime-pozzolana mortar. Mixture of lime-fly ash-sand with 5 percent addition of calcined gypsum can lead to good quality mortars.

NOTE — There are other technologies and materials available locally which use no cement and use flyash and binding agents. These options may be used if performance parameters are met.

For preparation and use of masonry mortars other than mud mortar, reference may be made to good practices [11(13)] and for mud mortar to good practice [11(14)].

9.2.1.10 *Glass*

See **9.2.3.1**.

9.2.2 *Surface Materials*

9.2.2.1 *Floor and floor coverings*

Stones, ceramic tiles, vitrified tiles, bamboo, linoleum, terrazzo, metal tiles, recycled or reclaimed wood and floorings with high recycled content may be some eco-friendly materials, if used with due consideration to sustainability. Following are recommendations on use of various floor covering materials which may replace conventional materials:

a) *Finish concrete flooring* — Concrete floor is highly durable, low in maintenance and can cope with water and chemicals. This flooring can be a resource efficient option where the main slab is finished with topping layer of concrete admixed with colourants and sealers. The finishing layer should be stamped with patterns and grid lines to prevent cracks and for improved appearance. Water dispersed acrylic sealers having lower VOC may also be used.

b) *Resilient flooring (bamboo and linoleum flooring)* — Bamboo is a natural, renewable, hard wearing and economical option for flooring. Bamboo flooring can be of solid bamboo (made with only bamboo) or bamboo mat board with or without wood veneers. Linoleum flooring is made with reusable and natural occurring material like cork, linseed oil, wooden flour and pine resin. Both the flooring materials require frequent maintenance and can cause indoor pollution if they are VCT (vinyl composition tile) or polyvinyl tile sheet based (release toxic materials in their production). *See* accepted standard and good practices [11(15)] for linoleum flooring.

c) *Terrazzo in-situ flooring and tiles* — These tiles may contain up to 60 percent recycled content (crushed stones) mixed with cement. It is a low embodied energy, inert and highly durable and low maintenance flooring. Adhesive used for tiles laying should be of low VOC, non-toxic in nature. Cement mortars with acrylic additives are the better options for adhesive. *See* accepted standards and good practices [11(16)].

d) *Ceramic/vitrified tiles* — These are durable, have low maintenance requirement and can have high recycled content (clay mixed with up to 95 percent recycled content like recycled glass and crushed stone and feldspar), and are water resistant and may also be recyclable depending upon the pigments added. Ceramic and vitrified tiles have higher embodied energy as compared to terrazzo tiles as there

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is firing process involved in their manufacturing. Also, these tiles may have pigments (metal oxides), many of which are environmental pollutants, hence rules for proper disposal need to be followed. Low VOC and non-toxic option for adhesive for laying these tiles should be used. Cement mortar with acrylic additives is most suitable and safer option. *See* accepted standard [11(17)].

e) *Wooden flooring* — Timber or reconstituted panel products used for manufacture of wooden flooring shall comply with **9.2.1.5**. For protective coating of these products water dispersed urethanes having low VOC (than solvent based), and not having toxic urea formaldehyde should be used. Use of acid cured varnishes and low VOC adhesive is preferred. Finishing of these materials (laminate, veneer or coatings) shall also be of low VOC.

f) *Stone* — Limestone, marbles, granites are some common stones that last longer than the manufactured tiles. *See* **9.2.1.4** for stone properties and sustainable alternative.

9.2.2.2 *External and internal wall finishes*

Selection of materials for external wall finishing is important as it affects the thermal and acoustic insulation of the building and materials for internal wall have effect on indoor air quality (IAQ).Following are recommendations from sustainability point of view:

a) *Plaster* — Plaster not only acts as a protective covering over walls and provide finishing, but also plays important role in indoor environmental quality of building. There are several alternatives in plaster available, depending on the surface to be plastered, climate of the place, elasticity, etc. The usual binders are lime, cement and gypsum or the mixtures of these substances. Fibre, mineral fibre, perlite, hacked straw, or even hair from cow, pig and horse are sometimes added for better binding, elasticity and/or insulation. Pigments, if added are generally metallic oxides, which should be fine grained and calciferous. For external plastering or plastering in rooms such as bathrooms, water proofing agents are sometimes added to plaster. The grain size of sand in plaster shall depend on the surface quality required and layers of plasters to be used. The raw material availability of the different component of plaster is generally good. Lime and gypsum based products have good moisture regulating properties. Waste of lime and cement based plaster, being inert can be used as fill. Pure lime plaster can be ground up and used to improve the soil. Dumping sulphur and gypsum waste can lead to sulphur pollution which can be reduced by adding lime. Features of various plasters having effect on sustainability are as follows:

1) *Lime plaster* — It is a very old and sustainable method of plastering which require higher degree of skill for good quality work. It is composed of lime, sand and water and is also suitable for use with clayey soils (lime: soil should be between 1:10 and 1:5). In the making of lime-pozzolana plaster, *Surkhi* (made by grounding waste bricks to fine powder), fly ash or reactive rice husk ash can be used in lime mortar. Lime can also be obtained from fertilizer industry (as an industrial waste). Lime plasters have low VOC and have approximately 25 to 28 percent lower carbon dioxide emissions, have lower embodied energy and can contain 50 to 65 percent post-industrial use recycled content. It has wide applicability in restoration of heritage buildings. It is most suitable for internal use but can also be used externally. However, for external use it should be protected against driving rain and continuous dampness, otherwise it may get damaged due to its high porosity. For external use, lime to sand ratio of 1:3 should be used. Lime plaster helps the walls to retain their moisture regulatory properties.

2) *Cement plaster* — This is mostly used as an external plaster and can be used on brick masonry, solid concrete walls, concrete block masonry, stone masonry, etc. For internal plaster, the proportions can be 1:6 (cement: sand), whereas for external use they may vary between 1:3 and 1:4 (depending upon the surface to be plastered and the climatic conditions). For application of cement plaster, reference may be made to good practice [11(18)].

3) *Cement-lime plaster* — This plaster is used externally. It is somewhat stronger than lime plaster and more elastic than pure cement plaster. In cement-lime plaster, 30 to 50 percent of the binder is cement. For applications of cement-lime

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plaster, reference may be made to good practice [11(18)].

4) *Gypsum plasters* — It is a dry mixture of gypsum and mineral fillers. Gypsum plastering is mainly for internal use especially as a moisture regulating layer, usually having a mix of one part of gypsum and two parts of sand. This mixture sets in 10 min to 30 min. Lime can be added to make the gypsum plaster usable for longer time. Gypsum is a natural mineral, has quality to absorb pollutant and can also be easily percent recycled completely. This plaster has good compressive strength, and thermal, acoustic and fire resistant properties. Gypsum can be obtained from either natural resources or it can be obtained as industrial by-product or as a product with recycled content. For materials for plaster, requirements and application, reference may be made to accepted standards and good practices [11(19)].

5) *Clay plaster* — Clay plaster is a natural, breathable material which is created by composing rocks and minerals, mixed with sand and water to create a workable mix for plastering. It is bio-degradable, absorbs odours, has good sound and thermal insulation properties, is fire resistant and has good temperature regulation properties. Plastering with clay is a quicker method than with traditional gypsum plastering. Long drying time means that it is workable for longer period. However, it is not as strong as other plasters in shear and compressive strength.

6) *Sulphur plaster* — This can be produced by melting sulphur at temperature from 120°C to 150°C. Sand, wood flour or the equivalent can be added. It has waterproofing properties but cannot be used over materials with high lime content.

b) *Mineral and fibre based sheeting/boards* — There are three main types of mineral based sheeting: cement based, calcium silicate based and gypsum based. Raw materials for all the three are abundant. Apart from the binder, they contain fibrous reinforcement. When they are mounted, the joints should be filled with filling material based on plastic binders, mainly PVAC glue or acrylate glue. Production of these sheets is relatively low in pollution. Calcium silicate and gypsum products are also good moisture regulators. Features of such boards having effect of sustainability are as follows:

1) *Fibre cement sheets/boards* — These are suitable for all modern and conventional constructions for both internal and external uses as they have high resistance against moisture, fire and termite. It may contain up to 35 percent fly ash and 5 percent recycled pulp and other recycled content, has a long life span, requires little maintenance and is economical. High embodied energy in its creation is compensated by the use of fly ash and recyclable waste. For requirements for some of these sheets reference may be made to accepted standards [11(20)].

2) *Calcium silicate sheet* — These can be used as both internal and external cladding. The sheeting is produced with up to 92 percent by mass of quartz mixed with lime and cellulose fibre. Vermiculite can be used as aggregate. Calcium silicate products can be crushed and recycled as aggregate in concrete. If it is finely ground it can be used in mortars and plaster. The waste is inert and can be used as fill.

3) *Gypsum plaster board* — These boards are manufactured from 95 percent gypsum with possible addition of fibreglass reinforcement (about 0.1 percent by mass). The substances such as calcium lignosulphate, ammonium sulphate and an organic retardant may also be added to a total of about 1 percent by mass. Pure gypsum sheeting is not too strong; hence, some lime and a large percentage of wood shavings are added to increase strength. The sheeting products are used mainly for internal cladding, and may be covered by wall papers or thin fibreglass woven sheeting for painting. Pure gypsum plaster board is too weak to be dismantled and re-used but it can be broken and recycled and used as 5-15 percent of raw material. However, since gypsum industry is very centralized, it makes it uneconomical to recycle. *See* **9.2.2.2** (a) (4) for properties of gypsum plaster. For requirement and use of different gypsum plaster boards and material for their manufacture, reference may be made to accepted standards [11(21)].

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c) *Grit wash* — This finish uses waste stone pieces and aggregates like marbles, granites, stones mixed with cement, etc. This is a permanent finish requiring less maintenance.

d) *Paints and coating* — Generally paints and coatings contain large quantity of VOC and create pollution indoors as well as outdoors (due to release of volatiles by oxidation of both solvent and water based paints). Water based acrylic paints are better option over solvent based oil paints because of durability and lower toxic release. Paints made from natural raw ingredients such as milk protein, minerals, bee wax, natural wax, lime, chalk, talcum, earth and clay pigments and plant oils and resins, should be preferred as they have little to no smell and low VOCs.

e) *Timber — See* **9.2.1.5**.

f) *Stone cladding* — Stones can also be used as external wall finishes. However, stone fixing has to be carefully considered for high seismic zone and high rises.

g) *Metal composite panels (MCP)* — These are formed by bonding two metal skins to a highly engineered plastic core placed between them, creating a sandwich panel. The bonding process occurs under very precise conditions of temperature, pressure and tension resulting in a metal/plastic composite sheet. MCP is used for cladding of building exteriors, entryways, canopies, soffits and facias. Metal skins may be of aluminum, zinc, copper, stainless steel, and titanium. MCPs can be finished in different colours. MCPs are flexible, durable, light weight and easy to install and maintain, weather proof and flexible with low emissivity and high reflectance. MCP shall be fire resistant, which can be achieved by using a fire resistant core in the sandwich construction.

   MCPs having high percentage of recycled content and made out of reused plastic core should be preferred.

h) *Wallpapers* — Wallpapers are for internal use. Wallpapers like grass cloth wall paper, bamboo wallpaper and jute wallpaper are some eco-friendly biodegradable wallpapers. The grass cloth wallpaper is hand-made from woven natural grasses and therefore is sustainable and manufactured from renewable resources.

9.2.3 *Building Fenestration and Detailing*

9.2.3.1 *Glazing*

Glass is a high embodied energy mineral material. Its usage is in skylights, windows, glazing systems, flooring, infill panels for doors. Glass helps to get in natural daylight to interior spaces and provides views. Glazing, if not chosen and positioned in a building properly, may lead to lot of heat ingress/egress.

Glass shall be selected with high recycled content and shall be so sized as to minimise wastages. Use of glazing in fenestration shall be in accordance with **8.1.3**.

9.2.3.2 *Door and window frames*

Frames made of stone, wood, steel, aluminium, reinforced concrete and UPVC are generally used for building construction. Use of stone frame should be preferred in the area where they are locally available as they provide an economical, durable, and termite proof frame. Likewise precast RCC door/window frames are another durable, economical and termite proof alternative. Wooden frames provide better insulation than metal frames. Metal frame although recommended for its durability, high recyclability, light weight and for larger spans, has high heat conductivity. Metal frames are required to be detailed with thermal break (low conductive material) to reduce their conductivity. Frames of plastic and aluminium can be made of profiles filled with foamed insulation of polyurethane to offset high heat conductivity. Composite products are now being available which use either aluminium with UPVC or timber with aluminium, where timber is the insulating material. Inferior quality timber can be used in that case, as the outer layer of aluminium provides weather protection to the same.

Plastic windows are usually made of unplasticized polyvinyl chloride (UPVC) stabilized by cadmium, lead and tin compounds and added colour pigments. All these products have very limited reserves, and cause high level of pollution during processing.

The manufacture of an aluminium and UPVC door and window frame uses very high energy input than a timber/RCC door/window frames. Both UPVC and aluminium windows can be reused if they are initially installed for easy dismantling. Pure aluminium frames can be recycled. Special precautions should be taken to dispose of wastes which contain cadmium, lead or tin. Considerations given in **9.2.1.6** may be followed.

Defective doors of solid timber can usually be recycled or composted but laminated products should be disposed of with special precautions or recycled in incinerators that filter the fume. Considerations given in **9.2.1.5** may be followed for selection of timber for frames. For requirements of wooden frames including such frames eligible for Certification for Eco-Marking, reference may be made to accepted standard [11(22)]. Depending upon the availability or otherwise of various alternatives and their suitability for sustainable

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considerations, use of precast reinforced concrete door and window frames may be considered as they are highly durable and also eligible for Eco-marking; for quality requirements of this frame, reference may be made to accepted standard [11(23)].

Sealing of frames should be done in accordance with **8.1.3.2.2**.

9.2.4 *Climatic Control Materials*

Climatic changes is the prime factor affecting longevity of the building, maintenance of a safe and eco-friendly environment and durability of building materials. There are several historic buildings which have existed for centuries due to the reason that they were built with durable materials to withstand different climatic conditions of the places in which these were built. These materials can be used for climate responsive designs as well as for reducing the harmful impact on environment.

9.2.4.1 *Thermal insulation materials*

The thermal insulation of walls and roof shall be done in accordance with **8.1.1** and **8.1.2**. Thermal insulation materials are used for making a building resistant to heat ingress and egress. A thermal insulator is a poor conductor of heat and has low thermal conductivity. Thermal resistance, thermal conductivity, thermal transmittance, stability, density of materials, long life, fire resistance, lack of odour, low chemical activity, ability to cope with moisture and good thermal resistance are some factors which have to be considered in selecting materials for thermal insulation.

9.2.4.1.1 *Types of thermal insulation materials*

Insulation materials may be divided into organic and non-organic groups (mineral fibres, glass wool, perlites) according to their raw materials. Organic materials can be subdivided into more environmental friendly for example natural materials (cork, cotton and wool) and less environment friendly for example synthetic materials (polyurethane rigid foam and polystyrene). Some thermal insulation material may be reflective and some high in embodied energy, which may get offset by saving in the operational energy of the building over their life span.

a) *Mineral wool* — Mineral wool products are light and have extremely good thermal insulation values. When used as insulation both glass and rock wool need a barrier of suitable material sheeting, partly to avoid dust and partly because the material cannot regulate moisture as required. Exposure to mineral wool fibres may cause skin problems, itching, eye damage and respiratory irritation. Raw materials are abundant for the main constituents of glass wool and rock wool. The production of glass wool occurs in relatively closed processes where emissions are little and limited to formaldehyde and dust. Large amounts of phenol, ammonia, formaldehyde and dust are released during the production of rock wool, and large amounts of wastes are produced. For requirements of bonded mineral wool, reference may be made to accepted standard [11(24)].

   1) *Glass wool* — Made from silica sand, limestone, boron, recycled glass (approximately 70 percent), phenol formaldehyde resin or acrylic resin, it is a lightweight and fire resistant insulation material commonly used for duct and wall insulation. Glass wool is a high embodied energy product as glass is melted at higher temperature to make the fibre. Glass wool is easily recyclable and possesses good acoustic insulation properties.
   2) *Rock wool* — It is a light weight high embodied energy and fire resistant product, made from natural rock basalt primarily under high heat. It is denser than glass wool and *R*-value is higher than glass wool. Rock wool may contain 10 percent recycled content in the form of building waste and 15 percent recycled content from waste from industry (slag from the steel production process). For requirements, reference may be made to accepted standard [11(25)].
   3) *Cotton* — This is a rapidly renewable product made from both natural fibres as well as industrial waste from recycled cotton textiles. Cotton is also a good sound insulator, requires little energy to manufacture as well as is non-toxic. Waste cotton, a high water absorbing material should be protected by moisture/vapour barrier.
   4) *Natural wool* — It is made with recyclable and renewable source and is non-toxic and bio-degradable. It does not contain any synthetic fibres but has a disadvantage that it absorbs VOC.

b) *Cellulose fibres* — These can have very high recycled content and can be made from waste papers (about 90 percent recycled papers) or pulverized pulp and are cost-effective. They can also be made from different types of cellulosic materials like card boards, waste papers, old newspapers, cotton, straw, saw dust and hemp. These fibres have very low

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embodied energy, but they need to be treated for fire retardance (such as by boric acid). This product may be reused and recycled but should not be incinerated.

c) *Plastic* — Many plastics have good water-proofing and high thermal insulation properties (when produced as foam). As a sealant, plastic can take many forms such as paint, sheeting, paper, sealing strips and mastics. The materials are foamed up using chlorofluorocarbons and carbon dioxide, and fire retardants and stabilizers are added. It is recommended to use products which do not use CFCs or HCFCs as blowing agents during manufacturing. Depending upon how the materials are built in, polystyrene can emit extra monomers of styrene while polyurethane can release small amounts or unreacted isocyanates and amines. Ashes from the furnaces and plastic waste which is not recycled needs to be disposed of safely to prevent seepage into the groundwater or soil. Properties of polystyrene are as follows:

   1) *Extruded polystyrene* — This material has very high *R*-value per unit thickness, good moisture resistance, and high compressive strength and is light in weight. It is commonly used in wall and roof insulation.
   2) *Expanded polystyrene* — It is a light weight and has high *R*-value, but it has low compressive strength and is not moisture resistant.
   3) *Closed cell flexible elastomeric foams* — These naturally resist ingress of water vapour, help in long term efficiency of the insulation and minimise chances of condensation and increased heat gain over a period of time.

d) *Autoclaved aerated (cellular) concrete blocks* — *See* **9.2.1.1**(f)(2).

e) *Preformed foam cellular concrete blocks* — *See* **9.2.1.1**(f)(4).These have better water resistance.

f) *Hollow concrete block* — *See* **9.2.1.1**(f)(1).

g) *Reflective Insulation materials* — These comprise highly reflective materials like aluminium foil. It may retard the heat transfer up to 97 percent. It is very effective in warmer climates, requires less area, acts as a vapour barrier also, and is non-toxic. However, it has less compressive strength and requires some backing support.

h) *Perlite and pumice products* — Perlite is a natural glass of volcanic origin. It is pulverized and expanded in rotating kilns at about 900°C to 1 200°C, which increases its volume from five to twenty times. It is used either as loose fill insulation or as aggregates in mortar and light weight concrete blocks. Perlite absorbs water, hence moisture preventive materials like bitumen or silicon are sometimes added. It can be used for thermal insulation of buildings, refrigerating rooms and high temperature insulations.

j) *Vermiculite products* — Vermiculite is formed through the disintegration of mica, which liberates lime and takes up water. When vermiculite is heated to 800°C to 1 100°C, it swells to become a light porous mass which can be used as an independent loose insulation or as an aggregate in a lightweight concrete in the proportion of 6 : 1 (vermiculite to cement). Prefabricated slabs can be made in varying thickness from 15 mm to 100 mm using this material. Vermiculite is useful for high temperature areas and equipment. It easily absorbs large amount of moisture, even more than untreated perlite. As normal wall insulation, it has a tendency to settle, hence needs to be compressed substantially after filling into the wall cavity.

k) *Saw dust and wood shavings* — They are wastes from timber industry or carpentry, and can be used for thermal insulation in walls or ceilings. Saw dust has hygroscopic property due to which it easily absorbs moisture, and then releases it in air and therefore is moisture regulating. Saw dust and wood shavings are chemically inert, non-toxic. However, they are not fire resistant, and the same can be improved by adding pulverized clay.

m) *Traditional techniques* — Following vernacular techniques have generally been used effectively for thermal insulation of building in the country:

   1) *Straw-bale insulation* — Straw bale walls (bales of straw commonly of wheat, rice, rye and oats which are agricultural wastes after harvesting) have good thermal insulation properties. These should be packed tightly for improving fire resistance. Straw bale is biodegradable, low embodied energy, non-toxic, easily available, cost effective and rapidly renewable product. These walls are porous in nature hence exposed walls require protection from rain in the form of plaster (generally lime plaster) and deep eaves/verandas.

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2) *Inverted earthen pot insulation* — Shading the roof top with inverted earthen pot is an easy and cost effective method to reduce solar gain. In this method roof is covered by inverted earthen pots, the top of earthen pot can be covered with a layer of earth or lime mortar finish or can be left uncovered. By virtue of air trapped within them they provide good insulation. Earthen pots painted with white paints further reduce the heat load. Pots made with earth are recyclable and locally/ regionally available.

3) *Brick bat coba* — This system involves laying mortar with broken brick (which may be waste brick pieces) as aggregates and ground brick with lime or cement as binding matrix. A thick mass of brick bats provide the thermal insulation for roof of the building.

4) *Mud phuska* — For this, good quality earth suitable for brick making not containing excessive clay or sand, free from stones, *Kankar*, vegetable matter and other foreign matter should be used. In this system a layer of puddled mud is mixed with grass straw applied on a sand-bitumen waterproofing layer which is then consolidated and plastered with cow-dung mortar. Tile bricks are laid flat on plastered surface and the joints are grouted with cement mortar. All materials are readily available, economical and non-toxic. Laying of mud *phuska* shall be done in accordance with the good practice [11(26)].

n) *Broken ceramic mosaic tiles* — Broken ceramic tiles can be used as a cost effective external roof finish to reflect the incident solar radiation. Broken ceramic light-coloured tiles reflect heat off the surface because of high solar reflectivity and effectively utilize the waste ceramic tiles.

p) *Cavity wall insulation* — Cavity wall consists of two layers of masonry separated by a hollow space that work as a thermal insulation as well as provide better sound insulation. Cavity wall made with fly ash blended cement concrete blocks or blocks with high recycled content or internal wall with under burnt clay bricks makes it more environmental friendly. Hollow space between the two walls can be filled with the insulation materials. Rat trap bond is a cavity wall construction technique with added advantage of economy in brick use (of about 25 percent). However, these walls occupy more floor area.

q) *Poured in-situ cellular light weight concrete* — This work to be done in accordance with accepted standard [11(32)].

r) *High SRI Paints* — The recent development has been the use highly thermal reflective paints for the exposed terrace areas which reflects incident heat and adds to the insulation values.

9.2.4.1.2 *Covering or finishing materials for thermal insulation*

These are used to protect and help to elongate the life and usefulness of the insulation from weather, water vapour condensation, and chemical attack and sometimes even from fire. Additionally, appearance coverings are utilized to provide the desired aesthetics. These may include:

a) *Weather barriers* — These should be installed on the outer surface of thermal insulation to protect the insulation from the weather such as rain, snow, sleet, dew, wind, solar radiation, atmospheric contamination and mechanical damage. Metals, plastics, paints and coatings and roofing felt are few weather barriers.

b) *Vapour retarders* — These are materials which retard the passage of moisture or vapour into the insulation. Laminated foil-scrim membranes and metal and plastic sheets are vapour retarders.

9.2.4.2 *Moisture and air regulating materials*

Moisture and air regulation in sustainable building is essential to get better indoor environmental quality as well as to protect building and building components from damage. Insulation and other components aimed at controlling seepage of moisture and air to and from building shall be included in the building envelope design. Common air sealing materials include caulks, expanding foams, weather-stripping of doors and windows, gaskets, door sweeps. Another environment friendly technique is to use high recyclable moisture regulating materials like adobe brick and mud construction.

9.2.4.3 *Water proofing materials*

Water proofing materials resist liquid water passing through, but may allow water vapour to pass through. They can be categorized on the basis of application (cold applied or injection type) or on the basis of their types or state (layer type or fluid type).

a) *Cement based waterproofing products* — These are suitable for both negative and

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positive water pressures. They contain no solvent. They are however low on elasticity and prone to cracking.

b) *Plastic-polymer products* — Plastic-polymers have good water proofing properties and have been successfully used due to their light weight, elasticity and non-porous nature. However, there are major limitations from sustainability point of view in using plastic products (*see* **9.2.1.6**). Some examples are coal-tar, bitumen, ethylene propylene diene monomer (EPDM), polyurethane and PVC, which are briefly described below:

   1) *Polymer modified bitumen* — These are available as hot/cold applied fluid products and as sheet membranes.
   2) *Polyurethanes/urethane membranes* — These are typically fluid-applied and remain elastomeric (flexible) throughout their useful life. This group of waterproofing membrane materials is commonly referred to as fluid-applied elastomers.
   3) *Thermoplastics (PVC) waterproofing membranes* — These are available in sheet forms and are typically applied with heat-welded seams.
   4) *Asphaltic membranes* — These typically consist of emulsified (liquid) asphalt and reinforcing fabric, fibreglass or organic, and are applied in layers.

c) *Brick bat coba* — It provides waterproofing up to some extent. Brick bats coba may be made cost effective by using waste generated during construction or demolition. It works more efficiently if used in combination with other water proofing material. The disadvantages of using brick bat coba are increase in dead load on slab as well as thickness as compared to other water proofing materials [*see also* **9.2.4.1.1**(m)(3)].

d) *Bentonite clay* — Bentonite is sedimentary clay composed of weathered and aged volcanic ash. It has the capacity of quickly absorbing large amounts of water and swelling to many times in volume. When the surroundings dry out again, the clay releases its moisture. It is useful as an absorbent waterproof membrane on foundations and foundation walls made of brick and concrete. It is available in rigid, flexible and granular form.

e) *Other waterproofing membrane materials* — These may be materials such as butyl rubber, crystalline and cementations products. Besides, there are some eco-friendly organo-silicone products based on nanotechnologies which also work as waterproofing materials.

9.3 Construction Phase Material Storage and Handling

It is essential for construction industry to have proper material handling and storage to provide a continuous flow of materials and components and ensure that materials are available when needed and to avoid wastage. For storage and withdrawal of construction materials from storage places, first in first out policy should be followed. Care has to be taken in storing moisture sensitive construction phase materials like cement, Plaster of Paris (POP), gypsum board, wood and other lignocellulosic materials based products, as well as steel components/materials which may get corroded in the presence of moisture. Inflammable, volatile materials may need proper segregated storage. There may be some materials or components which require to be so stored/stacked as to avoid undue stress over them and ensure safety of the personnel. For guidance on proper stacking and storage of building materials, a reference may be made to good practices [11(27)].

9.3.1 *Handling of Materials and Equipment*

Handling materials involves diverse operations of crane, truck and manual handling. The efficient handling and storing of materials is vital considering continuous flow through the workplace, and availability. Improper handling may cause severe damages. The workers should be aware of the potentiality of the injuries and hazards due to unsafe or improper handling. During mechanical shifting of materials, one should avoid overloading the equipment.

To reduce potential accidents associated with workplace equipment, employees need to be trained about the proper use and limitations of the equipment. The operating manuals of major handling equipment, for example, conveyors, cranes, slings and industrial trucks should be referred before using these equipment. Periodic inspection and checking of handling equipment should be carried out by the authorized persons only.

10 WATER AND WASTE MANAGEMENT

10.1 General

10.1.1 The country has been well endowed with large freshwater reserves. However, with the increasing population, industrial activity and pollution, surface and groundwater resources have been overexploited and severely polluted during the past few decades. As a result, the country is faced with immense water scarcity.

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Growth of the country's economy is driving increased water usage across sectors. Waste water generation is increasing significantly and in the absence of proper measures for treatment and management, the existing freshwater reserves get polluted. Further, increased urbanization is driving an increase in per capita water consumption in towns and cities. Urbanization is also resulting in change in consumption patterns and increased demand for water-intensive agricultural crops and industrial products.

10.1.2 Significant liquid and solid waste generation is witnessed and recorded in the urban areas of the country. The municipal solid waste generation ranges from 0.25 to 0.66 kg/person/day with an average of 0.45 kg/person/day. In addition, large quantities of solid and liquid wastes are generated by industries. Unless properly managed, most of the wastes generated may find their way into land and water bodies, emitting gases resulting in bad odour and air pollution as well as increase in the emission of greenhouse gases. This problem can be significantly mitigated through adoption of treatment, recycling and processing before disposal, and adopting waste to energy technologies. It not only reduces the quantity of wastes, but also improves its quality to meet the required pollution control standards and regulations, besides generating substantial quantity of resources and energy [*see also* **11.16** (c)].

10.1.3 Sustainable approach to water and waste management requires planning and design of building functions to integrate issues of water and waste management system at the early stages of project evolution, their management during construction activity and subsequently during occupancy and use of building. At the scale of building complex or at township level, the opportunities for water efficiency and waste management are large particularly in respect of external development and landscaping (*see* **7.1.3**). The sustainable approach should finally adopt an integrated approach to water supply, water waste and solid waste management aimed to create built facilities with zero anthropogenic waste design solution. Following are the broad aspects for achieving sustainable water and waste management:

a) *Conceptualization, planning and design stage* — Water is essential to create liveable neighbourhoods and public spaces. The function of a water supply system is to provide water from a source identified through considered selection, treat the same to render it suitable for its intended use, and deliver it to the user at the time and in the quantity prescribed. Major considerations during planning and design include yield and quality of raw water sources; topography, geology, population density of service areas; intended uses of water; and treatment of waste water. Since these considerations may vary from project to project, all water and waste management system solutions are unique.

   Planning and design of water and waste management system needs a holistic approach. The system should integrate functions, water supply systems, waste water system (including grey water use), storm water management (including rainwater harvesting) and solid waste management and waste to energy systems. The complexity of holistic design process requires coordinated decision-making process.

b) *Construction stage* — Objective of construction stage is to create the built facility. The concerns of efficient water use and waste have a potential to be ignored. It is essential to establish systems for water and waste management so that the project teams monitor water consumption, control wastes and disposal in an environmentally appropriate manner. The existing surface and groundwater resources should first be protected and suitability integrated in the building and layout plan. There is a scope for selection of materials and technologies, which are water efficient. Value engineering of material and technology selection should be undertaken so that the solutions are appropriate to the project peculiarities as well as environmental constraints. Construction, including in environmentally sensitive sites, necessitates compliance to legal and statutory requirements for water and waste management.

c) *Performance during use and corrective action* — Building projects are planned, designed and executed in accordance with the anticipated functional use. However, it is reasonable to expect some variance during use. Building use is a dynamic process and functional use is constantly evolving during life of a building. Also, engineering system designs are optimum solutions based on assumptions, which can only be validated during actual use. Design of systems should be done within a considered tolerance of functional use. The performance of water consumption should be monitored during use and compared with the benchmarks (industry specific, building specific or established standards) given in the Code and corrective actions undertaken. In this respect, it is

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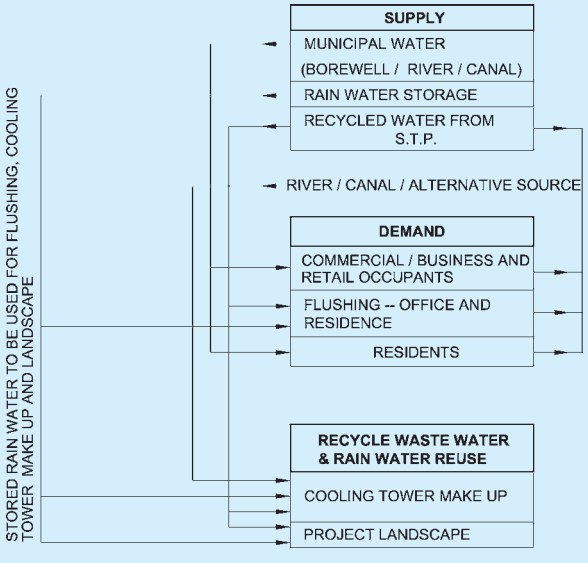
important to design systems that facilitate monitoring. Appropriate metering and corrective improvements should be integrated in the system design detailing. It may be desirable to design water system taking functional homogeneity into account and facilitate function specific corrections in response to environmental considerations and opportunities for conservation.

10.2 Planning and Design of Water Management System

10.2.1 *Planning and Design of Water Supply System*

Planning and design process begins with use analysis for demand assessment, identification of project constraints and water sourcing. Inputs on these parameters are critical design brief contents. Hot water systems are energy intensive building component. Opportunities for waste recovery, temperature setting and selection of technologies that use clean fuels such as solar water heaters need to be included in the planning and design approach for hot water systems. While the systems may be designed efficiently, the strategies for water efficiency and conservation need to be built into the system design. Finally, system components need to be integrated as part of sustainable planning and design approach. Figure 16 gives a typical scheme showing general components of water management system. This shall also incorporate water requirements for fighting fire.

It is recommended that an overall water balance chart



NOTE — In absence and non-viability of having recycled waste water for these purposes/use, river/canal/alternative sources may be considered.

FIG. 16 TYPICAL SCHEME SHOWING GENERAL COMPONENTS OF WATER MANAGEMENT SYSTEM

be prepared indicating all supply side resources, infusion of recycled water, and the actual consumption for potable and non-potable and other purposes. This chart should also indicate the extent of recycled water use for different consumption depending on the level of water treatment and reduction in freshwater intake through rainwater harvesting potential of the site.

A reasonably accurate estimate considering a calendar year long demand-supply assessment including demand fluctuations of the amount of water that should be supplied, is needed early in the planning stage of project development. The average daily demand is especially important since it may be used to assess the ability of available sources to meet continuing demands and to size raw water storage facilities that may be required to meet sustained demands during dry periods. Later, during the actual design process, the peak demand is required to properly size pumps and pipelines, estimate pressure losses, and determine water storage requirements so that it may be planned to store sufficient water and cater for daily water demand. Uses of water include agricultural, industrial, household, recreational and environmental activities. Its estimate for fire-safety purposes is also to be addressed in the design stage itself. Almost all of these human uses require freshwater.

10.2.1.1 *Availability of water*

The water availability and the associated features and constraints are as follows:

a) *Surface water* — Surface water is water in river, lake or freshwater wetland. Surface water is naturally replenished by precipitation and naturally lost through discharge to the oceans, evaporation, evapotranspiration and sub-surface seepage. Although the only natural input to any surface water system is precipitation within its watershed, the total quantity of water in that system at any given time is also dependent on many other factors. These factors include storage capacity in lakes, wetlands and artificial reservoirs, the permeability of the soil beneath these storage bodies, the runoff characteristics of the land in the watershed, the timing of the precipitation and local evaporation rates. All these factors also affect the proportions of water lost.

   Human activities can have a large impact on these factors. These often include increase in storage capacity by constructing reservoirs, decrease by reclaiming wetlands and increase in runoff quantities and velocities by paving areas and channelizing stream flow. Also, surface water may be lost (for example, become unusable) through pollution.

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The total quantity of water available at any given time is an important consideration. Some users have an intermittent need for water. For example, many farms require large quantities of water in the spring, and very less or no water in the winter. To supply water to such a farm, a surface water system may require a large storage capacity to collect water throughout the year and release it in a short period of time. Other users have a continuous need for water, such as a power plant that requires water for cooling. To supply water to such a power plant, a surface water system needs enough storage capacity to fill in for use later when average stream flow is below the power plant's need. However, over a long term the average rate of precipitation within a watershed is the upper bound for average consumption of natural surface water from that watershed.

Natural surface water can be augmented by importing surface water from another watershed through a canal or pipeline. It can also be artificially augmented from any of the other sources; however in practice the quantities of such water are negligible.

b) *Under river flow* — Throughout the course of the river, the total volume of water transported downstream will often be a combination of the visible free water flow together with a substantial contribution flowing through sub-surface rocks and gravels that underlie the river and its floodplain called the hyporheic zone. For many rivers in large valleys, this unseen component of flow may greatly exceed the visible flow. The hyporheic zone often forms a dynamic interface between surface water and groundwater, receiving water from the groundwater when aquifers are fully charged and contributing water to groundwater when groundwaters are depleted.

c) *Groundwater* — Sub-surface water, or groundwater, is freshwater located in the pore space of soil and rocks. It is also water that is flowing within aquifers below the water table. Sometimes it is useful to make a distinction between sub-surface water that is closely associated with surface water and deep sub-surface water in an aquifer.

Sub-surface water can be understood in the same terms as surface water: that is, in terms of inputs, outputs and storage. The critical difference is that due to its slow rate of turnover, sub-surface water storage is generally much larger compared to inputs than it is for surface water. This difference causes a tendency to use sub-surface water unsustainably for a long time. However, over long term the average rate of seepage above a sub-surface water source is the upper bound for average consumption of water from that source.

The natural input to sub-surface water is seepage from surface water. The natural outputs from sub-surface water are springs and seepage to the oceans. If the surface water source is also subject to substantial evaporation, a sub-surface water source may become saline. In coastal areas, use of a sub-surface water source may cause the direction of seepage to ocean to reverse which can also cause soil salinization. People can also cause sub-surface water to become unusable through pollution. The input to a sub-surface water source can be increased by building reservoirs or detention ponds (without lining).

d) *Desalination* — Desalination is an artificial process by which saline water (generally sea water) is converted to freshwater. The most common desalination processes are distillation and reverse osmosis. Desalination is currently expensive compared to most alternative sources of water. It may be economically viable only for high-valued uses, such as household and industrial uses, in arid areas.

e) *Rainwater harvesting* — Rainwater harvesting may be employed to augment water availability. *See* **7.2.1** for details.

10.2.1.2 *Project constraints and source constraints*

Quality aspects of demand depend upon functional requirements, occupancy type, pattern of use, variety of uses involved, occupant use behaviour, cold and hot water quality requirements (temperature, pressure, etc), etc.

Water quality requirements are directly related to intended use. The freshwater is intended mostly for human consumption, whereas treated waste water is intended to be used for non-potable uses. All the water supplied shall meet or exceed appropriate water quality requirements as applicable for its use. Requirements include microbiological, chemical, radiochemical, and aesthetic requirements that are applicable to quality of water for its respective uses.

The quality of available water sources is often a very important factor in water system planning and design. The quality of water for respective uses such as for domestic, flushing, irrigation, processes and construction requirements shall be in accordance with accepted standards and good practice [11(28)].

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For estimation of water demand for respective types of occupancy, reference shall be made to Part 9 'Plumbing Services, Section 1 Water Supply' of the Code. Cold and hot water proportion are drawn based on the local climatic condition of the region, type of occupancy and the general use pattern in the local region.

10.2.2 *Water Sourcing*

Based on the functional assessment of need, availability, environmental concerns and their optimization, the water sourcing is decided. Following are alternative sources of water that are generally suitable for domestic/ building water systems:

a) Direct connection to an existing water system,
b) Indirect connection to an existing water system (water hauling),
c) Development of groundwater resources,
d) Development of surface water resources,
e) Revamping of traditional water sources, and
f) Rainwater harvesting.

In majority of cases, in view of operation and maintenance considerations, it may be desirable to connect to an existing water supply system.

During the planning stage of project development, each potential source should be carefully evaluated in light of the water quantity and quality requirements. The final choice of source depends on many factors, such as the following:

1) Proximity and capacity of existing systems,
2) Necessary institutional arrangements for obtaining water from existing systems,
3) Yield and quality of available ground and surface water sources, and
4) Level of operation and management activity that is reasonable for the water system being designed.

The source of water is an important factor in deciding which environmental regulations apply, which shall be complied with. For the purpose, the sources may be classified as groundwater, groundwater under the influence of surface water, and surface water. Generally, surface water and groundwater under the influence of surface water, are regulated together.

Source selection should depend upon environmental considerations, reliability, cost (including capital cost and operations and maintenance cost) and water treatment facilities.

10.2.3 *Hot Water Systems Planning and Design Approach*

Water heating is a thermodynamic process using an energy source to heat water above its ambient/initial temperature. Typical domestic uses of hot water are cooking, cleaning and bathing. In industry, both hot water and water heated to steam have many uses. Appliances for providing a more-or-less constant supply of hot water are variously known as water heaters, boilers, heat exchangers, calorifiers or geysers. In domestic installations, potable water heated for uses other than space heating is known as domestic hot water. The most common energy sources for heating water are fossil fuels namely coal, natural gas, liquefied petroleum gas, oil or sometimes solid fuels. These fuels may be consumed directly or by the use of electricity (which may be derived from any of the above fuels or from renewable sources). Alternative energy such as solar energy, heat pumps and hot water heat recycling may also be used as available, usually in combination with backup systems supplied by gas, oil or electricity. The equipment used should be in accordance with the concerned Indian Standards available.

Alternative hot water systems such as electric, gas fired, oil fired and solar hot water systems; and hot water system using heat recovery are evaluated based on the availability, maintainability and limitation of the fuel feed. Large centralized hot water generation on electrical power should be discouraged and alternative clean and energy efficient fuels with efficient hot water generator should be evaluated in the project having high hot water requirement. All hot water system (equipment and plumbing pipes) shall be insulated with insulation to minimise heat loss.

10.2.4 *Strategies for Water Efficiency*

Efficient use of water is one of the underlying principles for sustainability in water management. Selection of water efficient products should be considered for both cold and hot water systems. Use of low flow fixtures for faucets, water closets, bath showers, hand-held bidet sprays, dish washers, aerators and clothes washers should be considered. One of the important considerations to ensure performance of low flow products is to design systems with correct pressures.

Low flow fittings should be considered mainly for areas with direct water consumption/human usage such as for wash basin taps, sink taps, and shower head, bath faucet and other faucet taps. Situations where water is filled for other requirements such as bath tub fillers, washing machine and for situations where water is filled, stored, used or situation where quantity of water supply may form the intent for which water is being drawn such as fire-fighting system and swimming pools, need not be provided with water saving features/use. The strategy of water efficiency shall also include low flush and dual flush cistern/flushing mechanism.

Technologies for high efficiency toilets and waterless

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urinals are emerging solutions but they need to be validated in the realistic use environment. It is important to ensure that the user's functional needs and satisfaction is not compromised. Social attitudes and user habits may need analysis while selecting such products. Dual piping is another strategy for efficient use of water. Planning and design approach to recycled water use should be integrated with dual piping systems and waste water reuse systems. In such cases, control of contamination in potable supply pipe shall be ensured.

10.2.5 *Strategies for Water Conservation*

Water conservation strategies aim to conserve the scarce water resource. Storm water is a major opportunity for conservation. Rainwater harvesting and rainwater recharge, and rainwater storage/use have a significant scope for conservation, especially at the neighbourhood level of developments. Rainwater can be harvested by adopting the following means:

a) Storing rainwater for ready use, in containers above or below ground.
b) Charging rainwater into the soil (groundwater recharging) to improve the underground water table. This needs to be critically planned as recharge is governed by stratification, groundwater table level and groundwater quality.

While water conservation strategies are most desirable in water-deficient areas, the maintenance of rainwater harvesting system assumes importance, else, they may not perform during raining days. For details reference may be made to **7.2**.

10.2.6 *Sustainable Design Detailing of Water Supply System Components*

For a system to be sustainable, the aspects of integrated performance, reliability, maintainability, life cycle performance including under adverse conditions and capability to undergo corrections during the use phase of the buildings, shall be considered. Pre-validation of integrated system performance is desirable. It is also desirable to consider implications of procurement, contractually assigned responsibilities and technical support during installation procedures. Quality assurance and quality control systems shall be employed to guide system design and execution.

10.3 Planning and Design of Waste Water System

This involves, quantity and quality assessment study, study of domestic water use-profile and scope of recycled water use, system conceptualization and integration with other water systems; planning for collection, treatment systems (combined and independent sewage and sullage treatment plant), treatment of on-site grey water and reuse. Sludge drying, composting and use for manure should be encouraged with proper hygiene considerations.

10.3.1 *Treated Waste Water Use for Landscape and Irrigation*

To reduce freshwater consumption for landscape/ irrigation, it is suggested to use alternative sources of water, such as grey water, reclaimed water and collected rainwater. Grey water is untreated household waste water from bathroom sinks, showers, bathtubs, and clothes washing machines. Grey water systems pipe carry this used water to a storage tank for later outdoor watering use. Reclaimed water is waste water that has been treated to levels suitable for non-potable uses. Collected rainwater is rainwater collected in cisterns, barrels or storage tanks.

Appropriate systems to monitor the quality of treated waste water in accordance with the standard practices should be provided while designing and analyzing the building use. Required safeguards should be provided and records of treated waste water parameters should be monitored on regular basis. Quality of treated waste water should be in compliance as required for non-potable and secondary use.

Proper techniques for landscaping and irrigation in respect of selection of appropriate plant species, use of efficient irrigation systems, etc, can result in substantial water saving (*see also* **7.1** and **7.3**).

10.4 Water and Waste Management During Construction

10.4.1 *Water Use During Construction*

Water from only authorized sources should be used for construction. Use of potable water for construction should be avoided unless required for specific purposes. It is suggested to consider use of treated waste water from appropriate sources with quality of treated waste water parameters confirming the quality required for use in construction activity. Water quality for concreting work shall be in accordance to Part 6 'Structural Design, Section 5 Concrete' of the Code. For sourcing of water, reference should be made to the statutory environmental provisions, if applicable. Inadvertent use of non-potable construction water for drinking purpose shall be prevented by proper distinct systems with appropriate markings. Wastage of construction water in piping network as well as storage tanks shall be prevented. Monitoring of water consumption shall be done by maintaining logs to control wastage and ensure its efficient use. Water efficient construction technologies should be considered along with other implications while deciding on the technology for respective construction activity.

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10.4.2 *Control and Use of De-Watering Output*

De-watering is essential for carrying out construction works below water table. The extent of de-watering is decided on structural considerations. Assigning responsibility within the organization shall ensure control of excessive de-watering. De-watering operations generate enormous amount of water. Organizations should explore to store and use water obtained as a result of de-water either at the site of construction or at another location productively.

10.4.3 *Management of Waste Water*

Construction sites may have a constraint of not having a waste-water disposal, hence, the arrangements have to be made within the construction site. It is imperative that the opportunities are identified to reduce the water consumption and re-use treated waste-water. In the absence of appropriate waste-water disposal facilities, unhygienic and unsightly conditions may prevail which may cause water borne diseases and act as breeding ground for mosquitoes and develops unhealthy environment with bad odour and flies. Wastewater at construction sites may contain residues of construction materials (such as cement, sand, bentonite slurry, etc), oils and domestic waste. It should be possible to treat water, specially containing residues of construction materials and re-use the same in construction. However, disposal of other forms of wastewater should be planned in suitable manner at site after appropriate treatment.

10.4.4 *Waste Management During Construction — See* **12.7**.

10.5 Process Water Requirement and Effluent Treatment

Certain processes, such as pharmaceuticals, hospitals, industrial processes, etc, need water quality specific to their needs. Water for such processes is to be provided in accordance with industry standards applicable to the respective industries as well as the applicable statutory environmental provisions. Therefore, planning and design of water supply schemes for such processes shall adhere to the concerned regulations and standards.

Effluent treatment of some special processes is a cause of concern. The impact of treatment of water for supply as well as process effluent shall be assessed through environmental impact assessment (EIA). Environmental management plans (EMP) should be developed to mitigate the adverse environmental impacts. In such situations, it is desirable to establish proper environmental management system (EMS) to ensure compliance to the norms through defined managerial responsibility. For such special process facilities, proper water and effluent quality testing laboratory shall be established and records maintained to control compliance parameters.

10.6 Planning and Design of Solid Waste Management System

Solid waste generated in buildings, if not managed properly may result in unhygienic conditions, spread of foul smell, unsightly conditions and hazards such as fire within the buildings, and hindrance in productive use of building. The solid waste has also bearing on the functional planning of buildings. Collection and movement of solid waste often overlaps with building circulation and, hence can cause interference with the use that may be prohibited in occupancies such as hospitals and hotels. Thus, the interventions during planning and design are critical for solid waste management.

The cumulative effect of improper solid waste management in buildings and its indiscriminate dumping in landfill sites, is an environmental problem of immense proportions. While reduction of solid waste is aimed during building use, as a part of solid waste management it, should be considered to utilize the considerable scope of using solid waste as a resource for waste recycled products and energy. For this, solid wastes recycle facilities should be considered for building complexes. The aim should be to reduce the burden on municipal waste disposal facilities and thereby, reduce the need for transportation of wastes. Solid waste processing may include sorting out various materials and compacting for effective onward transport to re-cycling plants.

10.6.1 *Documentation of Nature of Waste and Quantification*

For proper planning and design of solid waste management, study of various functional areas shall be carried out. The study should include identification of solid waste that may be generated during use, their characteristics and the anticipated quantities. It may be desirable to study similar projects and take cognizance of their experiences while undertaking such identification.

It may also be desirable to study the socio-cultural context affecting behavioural aspects of users to anticipate extent of their participation in solid waste management process and appreciation of systems implemented. In planning solid waste management system from sustainability point of view, the role, responsibilities and response of users should be considered. The context of users, characteristics of waste and expected quantities shall be documented for making strategic decisions.

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10.6.2 *Identification of Strategies for Solid Waste Management*

Considering the solid waste characteristics, expected quantity, socio-cultural context of users and possible technological solutions, strategic planning of solid waste management shall be developed. Technological and managerial alternatives shall be explored and compared. Reference shall be made to the statutory provisions governing building use and the environment. While developing strategies, the following aspects shall be considered:

a) Solid waste minimization;
b) Space requirement for collection sorting, movement for sorting and for disposal, including on-site pre-processing and off-site transport in accordance with legal provisions;
c) Effectiveness of possible alternatives;
d) Environmental sensitivity for solid waste processing and constraints of off-site disposal;
e) Organizational constraints of building occupants to participate and involve in management of solid waste; and
f) Economic considerations of technology and their reliability.

The strategic approach to solid waste management shall be documented as a report that shall form a basis of planning and engineering services design.

10.6.3 *Solid Waste System Planning*

Documented strategic approach should lead to planning of the system as the preliminary design begins to evolve. Design configuration shall consider solid waste management also as one of the functions of the building. Planning and design shall include appropriate physical space requirements for,

a) provision for collection at suitable locations for solid waste to facilitate the occupancy functions;
b) need for ventilation, washing, isolation and provision for persons performing duties of waste collection;
c) provision of appropriate containers for wastes;
d) circulation planning for solid waste from individual collection locations to central facility (for example, waste chutes, physical movement through service corridors, etc);
e) segregation space with necessary illumination, ventilation, washing and other provisions for performing segregation duties at appropriate location(s);
f) treatment facility within the building or building complex for compacting for recycling and disposal (for transport to city level facility), composting for biodegradable waste, re-cycled materials, and heat recovery during disposal through thermal chambers; and
g) composting and manure generation systems in buildings, clusters, neighbourhoods, districts and city levels.

Composting and manure generation at all levels opens up channels to capture substantial part of biodegradable waste and increases green activity like gardening and vegetable growing. The system can reduce, recycle, reuse and regenerate as per sustainability concept. Adequate protection shall be provided to segregate waste area to permit restricted access to only authorised personal. Access to birds and animal should be strictly avoided. The solid waste disposal system should try to use the combustible but non-recyclable items like dry plant parts, wooden wastes, fabric waste, etc, for waste-to-energy systems at district level on wards. Using combustible garbage items for energy generation will reduce volume of garbage to be disposed, transportation along with requirement of land fill sites. Energy generation will reduce the carbon foot print of the area/ zone and hence the sustainability of the building.

A schematic plan for solid waste management shall be developed and coordinated with the building plan. Schematic plan shall also indicate technologies employed in the process of solid waste management after due consideration to alternatives, cost implications to the project; statutory approvals that may be needed; specifications of civil and engineering works needed to be executed, contractual conditions for executing agencies; etc. Documented plan shall be the basis for preparing detailed designs.

10.6.4 *Design Detailing of Solid Waste System Elements*

Design of solid waste system shall coincide with detailed architectural and engineering design. While physical space requirements are necessary for the architectural design, design calculations for engineering services requires inputs from various elements of waste management. Design detailing should be adequate to ensure information needed for vendor selection and tender action.

System design detailing shall ensure that the components are compatible with each other. For instance, the design of segregation facility shall consider aggregate space requirement arising out of various collection locations. Similarly, the quality of finishes should be compatible with the nature of waste and the processes needed.

From sustainability considerations, it is desirable that the representative group and other stakeholders review

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the proposed solid waste management system, including technical and managerial component, so that the performance is assessed from multiple standpoints. *See also* Part 9 'Plumbing Services, Section 3 Solid Waste Management' of the Code.

10.6.5 *Provisions for Waste(s) Requiring Special Management*

Wastes generated in special occupancies and processes need safe handling and disposal in accordance with industry practices, and statutory and environmental laws. Buildings are required to make special provisions, physical spaces and measures to collect, segregate, transfer and dispose of the waste. Management system should be established for disposal of such special wastes. Management systems should define delegation of responsibilities, prerequisite competencies, procedures, protection for personnel performing waste management duties and procedures for emergencies and disaster management. Issues related to wastes requiring special management shall be taken care of as follows:

a) *Biomedical hospital waste management* — Hospital wastes include human parts, infectious materials, shrapnel (needles, surgical blades, etc) and radioactive materials. Each of the waste types shall be collected and segregated at designated locations as per the norms applicable, with adequate precautions for safety, disinfection and containment. The circulation route for waste shall be segregated from other hospital circulations. Location for further processing of waste for final disposal shall be defined at the master planning stage. Special care shall be taken for ventilation exhaust so that the same does not mix with air intakes in hospital ventilation system. The hospital waste shall be treated using appropriate technologies like incineration, autoclaving, microwave or hydroclave and also as per the statutory laws and procedures.

b) *Management of radioactive waste* — Disposal of radioactive waste shall be carried out strictly in accordance with the Board of Radiation and Isotope Technology (BRIT)/ Atomic Energy Regulatory Board (AERB) regulations/guidelines. In such cases, proper records shall be maintained as required by the regulatory authority concerned.

c) *Management of toxic and chemical waste* — Toxic chemical wastes shall be disposed of according to the relevant regulations, standards and best industry practices. Under no circumstances, these should be disposed into sewerage. Specific arrangements shall be provided for management of emergencies such as control of spread of toxic fumes and emergency health care to the exposed populations.

d) *Management of inflammable and combustible wastes* — Combustible and inflammable waste is a potential source for fire hazards in buildings. Collection, segregation and handling of such wastes shall not be carried out in vicinity of any source of ignition. Adequate provisions for spread of smoke and fire-resisting enclosures shall be provided at locations for collection and segregation. Necessary fire protection measures, such as portable extinguishers, fire hydrants and sprinklers should be provided considering fire risk, damage potential and statutory provisions. Provisions under explosives act shall be followed for storage and disposal, as applicable.

e) *Management of electronic waste* — These shall be taken care of in accordance with the applicable act, rules and regulations relating to the management and handling of e-waste.

10.7 Integrated Approach to Water Supply, Water Waste and Solid Waste Management

An integrated approach towards water supply, waste water and solid waste management should be adopted with a view to meeting the objectives as given in **10.1** to **10.6** in respect of these.

10.8 The construction and demolition waste management shall be done in accordance with **12.7**.

11 BUILDING SERVICES OPTIMIZATION

11.1 General

Optimization of electro-mechanical services is one of the important aspects towards achieving a sustainable building. Reduction in heating, cooling and lighting loads through climate-responsive designs and conservation practices can enhance the energy efficiency of a building. In addition, an integrated project delivery (IPD) approach results in a well-designed, cost effective solution wherein all building systems and components can in coherence facilitate overall functionality as well as required environmental performance. The passive design features and proper initial planning helps in reduced energy demand and, therefore, the same should be carefully analysed prior to actual sizing of equipment where provided.

11.2 Concept Development

In addition to achieving the optimum energy performance, the building should also provide the desirable thermal and visual comfort to its occupants.

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Incorporating solar passive techniques in a building optimizes building performance by minimizing the use of artificial energy and thereby minimizing load on conventional systems for heating, cooling, ventilation, lighting, etc.

Solar passive techniques that can be adopted in different climate zones of India are,

a) landscaping (to reduce heat island effect);
b) optimum building orientation;
c) arrangement and shape of buildings;
d) effective surface to volume ratio;
e) location and size of openings on building facade and other elevation;
f) glazing type and performance; and
g) shading devices on windows and judicious selection of building materials.

Prior to developing the design drawings, the design team shall carry out a thorough review of the fundamental assumptions, owner's brief and available resources on site, in an integrated manner, addressing the key target issues such as the following:

1) *Building orientation* — Building orientation affects many aspects ranging from energy performance to visual simulation of the building. Building location and its exposure to solar direct radiation affect the HVAC design, day-lighting strategies and the overall energy demand.
2) *Building envelope* — Building envelope provides a starting point for determining heat transfer coefficients for external walls/ceiling/ roof and glazing (*see* **8** for details).
3) *Harvest site energy* — Project shall explore the use of natural resources such as daylight, variations in ambient temperature (economizer cycles) to reduce cooling/heating demand and utilize solar/wind energy. For large projects, the master planning team should explore district level solutions and identify potential site integrated opportunities.
4) *Design assumptions and internal load assessment* — Energy demand reduction may be accomplished by carefully analyzing the initial design assumptions and by reducing internal heating and/or cooling loads and interior lighting improvement. It can be achieved through multiple design strategies such as reducing the overall building footprint, reviewing the indoor temperature design criteria to allow for a wider acceptable band, on-demand operation of utilities (using sensors to link the operation to an established criterion), climate responsive envelope, etc. In case of air-conditioned building, the project team may also consider a review of indoor design temperature (which is consistent with adaptive thermal comfort model) as every degree shift closer to outdoor design temperature can help in optimizing the equipment sizing. In addition, the thermostat set point temperature can be kept closer to seasonal average outdoor temperature during regular operation to minimise building energy consumption.
5) *Maximize efficiency* — Energy consumptions should be optimized to avoid over-sizing of equipment rating. It may be achieved by analyzing the estimated monthly and annual energy consumption profiles of the building and compare the same with building peak loads. Computer based design tools may be used to identify feasible energy conservation measures for a building.

11.3 Natural and Mechanical Ventilation Strategies

The term natural ventilation is used to describe air movement caused by naturally produced pressure differences due to wind and the stack effect. Natural ventilation is achieved by infiltration and/or by allowing air to flow in and out of a building through doors, windows, openings, louvers and *Jalis*. Typically, preferred mode of ventilation in non-air conditioned spaces is by natural draft or convection. A thorough assessment of natural *versus* mechanical ventilation strategy should be performed to minimise the need for artificial cooling by lowering the space temperatures (of attics) as well as eliminate/minimise the need for mechanical blowers. For this, validation through computer simulation may be helpful. Following are some of the important aspects which may be considered for the purpose:

a) *Stack effect* — Convective air currents may be induced in a building by exploiting temperature difference between a space and the environment adjacent to it as the lighter warm air rises to be replaced by cooler air. This phenomenon may be especially useful for ventilation in tall buildings, vertical passages such as stairwells, elevators, and shafts. This helps in reducing the fan power energy demand.
b) *Wind-induced pressure differences* — Wind pressure on a building depends on wind direction, speed, shape of the building and location of its openings. The spatial cooling techniques may be explored through windows/ openings to induce airflow from the windward side and outflow on the leeward side. This is especially suited for tall buildings.

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c) *Night purging* — Night purging takes advantage of the diurnal variation in temperatures to lower the cooling demand of the space. In regions, where a significant difference exists between day and night temperatures, this technique is useful for dissipating heat by flushing the indoor space through ambient cool air.

d) *Wind towers* — Use of wind towers may be explored in hot and dry climates for cooling. The function of this tower is to catch cooler breeze that prevail at a higher level above the ground and direct it into the interior of the buildings. Wind towers operate in many ways depending on the time of day and wind availability.

11.4 Passive Heating Techniques

Passive heating is the spontaneous warming effect resulting from the absorption of solar radiation wherein solar energy is exploited to induce heat flow from the affected surface to indoor air, as well as promote heat storage within the building structure. In the climatic zones requiring indoor space heating, it may be explored to use the following strategies:

a) *Direct gain method* — Controlled sun may be permitted into the habitable spaces through an opening to directly heat the floor, walls or other internal components and objects, which, in turn, heat the air within the room. Some examples of building materials that enable direct solar gain by acting as thermal storage mass are concrete, bricks, stone and water. The high thermal mass is usually located in the internal or external walls, floors or other built-in structures that receive sun directly.

b) *Indirect gain* — A thermal storage wall may be placed between the glazing and habitable space which prevents solar radiation from directly entering the living space. The solar energy incident on wall is absorbed by the wall and then indirectly transmitted to the habitable space over a longer time.

c) *Trombe wall* — It is a thick solid wall with vents at its lower and upper ends. This wall may be placed directly behind the glazing with an air gap in between. The vents act as inlets of warm air into the room and as outlets for flushing out cool air from the room.

d) *Solar chimneys* — This system is a kind of modified trombe wall that is incorporated into the roof. A solar chimney is essentially a collector panel with minimum thermal inertia on the south facade of the building. It absorbs incident solar radiation and heats up the air inside the space.

e) *Sunspaces/Solaria* — It is an integration of direct gain and thermal storage concepts. Solar radiation admitted into the sunspace heats up the air, which by convection and conduction through the mass wall reaches the habitable space. It essentially consists of a greenhouse constructed on the south side of the building with a thick mass wall linking the two.

11.5 Passive Cooling Techniques

Passive cooling systems rely on natural heat sinks to remove excess heat energy from a building. They derive cooling directly from evaporation, convection and radiation without using electrical energy. All strategies rely on diurnal changes in temperature and relative humidity. The applicability of each system depends upon the prevailing climatic conditions.

The building envelope can be designed to effectively exchange heat with the surrounding ambient air. In order to have an appreciable net heat flux between two bodies, the temperature difference should be significant (typically at least 7°C). Some of the techniques are as follows:

a) *Nocturnal cooling* — In this technique, night sky cooling may be very effectively used to dissipate the heat stored in building envelope so that it is regenerated to store the day heat gain. Such buildings will require high thermal mass and application is ideally suited for day use buildings such as offices.

b) *Roof pond with movable insulation* — A water body on the roof may provide cooling where during summers it is covered with insulation with a surface finish of low absorptivity. During the day time, this minimises the solar radiation impact on the roof, as the water in the pond holds the heat gain and further increases the time lag. During the night, insulation is removed and the heat stored in the day time is exchanged with the night sky. In winter, the operation of the movable insulation is reversed to allow heat gain in daytime and reduce heat loss during the night. All such provisions shall however be without prejudice to the need of compliance to the requirement of structure safety as prescribed in this Code.

c) *Courtyards* — Due to incident solar radiation in courtyards, the air gets warmer and rises. Cool air from ground level flows through louvered openings of rooms thereby inducing airflow.

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11.6 Pre-Cooling of Ventilation Air

To conform to the IAQ requirements, it is necessary to introduce outside air for ventilation of conditioned spaces. This enables reduction in internal air-contaminants, as well as dilutes odour from occupants. The introduction of hot and humid air leads to significant increase in cooling/heating load and, therefore, strategies, as follows, may be considered to minimise the energy demand:

a) *Demand controlled ventilation* — Carbon dioxide or air quality sensors may be used to check the level of pollutants in the occupied space and provide the indication to building management system to control the opening of outside air dampers thereby effectively providing ventilation on demand.

b) *Heat recovery* — Pre-cooling of hot/cold outdoor air can be achieved by recovering energy from exhaust streams of a building (toilet/pantry/atrium) through either heat recovery wheel, run around coils, cross plate heat exchangers or heat pipes. This helps in lowering the installed capacity of cooling/ heating equipment.

c) *Economizer cycles* — In certain climates, air and/or water side economizer cycles may be used to take advantage of lower ambient air temperatures. Outside air load may be reduced by pre-treating the air and possibly combining strategies like earth air tunnel and adiabatic cooling.

11.7 Low Energy Mechanical Cooling Techniques

It is desirable to explore possibility of using low energy cooling/heating techniques for indoor space as an alternate for compressor driven energy intensive conventional air-conditioning systems. Passive systems in combination with mechanical systems may also be suitably hybridized to offer systems that have significant lower energy consumption in comparison to conventional HVAC systems. The following alternative technologies may be considered for implementations to comply with the comfort criterion:

a) *Evaporative cooling* — It is suited for hot climates with low humidity. The cooling of air is achieved by simple evaporation of water in air. In high humid climates, evaporative cooling may have little thermal comfort benefit beyond the increased ventilation and air movement it provides. Various types of evaporative coolers are as follows:

   1) *Direct (single stage) evaporative cooling (open circuit)* — It lowers the temperature of air by using latent heat of evaporation thereby changing water to vapour state.

   2) *Indirect evaporative cooling (closed circuit)* — It is similar to direct evaporative cooling, but uses a heat exchanger. In addition, in indirect evaporative cooling, the cooled moist air does not come in direct contact with the conditioned environment. Efficiency of these systems is low as compared to direct evaporative cooler.

   3) *Two-stage evaporative cooling or indirect-direct system* — It does not produce humidity levels as high as that by traditional single-stage evaporative coolers, but operate at a lower efficiency. Two stage evaporative coolers combine indirect with direct evaporative cooling.

   4) *Passive (or natural) downdraft evaporative cooling (PDEC) system* — It is a low energy passive system. PDEC system does not need the blower and require only pump for re-circulating water. Some designs may even eliminate the re-circulation pump and utilize the pressure in the supply water line to periodically surge water over the pads thereby eliminating the requirement for any electrical energy input.

b) *Desiccant dehumidification/cooling systems* — Desiccant dehumidification/cooling technology provides a tool for controlling humidity levels for conditioned air spaces.

c) *Geothermal heating and cooling* — Geothermal exchange loop use the constant temperature of the earth as the exchange medium instead of the outside air temperature. As the ground is warmer than ambient air during winters and cooler than ambient air during summers, geothermal exchange loop harnesses this phenomenon by exchanging heat with the earth through a ground to water/ air heat exchanger. Thus it helps in meeting indoor heating/cooling demand and also hot water generation for small scale buildings like homes and commercial establishments. Geothermal exchange loop can be classified as closed looped system and open loop system. The pipes can be installed in three ways, namely, vertically, horizontally and in a pond or lake, depending upon the availability of land area and soil type at the chosen site.

d) *Earth air tunnel system* — As earth temperature remains constant throughout the year at a depth of 4 m to 5 m, an earth air tunnel (EAT) is created by burying a pipe at this depth. Ambient

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air, thus sucked from one end is passed through EAT and depending on the ambient temperature, air gets cooled in summer and heated up in winter. This cooled/heated air is then supplied to the various areas in the building for meeting space cooling/heating demand and can provide recommended thermal comfort to the building occupants.

e) *Radiant cooling or thermally active building systems* — These systems work on the principle of thermal storage of energy (heating/cooling) within the building structure components such as slabs, false ceiling, walls, etc. Further the building components radiate the heat/coolness to the building interiors thereby off-setting the heating or cooling loads. These systems specially work best in climates with high diurnal variations. These systems can be integrated with the HVAC system or can operate independently.

11.8 HVAC System

The following may be considered with regard to planning, design and installation of HVAC system:

a) *Equipment sizing* — As the air conditioning system account for nearly 50-60 percent of annual electricity bill for a conditioned building, prior to equipment selection, it is important to optimally size the cooling and heating equipment of the building. As the internal loads may not peak simultaneously at any given time, a suitable diversity factor may be considered for sizing the equipment. Multiple smaller machines, chiller with multiple compressor or variable frequency drive (VFD) on chiller may be explored for ensuring operation at highest efficiency point in spite of variation in demand.

b) *Unitary/split equipment* — The unitary products like window air conditioners and split units are ideally suited for standalone smaller applications like houses and shops. However, the IAQ and energy efficiency need a special attention. These shall conform to relevant Indian Standards.

c) *Variable refrigerant flow systems* — These are the systems for middle size commercial establishments like shops, small hotels, nursing homes, restaurants, large residences, bank, education institutes, small office, etc and can provide a superior performance over conventional unitary equipment/package units. However, the IAQ, redundancy and long refrigerant pipe lengths required, need a special attention.

d) *Central plants* — These are ideally suited for all medium and large scale projects that require air-conditioning wherein the chilled water is transported to remote air terminal units for heat transfer. The water chilling machines (chillers) are categorized with respect to type of compressor and heat transfer mechanism. Their selection calls for a careful review in terms of anticipated variation in load, part load efficiency, redundancy, etc. The benefits of central plants include highest efficiency, reduced maintenance costs and overall lower total installed capacity (due to overall diversity) in comparison to other options.

e) *Water chilling machines (chillers)* — Chillers may be used either singularly or in groups and in either air-cooled or water-cooled options. As a guideline, air-cooled chillers are recommended when water is either in scarce supply and/or expensive or in case the ambient conditions are favourable. Water-cooled chillers are more energy efficient than the air-cooled chillers but do require a cooling tower which demands a supply of suitably treated water. Cooling tower may be provided with side stream filtration system to conserve water that is wasted away during blow down. They have a longer operational life and are often selected for larger capacity applications. It is worthwhile to look at other saving strategies like heat recovery (heat machine/heat pumps/ de-superheater/double bundle condensers/ condenser heat recovery/heat recover in AHUs), possibility of hybrid cooling options or closed cell cooling towers to reduce energy consumption. The use of recycled water from a sewage/effluent treatment plant for cooling tower make-up is desirable.

There are two recognized methodologies to determine chiller efficiency namely coefficient of performance (COP) and integrated part load value (IPLV). This offers a mathematical way to rate and compare single chillers but is not suitable for multi-chiller configurations. With energy modelling, multi-chiller configurations may be simulated with greater accuracy. Early use of recognized modelling software in the design process may help in addressing common design shortcomings such as, the tendency to over-size chiller installations.

Parameters that need to be optimized while designing a chiller-water plant include flow rates and temperatures, pumping options, plant configuration and control methods. For each specific consideration, the design professional

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should understand the owner's need, objectives and implement the chiller plant options to best satisfy them.

It is also worthwhile to look at other energy saving strategies like heat recovery (heat machine/de-superheater), low flow applications (higher ΔT) on chiller and condenser, low approach cooling towers, series counter flow configuration, use of variable frequency drives, advanced controls, water economizers, lower fouling factors, higher chilled water temperature, etc, for reducing the energy demand. In addition, use of VFD in compressor may also be explored in case it offers improved part load efficiency.

f) *Refrigerants* — Refrigerants are classified into two classes based on their toxicity, namely Class A having lower chronic toxicity and Class B having higher chronic toxicity. They are classified into four classes based on their flammability, namely, Class 1 (no flame propagation), Class 2L (lower flammability), Class 2 (flammable) and Class 3 (higher flammability).

Refrigerants shall be designated and classified for safety in accordance with the accepted standard [11(33)].

1) *Matrix Diagram of Safety Group Classification System*

The toxicity and flammability classifications for refrigerants as above yield eight safety groups, namely, A1, A2L, A2, A3, B1, B2L, B2 and B3. These safety groups are represented by the matrix shown below:

Safety Groups as Determined by Flammability and Toxicity

	Safety Group	
Toxicity → / *Flammability* ↓	*Lower Toxicity*	*Higher Toxicity*
Higher flammability	A3	B3
Flammable	A2	B2
Lower flammability	A2L	B2L
No flame propagation	A1	B1

2) While selecting refrigerants, manufacturers and designers shall adopt balanced approach considering environmental impact and human health. The key criteria that shall be considered are as follows:

i) *Ozone depletion potential* (*ODP*) — ODP of the refrigerant should preferably be zero and shall be as permitted under *The Ozone Depleting Substances (Regulation and Control) Amendment Rules*, 2014 as amended from time to time (*see* Note);

ii) *Global warming potential* (*GWP*) — GWP of the refrigerant should preferably be low to reduce green-house gas (GHG) emissions, which is in line with the ongoing discussion for phase-down of production and consumption of hydrofluorocarbons (HFCs);

iii) Refrigerant with zero ODP and low GWP should be adopted for balance approach considering overall environmental impact;

iv) *Flammability* — The refrigerant should preferably be non-flammable/ having flammability as low as possible, and suitable risk mitigation process/infrastructure (sensors, ventilation, etc) should be opted to mitigate the risk of flammability, if any in line with the accepted standards;

v) *Toxicity* — *The* refrigerant should have toxicity as low as possible, and suitable risk mitigation strategies/ infrastructure (sensors, ventilation, etc) should be opted to handle toxicity, if any in line with the accepted standards; and

vi) The refrigerant should also support other key performance parameters, including high energy efficiency, low emissions, chemical and thermal stability and material compatibility.

NOTE — The production and consumption of ozone depleting substances (ODS) including HCFCs, for example, HCFC-22 and HCFC-123 is being phased out by 2030. The import of refrigeration and air conditioning equipment containing HCFCs has already banned from 10 July 2015, and the manufacturing of all such equipment with HCFC will be banned in the country from 01 January 2025 in accordance with *The Ozone Depleting Substances (Regulation and Control) Amendment Rules,* 2014.

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For ODP, GWP and safety group (flammability and toxicity) of different refrigerants, reference shall be made to Table 8. As there are ongoing developments with respect to refrigerants with HCFC Phase-out Management Plan (HPMP) and HFC phase down proposals, latest regulations applicable at the time of selection of equipment/systems with various possible refrigerants shall be followed. As research is going on for alternative refrigerants to various HCFC/HFC/HFO refrigerants, it is recommended that project teams should make a conscious effort to select equipment/systems with refrigerant with high energy efficiency, least negative impacts on health, safety and environment as per the latest developments.

g) *Chilled water pumping systems* — In a central plant, the pumping systems contribute to second largest energy consumption source and it should be carefully analysed for selection for highest efficiency point and required head only. It is recommended to install variable frequency drives for all applications. There are following two types of chilled water pumping system options:

1) *Primary-secondary (decoupled) system* — In this system, flow rate through each chiller remains constant and yet accommodates a reduction in pumping energy, since the system water flow rate varies with the load.
2) *Primary only variable flow (PVF) system* — In this system, flow varies through evaporator. It helps in saving on initial as well as operating costs/energy. The control strategy/priorities of a PVF system are significantly different from that of a primary-secondary system.

h) *Thermal energy storage (TES)* — TES is a technique ideally suited for utilizing advantage of differential power tariff and power rationing during peak load hours. This becomes a tool for use by the designer as conventionally peak load may be considered as refrigeration load for selecting equipment capacity; thus, in such case most part of day refrigeration machine operates at part loads or kept idle. To

Table 8 ODP and GWP Values (100 Year Values) and Safety Group of Different Refrigerant Types

[*Clause* 11.8 (f)]

Sl No.	Refrigerant		ODP	GWP	Safety Group {*see* Accepted Standard [11(33)]}
	Refrigerant Number	Composition Designating Prefix			
(1)	(2)	(3)	(4)	(5)	(6)
i) **Hydrochlorofluorocarbons (HCFC):**					
a)	R-22	HCFC	0.055	1 810	A1
b)	R-123	HCFC	0.02	77	B1
ii) **Hydrofluorocarbons (HFC) and their Blends:**					
a)	R-32	HFC	0	677	A2L
b)	R-134a	HFC	0	1 300	A1
c)	R-245fa	HFC	0	858	B1
d)	R-404A	HFC	0	3 922	A1
e)	R-407C	HFC	0	1 774	A1
f)	R-407F	HFC	0	1 825	A1
g)	R-410A	HFC	0	2 088	A1
h)	R-507A	HFC	0	3 985	A1
j)	R-448A	HFC	0	1 386	A1
iii) **Hydrofluorooelefins (HFO):**					
a)	R-1233zd(E)	HCO	~0	1	A1
b)	R-1234ze(E)	HFO	0	0.97	A2L
c)	R-1234yf	HFO	0	0.31	A2L
d)	R-1336mzz(Z)	HFO	0	2.0	A1
e)	R-514A	HFO	0	1.75	B1
iv) **Hydrofluoroolefins (HFO)/Hydrofluorocarbons (HFC) Blends:**					
a)	R-452A	HFO and HFC blend	0	2 141	A1
b)	R-452B	HFO and HFC blend	0	675	A2L
c)	R-513A	HFO and HFC blend	0	573	A1
v) **Natural Refrigerants:**					
a)	R-718 (Water)	—	0	0	A1
b)	R-744 (Carbon dioxide)	—	0	1	A1
c)	R-717 (Ammonia)	—	0	0	B2L
d)	R-290 (Propane)	HC	0	3.3	A3

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overcome this shortcoming, concept of thermal energy storage may be evaluated to store the energy during the time when load is less than installed capacity and releases the energy when the load is more.

Thermal storage systems may be suitable for situations wherein, due to water shortage the usage of water cooled chillers are limited. The air-cooled chillers may run during nights when the ambient temperatures are lower. Also, the technique may help reduce the size of the refrigeration equipment, installed electrical sub-station equipment and power back up requirement. Recommended to evaluate the option of placing ice/chilled water storage tanks in parallel/series arrangement.

j) *Vapour absorption system* — Alternate sources of energy particularly waste steam/ heat may be used for refrigeration. One such system uses water as the refrigerant and lithium bromide as the absorber. It has less moving parts and hence results in lower power consumption. Vapour absorption system may also utilize waste heat from the diesel/gas generating sets/bio-waste using heat recovery boilers or heated water from the solar panels to produce cooling in buildings.

Vapour absorption machines may also be considered in co-generation systems.

k) *Air handling units (AHU)* — Choice of air handling units with supply and return/exhaust air fans may help in energy saving. During free cooling conditions when the ambient temperature is comfortable, the supply fan draws all outside air, whereas the return/ exhaust fan exhausts the air from the conditioned area. The air handling unit with VFD may be considered so as to meet the varied air quantities for various seasons. This can work in tandem with a variable frequency drive.

The air handling units work in sequence with heat recovery wheel with which the fresh air drawn may be cooled by return air resulting in energy saving while maintaining the IAQ levels which requires higher outside air. Toilet exhaust fans may be connected with an infrared sensor/timer or such other means which facilitates operation only during occupancy.

m) *Server rooms/data centre* — Facilities such as server rooms and data centre that require round the clock operation and high energy demand are beyond the purview of this Part. However, as smaller server and hub rooms are part of every building that has multiple computers, for such installations use of dual fluid precision units may be considered. When the chiller is in operation the unit is running in chilled water mode and shifts to direct expansion (DX) mode when the chiller is not functional. When the chilled water temperature is maintained higher, it can run on both chilled water and refrigerant mode so as to meet the duty conditions. The blowers may be of variable volume type or with electronically commutated (EC) motors to meet varying duty conditions. Where DX system is used, its unit should have variable speed compressor to best efficiency.

n) *Fans and blowers* — Proper selection of a fan for a given application requires consideration of the following factors:

1) Required air flow (volume);
2) System pressure drop at required flow;
3) Operating point;
4) Type of installation namely, ducted or free flow;
5) Air flow configuration, for example direction of inlet and outlet flow;
6) Nature of air to be handled namely, clean, contaminated or hot; and
7) Space constraints.

It is recommended to select high efficiency fans and couple them with equally efficient motors (preferably high efficiency IE2/IE3 type as per accepted standard [11(34)]. Use of EC motors can also be a viable option for lower rating fans. Other factors such as type of belts (V or flat), airflow (axial/centrifugal/ mixed mode), fan types (backward/forward/ plug) and use of guide vanes, may be considered appropriately.

p) *Air distribution* — The design of an air distribution system should take into consideration the factors of occupant variables and space conditions so that occupants' heat loss is maintained at a comfortable rate. Occupant variables include activity level, metabolic rate and clothing levels. Space conditions are influenced by dry bulb and radiant temperatures, relative humidity and air velocity. Various types of air distribution methodologies that may be adopted on a project are:

1) *Mixing air systems* — To improve the efficiency of such mixing air systems, a careful analysis of the energy savings accrued due to improved COP such as the

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increase in fan power should be carried out for effective implementation. Most mixing air systems tend to be designed using a constant volume flow in the occupied zone. A good strategy for optimizing energy usage should be to examine the feasibility of incorporating a pressure independent, variable air volume system. Such systems can constantly monitor the air flow needs in any occupied zone and continuously modulate the air flow to the occupied zone.

2) *Variable air volume systems* — Cabins and conference areas which have partial usage may be provided with variable air volume units so that they may be operated based on the usage which further results in energy saving. Variable air volume units coupled with motion sensors enables closure of the units to the minimum levels to enhance energy efficiency.

   Open areas may also be provided with variable air volume units for various zones so that the zones may be operated based on the usage. They may be actuated by a motion sensor so that the VAV will close to the minimum position in the un-occupied areas. Variable air volume unit further facilitates change of temperature set points during various seasons. Zones located in the building periphery which have the direct solar exposure should be equipped with variable air volume units.

3) *Displacement Systems* — In the case of displacement systems, while evaluating the primary air flow, complete mixing is not assumed. Only direct heat infiltration into the occupied space from the entire fabric load is considered for the room sensible heat evaluation. All fabric loads from walls and glazing above the occupied zone, the loads from the ceiling, lighting, etc, should be accounted for, for determining the return air heat gain. This results in significantly lower primary air requirement, leading to smaller fan and fan motor sizes. In addition, due to the higher primary air temperature, the COP of the refrigeration system may be significantly improved.

   The ventilation efficiency of the displacement system is generally about twenty percent higher as compared to a mixing air system. This permits the use of lesser volumes of outside air for ventilation. As the primary air is admitted directly into the occupied zone, it shall be done at very low air speeds to avoid uncomfortable drafts. This results in low outlet velocity, low noise levels and pressure drops leading to quieter operation, improved thermal comfort, increased energy savings and improved IAQ.

4) *Under floor air distribution systems* — A well designed system requires less energy and is more flexible in providing and maintaining building services than traditional overhead systems. Low operational static pressures in the under floor air supply plenum may help to reduce central fan energy use. In such system, the thermal exchange with surroundings is reduced leading to better efficiency. For improved thermal comfort and maximized energy savings, it is also possible to provide under floor VAV terminal units. A ducted system facilitates the use of under floor VAV Units, particularly in perimeter zones or in special zones that are subject to load variations. It is desirable to insulate the under-floor to prevent thermal gain, especially if the floor below is at elevated temperatures, and also to prevent condensation on the ceiling slab below.

5) *Chilled beam and slabs systems* — Chilled beams and slabs are increasingly finding acceptance for energy efficient, comfortable, quiet operation in a robust system with very few moving parts and low maintenance needs. The system benefits from the increased density and energy carrying capacity of water, hence are more energy efficient than forced air systems.

q) *Ducting* — The ductwork should be appropriately sized and balancing dampers need to be installed to reduce velocity losses. Ducts with larger cross sectional areas have much lower resistance and can reduce fan energy significantly. Duct having cross-sectional shapes such as round or oval can further reduce losses. Lower air speeds in duct reduce energy needs and noise. Ducts should be insulated and sealed but indoor air quality issues should also be considered. Factory made ducts with good workmanship may result in the lower leakage losses.

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r) *Variable speed drives* — Variable frequency drives (VFDs) are used for energy saving. These drives may be used on condenser water circulation pump (to modify the flow rate), cooling tower fans (to modulate the speed of fan during low ambient). Chillers, primary and secondary water circulation pumps set by sensing the temperature and pressure differential in the chilled water lines. Two way motorized valves in the air handling units may be actuated by a thermostat which varies the flow according to the loads resulting in pressure changes which may be sensed and used for changing the speed of the pump sets.

These drives should be used on,

1) condenser water circulation pump to change the flow during low load or low condenser water to optimize the plant room efficiency;
2) cooling tower fan to change the speed of fan during low ambient to optimize the plant room efficiency;
3) water cooled chillers with VFD unload more energy efficiently on part load, and; and
4) primary and secondary chilled water circulation pumps.

Variable speed drives are used for the air-handling units. Variable air volume units regulate the airflow for various zones based on the occupancy and temperature by a variable air volume unit, which gives a pressure signal for the VFD to change the speed of the air handling unit.

A demand controlled ventilation system uses a variable speed drive operating based on the opening and closure of the fresh air dampers controlled by the carbon dioxide sensors. A typical basement exhaust system may use a variable speed drive controlled by carbon monoxide sensors centrifugal/screw chillers with variable speed drives.

Projects in composite climate with 24 h working schedules may incorporate free cooling systems.

s) *Controls* — Usage of accurate/sensitive controls may save power by 10 to 20 percent. Building control system plays an important part in the operation of a building and determines whether many of the sustainable design aspects included in the original plan actually function as intended. The main objective is to improve the quality and supply of information on the air conditioning system and to thereby reduce the operating costs. The system can establish basis which may be used as bench mark for energy efficient operation subsequently. Use of intelligent control at HVAC plant room level may be considered for efficient communication and operation of all HVAC plant room components.

11.9 Electrical System

Efforts should be made to select electrical installations and systems which are energy efficient, while complying with the Indian Standards for the same which provide apart from efficiency, the various other important requirements including relating to performance and safety.

The requirements for energy efficient design of electrical installations in buildings are classified under the following four categories:

a) Minimizing losses in the power distribution system,
b) Reduction of losses and energy wastage in the utilization of electrical power,
c) Reduction of losses due to the associated power quality problems,
d) Appropriate metering and energy monitoring facilities, and
e) Reduction in losses due to usage of inefficient/ old motor, replacing motors with IE2/IE3 motors as per accepted standard [11(34)].

The active energy efficiency measures include making use of energy saving equipment, low energy lighting, efficient motors, low loss transformers, efficient appliances, suitable power carrying devices and optimized electrical distribution. These active measures along with high efficiency standby emergency generating plants using diesel, natural gas, alternate fuel, etc coupled with high efficiency uninterruptible power supply (UPS) systems contribute towards sustainable development.

Passive features include good practices like simple switching off (to turn off a device when not in use), paying attention to vampire electric loads (associated with electronic appliances like computers), etc.

Some of the recommended design criteria that may be adopted are as follows:

1) The transformer selection may be done in accordance with minimum efficiency performance standard (MEPS).
2) Higher voltage distribution systems should be employed for high-rise buildings to suit the load centres at various locations.
3) The locations of distribution transformers and main LV switch boards should preferably be sited at their load centres.

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4) To reduce energy losses in the conductors of cable and bus-bar trunking, their appropriate selection should be done based on voltage drop calculations.
5) Reduction of energy losses in the conductors of cables and bus-bar trunking may be kept in mind in the choice of conductor cross-section.
6) Use of bus ducts/rising mains (stacked configuration) in place of multiple runs of cables and use of dual-bus design with bus coupler is recommended for better fault current withstanding capacity, avoidance of fire hazard, and ensuring higher reliability with low energy loss in the main power distribution system.
7) The loss of every main circuit connecting the distribution transformer and the main incoming circuit breaker of a LV switchboard should be minimised.
8) The effective current-carrying capacity of neutral conductors should have ratings not less than those for the corresponding phase conductors.
9) The maximum loss in every feeder circuit/ sub-main circuit should not exceed 1.5 percent of the total active power transmitted along the circuit conductors at rated circuit current.
10) The maximum loss for every single-phase or three-phase final circuit/sub-main circuit over 32A should not exceed 1.0 percent of the total active power transmitted along the circuit conductors at rated circuit current.
11) Any motor control centre (MCC) or motor for air conditioning installations, having an output power of 5 kW or greater, with or without variable speed drives, should also be equipped, if necessary, with appropriate power factor correction or harmonic filtering devices to improve the power factor to a minimum of 0.85 at motor and restrict the total harmonic distortion (THD). This may be achieved through use of capacitor banks.
12) All electrically driven equipment and motors forming part of a vertical transportation system should preferably comply with the energy efficiency requirements for lift and escalator installations.
13) Every motor having an output power of 5 kW or greater may be sized by not more than 125 percent of the anticipated maximum system load unless the load characteristic requires especially high starting torque or frequent starting.
14) A variable speed drive (VSD) shall be employed for motor in a variable flow application.
15) Motor users should insist on appropriate rewinding practices for any rewound motors.
16) Fix type capacitor should be used in capacitor bank to compensate inductive load of transformer.
17) The total power factor for any circuit should not be less than 0.85.
18) The power factor correction device should preferably be installed at the source motor control centre or distribution board just upstream of the circuit in question.
19) Office equipment and electrical appliances should have desired energy efficiency levels complying with relevant Indian Standards.
20) Consumers should be encouraged to select and purchase office machinery/equipment, for example personal computers, monitors, printers, photocopiers, facsimile machines, etc, complete with power management/energy saving feature.
21) Consumers should be encouraged to select energy efficient electrical appliances such as refrigerators, room coolers, washing machines, etc, complying with relevant Indian Standards.
22) Designers are encouraged to incorporate into their design all available latest demand side management (DSM) programmes in order to reduce the maximum demand and the electrical energy consumption in buildings.
23) All single-phase loads, especially those with non-linear characteristics, in an electrical installation with a three-phase supply should be evenly and reasonably distributed among the phases.
24) A system approach to measure and verify energy savings in the electrical distribution installations in buildings (especially high rise and commercial ones) should be adopted.
25) Wherever conventional fossil fuel based captive generation systems are deployed scoping for heat recovery systems, including tri-generation, may be explored.
26) To achieve peak demand avoidance programmable logic controller (PLC) controlled automatic electrical distribution systems should be opted for.
27) Consumers should be encouraged to use IE2/IE3 motors in line with accepted standard [11(34)] and replace old inefficient motors with the mentioned standard. They should be

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encouraged to replace the motors rewound more than 4 times.

28) Air handling units should use energy efficient motors.

11.10 Lighting

Lighting has a significant impact on building loads and energy usage**.** The lighting design should focus on providing high quality visual environment with an emphasis on energy efficiency. With efficient lighting technologies and moderated interior illuminance, it is possible to design high quality lighting at connected power level that are much lower than that in a conventional building. Renewable energy sources should be emphasized for lighting in the outdoor having access to ample sunlight.

11.10.1 *Daylighting and Controls*

The optimal use of daylight shall be made to reduce the load of the electric lighting system by dimming or switching off luminaires when natural light provides ample illuminance for the task performed in the space. Daylight harvesting has a significant energy saving potential if it is integrated with the building design after comprehensive understanding of site, building orientation, weather conditions, materials and system design. Design for daylighting shall be done in accordance with Part 8 'Building Services, Section 1 Lighting and Natural Ventilation' of the Code. It is recommended to explore use of automatic light controls like those based on occupancy, timer, and dimmer.

11.10.2 *Artificial Lighting*

Lamps, luminaries, ballasts and the controlling systems should be monitored for achieving energy efficiency through artificial lighting. Factors that play crucial role in designing an energy efficient lighting system are:

a) Reflectance,
b) Design of interior spaces,
c) Efficiency of lighting systems,
d) Task lighting,
e) Controlling systems, and
f) Monitoring and maintenance.

Reference may also be made to the National Lighting Code.

11.11 Lifts, Escalators and Moving Walks

To minimise the environmental impact, the materials used for manufacture of lifts, escalators and moving walks should be recyclable, shall not have a potential for depleting ozone layer, shall not be hazardous, and shall be easily disposable at the end of life cycle. As power consumption during utilization phase has the maximum environmental impact, lifts and escalators to be installed shall be energy efficient.

In case of high rise buildings with multiple lifts having peak traffic demand, to increase the efficiency, the destination control system wherein passengers key-in their destination before entering the elevator, which optimizes the number of trips made by the lifts, may be installed. The controller groups the people such that the stops are minimised and travel time reduced.

Electrical traction lifts should be preferred over hydraulic lifts. Use of high efficiency motors such as permanent magnet synchronous motors, or induction motors having minimum efficiency class equivalent to IE2 as per accepted standard [11(34)] is recommended. The brake liner material should be environment friendly.

It is also recommended to provide lifts with regenerative drives. The efficiency of the drive in both motoring and generating mode should not be less than 0.8. LED lights should be preferred for illumination.

The planning, design and installation of lifts and escalators shall be done in accordance to the Part 8 'Building Services, Section 5 Installation of Lifts, Escalators and Moving Walks' of the Code.

11.12 Good Installation Practices

For installation of equipment and other installations, good installation practices with stringent quality control measures should be followed which also results in easy maintenance and energy saving, subsequently.

11.13 Commissioning and Handing Over

Commissioning is a systematic process to ensure that the installed systems perform according to the design intent and the owner's operational needs. A commissioning plan should be created early in the design phase. The readings should be logged and tabulated properly. The operation and maintenance staff shall be adequately trained by qualified personnel so that the staff has all the information and skill needed to optimally operate and maintain the systems. Operation and maintenance manuals with as-built drawings should be obtained from the contracting agency/agencies.

11.14 Operation and Maintenance

The operation and preventive maintenance schedule should be diligently complied with. Operation should be specially focussed, from sustainability point of view, in areas which can result energy saving. Such savings shall be aimed at without compromising the design intent.

11.15 Ongoing Performance

Regular maintenance and cleaning, periodic calibration, monitoring emissions and leaks, purge operation, record keeping, proper refrigerant levels, etc, help in continued peak performance of operation.

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11.16 Renewable Energy

All efforts should be made to utilize in the building, the renewable energy available in various forms. Following aspects may be considered for the purpose:

a) *Solar energy utilization* — Solar energy may be utilized in building through the following applications:

1) *Solar water heating systems* — Hot water requirement in buildings may be met through use of various types of solar water heating systems. Major types of water heating systems are:

i) Flat plate collector: Single glazed, double glazed;

ii) Evacuated tube collectors; and

iii) Water heating with solar concentrators.

Considering the possibility of overcast conditions, or maintenance of collector, etc, the solar water heating system should be fitted with auxiliary heating system using conventional sources of energy such as electricity or gas. Application of auxiliary heating should be determined in such a way to avoid heating of excess amount of water. For example, if the heating is provided in a tank, it keeps the entire amount of water at the set point temperature, irrespective of the requirement/usage, resulting in wastage of energy.

In case of buildings where roof area is not sufficient to cover entire requirement of solar water heating, especially in case of high rise buildings, solar concentrators may be used for focusing solar energy over smaller area.

Decision about single glazed, double glazed, evacuated tube, concentrating type, etc, shall be done as per the local site conditions, solar radiation, ambient temperature, wind velocity, shading of neighbouring buildings and other similar features.

Capacity of such systems should be determined as per the average requirement instead of peak requirement, as the later increases the investment involved and reduces the financial payback period.

2) *Solar steam systems for cooking, laundry, etc* — Steam can be generated on the roof top of buildings through use of solar concentrators. Steam generated through such concentrators can be used to meet requirement of steam in buildings such as for cooking and laundry, and to meet the energy demand for other applications such as for heating/preheating of air and disinfection/sterilization of instruments. Specifications of such systems shall be determined according to availability of solar radiation, size and concentration ratio of the concentrator, ambient temperature, and steam storage for operation during off-sunshine hours. Wherever such systems are used/installed, attempts should also be made to recover condensate or warm water after its application.

3) *Solar assisted refrigeration/air conditioning systems* — It should be also attempted to utilize solar energy to operate vapour absorption or vapour adsorption based refrigeration/ air conditioning systems. Similar to solar water heating systems, such systems may also be designed with auxiliary heat supply provisions so that they may also operate during overcast days.

4) *Solar photovoltaic systems* — Solar photovoltaic (PV) systems are direct energy conversion systems that convert solar radiation into electric energy. Roof of buildings as well as other exposed areas such as of parking shade, can be installed with solar PV system. Major considerations while designing a building integrated PV system are:

a) Sufficient spacing between consecutive rows of modules as per the sun-path diagram;

b) Inclination of modules to match requirements as per latitude;

c) Periodic cleaning of dust from the cover of modules;

d) Matching of specifications of PV modules, array, power conditioning unit (PCU)/inverter, battery storage and wiring; and

e) Checking of operating point of PCU/ inverter, depth of discharge of batteries.

Components of solar PV systems and factors of performance are as follows:

i) *PV modules* — These contain solar cells. Efficiency of cells and module should be as high as possible. Currently, cells having 16 percent efficiency are commonly used and suggested.

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ii) *Charge controller/inverter/PCU* — It is part of PV system that matches the output of PV modules with acceptable form of electricity by battery bank or load or grid. Since considerable power loss may take place in this unit, efficiency of inverter/ PCU should be more than 90 percent at full load and not less than 85 percent at 25 percent load.

iii) *Battery bank* — It is where energy can be stored in batteries for use during off-sunshine hours. When operating in stand-alone mode, usually additional one day energy storage capacity is provided in the battery bank. Location and type of batteries should be such that they do not affect indoor air quality. If kept indoor, the space should be sufficiently ventilated with fresh air with no recirculation of air.

b) *Wind energy utilization* — If sufficient wind velocity exists at the site, it should be attempted to make use of available wind velocity through installing wind turbine for power generation. Usually wind velocity increases with height, hence wind turbines may be installed on the roof of high rise buildings or between two buildings causing Venturi effect due to their shapes, with due care towards structural safety considerations. Hourly wind data of whole year at the site should be the basis of machine selection, and not just wind velocity during few days of the year.

Annual power output from the turbine should be more than power output equivalent to full load output for 20 percent of the whole year. However, exact number in this regard shall be governed by the cost of wind turbine, cost of electricity and other case specific variables.

The visual disturbance caused by the rotating wind turbine, acoustic disturbance to neighbouring area and to occupants of buildings should be considered while selecting machine and its location.

At some locations where wind and solar radiation both are available, and especially when wind is available during the time when there is no or less solar radiation, hybrid wind-solar PV systems can also be considered. Wind energy systems may also be operated in hybrid mode with other sources of electricity such as diesel generating (DG) sets to ensure availability of power throughout the year.

c) *Waste utilization* — It should be attempted to make full utilization of all wastes, especially waste heat and bio-degradable solid waste.

1) *Waste heat utilization* — Waste heat available from different sources such as exhaust gases and cooling water of electricity generators, or any other process going on in the building that discharges solid, liquid or gaseous hot waste, may be utilized directly through heat recovery methods for heating applications such as space heating, service hot water, etc. Alternatively, the waste heat available can also be utilized for operating vapour absorption or vapour adsorption refrigeration/air conditioning systems.

2) *Solid waste utilization* — Bio-degradable solid waste generated within the building, such as kitchen waste, human excreta, branches and leaves of trees, grass cuttings should be utilized through anaerobic digestion process to produce combustible gas. This gas may be utilized to replace some fuel requirement in the building. Manure is a by-product of such bio-gas digester that may be used to improve the economics of utilizing solid waste. Other alternatives of anaerobic digestion, such as briquetting for direct combustion, gasification may also be used as per properties and availability of solid waste.

d) *Bio-fuels* — The term bio-diesel or bio-fuels is usually referred to liquid fuels that are not obtained from fossil based sources of energy such as crude oil, but are obtained from plant species.

In case of buildings where open space is available, attempts should be made to grow such plants and use their oil to substitute some of the conventional fuel. For example, DG sets may use a blend of bio-diesel and diesel or may even operate on 100 percent bio-diesel.

Similarly, other possibilities of obtaining combustible fuel, such as from vegetable waste oil of restaurants and hotels should also be explored and utilized, wherever possible.

e) *Hydropower* — The flow of tides of an ocean or a stream is harvested to produce hydropower. As the water is released from the upper reservoir to the lower reservoir it generates power using the hydro-kinetic energy of the water flower through a generator. The ability to use hydropower is limited on an individual building scale. On rare occasions, buildings can take advantage of

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streams to generate hydropower on site.

f) *Other renewable energy sources* — Depending upon climatic location and site specific features, possibility of exploiting other renewable energy sources, such as, geothermal heating and cooling systems should also be considered.

12 CONSTRUCTIONAL PRACTICES

The framework for sustainable construction practices includes the following issues:

a) Pre-construction pre-requisites;
b) Planning for sustainable construction;
c) Preparation of sustainable construction management plan;
d) Planning, monitoring and control of environmental descriptors;
e) Sustainable work execution procedures;
f) Effective use of water;
g) Construction waste management ;
h) Post-construction closeout;
j) Construction methodology for heritage buildings; and
k) Alternative use, de-construction, dismantling, demolition.

12.1 Pre-Construction and Pre-Requisites

Sustainable construction bears upon developing the design proposal, which is efficient in terms of functional performance as well as detailed out to ensure that the material resources and construction technologies are used efficiently during construction stage. Frequent changes to the design during construction stage often lead to wastage and other resources, rework and redundant handling and construction processes. Construction practices to execute design proposals, which inherently cause higher wastages and do not facilitate efficient planning, should be avoided. The pre-construction stage proposal development should incorporate certain pre-requisites that lead to sustainable construction practices (*see also* **12.4**).

12.1.1 *Architectural and Structural Design*

Architectural design should be detailed out so that use of materials and technologies may be planned in advance. Design detailing should facilitate planning of procurement of materials in sizes, volumes and lots, such that the wastage during construction is least. It is desirable that the design is consistent with the available material sizes, shapes and volumes. Design should, therefore coordinate to incorporate quality and quantity aspects from the point of view of construction.

Design detailing should facilitate procurement process. Storage of materials at site for unduly long period may adversely affect its quality and short supply may lead to interruptions in interfacing activities. Thus, the efficient procurement process ensures optimum procurement.

Structural design is critical in ensuring optimum use of materials. Inadequate rigour in design analysis can lead to over-sizing of structural members, while uncertain quality assurance and control may render structural members unsuitable due to permanent construction defects.

It may be desirable to develop building designs through digital models so that the dimensional coordination and interfacing between architectural, structural and engineering services is ensured with an aim to avoid improper execution during construction stage. Application of 'modular coordination' is desirable in mass repetitive construction works especially using mechanized or industrialized construction techniques.

Drawings generated as 'good for construction drawings' shall be reviewed for coordination across various disciplines before their release for construction. Coordination between architectural drawings, structural drawings and engineering services (mechanical, electrical, plumbing) drawings, etc, shall be assessed in plans and sectional details. It may be desirable to undertake three-dimensional clash analysis using appropriate information technology tools and software. Therefore, all efforts should be made at design stage to ensure that the time and resources are not wasted during construction stage work.

12.1.2 *Inclusion of Sustainable Construction Needs in Feasibility Report*

Feasibility report directs planning, design and execution of a project. It acts as a reference boundary for the project within which the project is viable. It details out the manner in which objectives of the project are achieved. Project requirements shall be accomplished within the planned resources. In light of the significance of feasibility report, is it essential that the sustainability objectives, both in terms of operational phase of the project as well as the construction phase, should be highlighted. As a result of that, the resources, technical procedures and benchmarks may be established for execution to be viable within the overall sustainability parameters of the project.

Specifically, benchmarks for the energy consumption, water utilization, waste generation, reuse of waste generated during construction and operation phase should be established in the feasibility report for sustainable construction.

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12.1.3 *Construction Methodology*

For sustainable construction practice, it is essential that the physical execution of works should only be undertaken when the construction methodology is established, and reviewed for its reliability under the risk environment that may prevail under specific conditions of the project. Construction methodology details out process of execution, its work flow, deployment of various resources, planning for eventualities and contingency measures. In absence of an established sustainable construction methodology, the efficacy of work procedures may not be ensured.

It is desirable to evolve construction methodology on digital models so the physical developments at site may be simulated under working conditions. Information tools that identify inter-disciplinary clashes are identified. In many a cases, it may be necessary to plan in a predetermined manner for the structural considerations, failing which the stability may be jeopardized. It is essential for construction works that involve a fair amount of pre-fabrication, especially off-site, so that the fabrication is compatible and the installation procedures are fail-safe during the installation as well until the stage when structure is capable to endure itself independently.

12.1.4 *Mitigation of Impacts Due to Materials and Technologies Deployed*

Construction materials and technologies used at site may impact the environment, especially during processing of materials, such as cutting, mixing, fabrication, etc causing noise, dust and sometimes release of fumes. Such materials and technologies need to be identified and procedures planned to mitigate impacts.

12.1.5 *Deployment of Plants, Equipment and Machineries*

Selection of efficient plants, equipment and machineries and their proper scheduling of operation are key considerations for sustainable deployment. While selection, it is essential to ensure that plants, equipment and machineries have their performance ensured not in isolation but also when considered in relation to the supporting plants, equipment and machineries. For example, the selection of excavator of a certain capacity is linked to the availability to earth transportation out of site and the clear working space available for the excavator and the transportation vehicles. Having selected an optimum set of plants, equipment and machineries, it is essential that their operation is scheduled such that their combined performance is maximized. Failure to deploy plants, equipment and machineries in an efficient and effective manner may result in undesirable loss of fuel, and noise and air pollution.

12.1.6 *Procurement Policy*

In order to ensure sustainable construction, the organizations involved should have a resolve and commitment to procure processes, services, works and supplies that help in achieving the objective of sustainability. Since sustainability is project and context specific, the policy should entail requirements in respect of sustainability pertinent to the project.

12.1.7 *Contractual Obligations towards Sustainable Construction*

Contracts determine obligations of individuals and organizations. In this respect, the contracts shall make it obligatory on the part of the supplier (materials, equipment or services) to follow sustainable practices and processes. The scope of such obligations shall include the relevant issues described under **12**. Contractually binding obligations ensure system-wide responsibilities so that necessary mitigation resources may be budgeted within the project scope.

12.1.8 *Assignment of Responsibility for Sustainability Practices During Construction*

The responsibility for sustainability practices during construction shall be clearly assigned, also explicitly assigning liabilities that may accrue on account of lapses. This strengthens the responsibility delegation and also act as deterrent for slackness while discharging duties. Liabilities may include contingencies for risks known as well as management reserves towards unknown risks.

12.2 Planning for Construction

Pre-construction pre-requisites are important inputs to the planning for construction in a sustainable manner. Planning processes describe the approach towards the construction. A proper planning, considering peculiarities of project, helps ensure successful execution. The planned processes towards sustainable construction may be far more effective than spontaneous actions taken without comprehensive planning at early stages. Also, cost for mitigations and possible alternative strategies for mitigation may be better analysed for arriving at managerial decisions.

12.2.1 *Identification of Sustainability Issues During Construction*

The procedure to identify sustainability issues during construction should include the areas of analysis given in **12.2.1.1** to **12.2.1.5** and other applicable concerns in respect of project scope and context of site and environment.

12.2.1.1 *Construction methods review and impact on sustainability*

Design details determine the construction procedures.

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It is desirable to prepare a construction methodology and review the same from the point of view of its impact on the suitability to achieve quality, control of wastages, safety, resource optimization, energy conservation, water use, site contamination and pollution.

12.2.1.2 *Consideration to environmental impact assessment*

Environmental Impact Assessment (EIA) report systematically identifies the risks and impacts and recommends mitigation measures. Framework of EIA is defined in accordance with the statutory requirements and, hence, it is essential to consider the impacts so identified. Construction methodology and processes shall take cognizance of EIA report and environmental management plan (EMP).

12.2.1.3 *Considerations to social impact assessment*

Construction activities have significant impact on the socio-cultural interests of the populations surrounding the project sites. Continuance of human activities, especially related to their economic sustenance, livelihood and socio-cultural aspects, need special sensitivity. Dealing with social impacts during construction stage need managerial decisions to provide privileges to the affected populations and undertake actions to contribute towards deployment of social infrastructure. Such initiatives should be planned for.

12.2.1.4 *Prevention and management of construction accidents*

Accidents shall be prevented during construction stage. Construction teams shall analyse potential hazards and plan for their prevention and management. Accidents may endanger life of workers and population in and around the sites, cause disruptions to work and lead to loss of material and other resources. Efforts in prevention of accidents is often insignificant as compared to the problems in facing consequences. Deep excavation, scaffolds, shuttering and hoisting operations are known to be prone to accidents at sites. In addition to the accidents that may be caused due to the activities on site, there may be environmental conditions that may cause accidents during construction works since works may not have attained the stage of adequate stability and endurance to counter the impinging environmental conditions. Accidents due to floods, landslides, cyclones, high winds and earthquakes may need special attention requiring proper disaster preparedness (*see also* **12.11**).

12.2.1.5 *Identification of training needs and workforce training*

Sustainable construction practices require specific processes to be followed in respect of planning, monitoring and control. Involvement of workforce at all levels need training to deal with sustainability issues during construction. Project management functional responsibilities shall include identification of processes, competencies of persons involved in discharge of such duties, assessment of performance and conduct training programme. The effectiveness of training programme shall be assessed through performance appraisal system and corrections made as needed. Training need assessment frequency should be determined based on the type of work and the human resource competencies.

12.3 Preparation of Construction Management Plan

Having identified sustainable issues specific to the project, a comprehensive planning needs to be documented in a management plan. The management plan documents the approach to site management, project management processes, systems for management, site organization, data inputs to determine effectiveness of management systems and site planning.

12.3.1 *Establishment of Construction Project Management Processes*

Objectives of sustainable construction can only be realized through effective project management processes. Time, cost, quality, scope, risk, procurement, human resource, health and safety are some of the basic project management processes that shall be elaborated. Reference should be made to good practices [11(29)] for detailing out construction project management processes.

12.3.2 *Establishment of Management Systems*

Management systems define organizational commitment, organizational structure, resource allocation, relevant critical planned processes, procedures for monitoring and control to ensure continual improvement. The approach of management systems is preventive with an objective to achieve excellence in terms of absence of non-conforming works. Management systems approach sustains on documented voluntary initiatives, due monitoring thereof, and the same way be considered. Reference should be made to appropriate Indian Standards for developing and complying the above systems.

12.3.3 *Establishing Site Organization Structure*

Establishing site organization structure, considering management systems and involvement of other agencies in construction, is very critical. Interfaces across various agencies involved in construction need clarity for effective coordinated decisions which can lead to prevention of wastage of resources, reworks, rejections, delays and such other non-conformities detrimental to quality of work and delay in execution.

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12.3.4 *Establishing Energy Consumption Data Collection, Analysis, Documentation System and Creating Benchmarks*

Monitoring of performance of management systems and processes of execution need establishment of indicators so that specific improvements may be achieved. In this respect, energy consumption monitoring is fundamental. At construction sites, electricity and diesel are primary sources of energy and their consumption shall be monitored so as to improve methods and the operation of equipment is energy efficient. Data collected should be analysed with respect to processes of significance in terms of consumption and pollution. Database so generated can also be used for establishing project specific, organization specific or process specific benchmarks for future reference. Appropriate documentation of fuel consumption logs, energy metering and execution processes shall be planned and assigned organizational responsibility. Site management decisions shall take cognizance of energy consumption data.

12.3.5 *Overall Construction Site Planning*

Improper site planning is often reason for redundant material handling, processes involving unnecessarily long lead, wastage during multiple handling, inefficient deployment of equipment, etc. Circulation and movement of workers and visitors can be reason for unsafe working conditions. Following issues, therefore, need specific attention while undertaking site planning:

a) Layout of roads and services;
b) Deployment of plants, equipment and machineries;
c) Location of temporary structures, fabrication area and storage areas;
d) Work area demarcation and safe surrounding;
e) Emergency plan and medical facility;
f) Control of site dereliction;
g) Prevention and management of top soil; and
h) Storage of chemicals, fuels and explosives.

12.3.6 *Location of Infrastructure for Labourers*

Labour is at the bottom of the organizational structure of construction practices. Project organizations may tend to ignore the interests of labour and tend to be indifferent to their needs. Indifferent and ignored labour, on the other hand, can cause inherent inefficiencies in the system and lead to unreliable performance. Infrastructure for labour needs to be planned and budgeted suitably considering the following:

a) Compliance to labour laws including *Building and Other Construction Workers (Regulation of Employment and Conditions of Service) Act*, 1996;
b) Policy and location of labour camps;
c) Policy for deployment of labour from local communities;
d) Labour movement;
e) Social infrastructure for labour;
f) Health, hygiene, amenities and waste disposal; and
g) Training need assessment, training infrastructure and effectiveness monitoring.

12.3.7 *Setting Up of Health and Hygiene Infrastructure*

Health and hygiene infrastructure is needed for the construction site as well and the labour infrastructure, especially if labour camps are off site. In addition to the construction project specific injury and emergency treatment facilities, facilities shall be provided for conducting periodic health check-ups for the workers so that the effects of construction activities on the health are monitored. Medical facilities shall be established with suitable expert physicians and paramedics, availability of appropriate medicine supplies, diagnostic facilities and organized record keeping.

As a part of hygiene infrastructure, potable water supply, waste water disposal and solid waste disposal (non-construction) are planned in a proper manner. In order to determine the standards, the needs of vulnerable groups, such as children, shall be considered.

12.3.8 *Location of Facilities for Hazardous Materials*

In special cases, the facilities for storage of hazardous materials may be provided very carefully. There may be a case for locating such facilities off-site. Specific statutory guidelines in respect of such requirements shall be referred to. The facilities and the handling procedures shall be well established.

12.4 Planning, Monitoring and Control of Environmental Descriptors

Environmental impact assessment (EIA) undertakes characterization of the existing status of the land, water, air, biological and socio-economic environment in the project area and its surroundings. It seeks to identify potential environmental impacts of the project, and formulation of an effective environmental management plan (EMP) to prevent, control and mitigate the adverse environmental impacts, and ensuring the compliance with the environmental legislations. Thus, the scope for planning, monitoring and control of environmental descriptors during construction phase is identified and described in the EIA and EMP. Construction agencies shall develop further and detail out their respective compliance requirements accordingly.

Depending on the nature of project, construction agencies shall be required to establish infrastructure and procedures for soil monitoring, water quality

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monitoring, ambient air quality monitoring, noise monitoring, tree counting and traffic survey, with a view to having required controls thereon.

12.4.1 *Soil Monitoring*

Soil samples from representative locations in the site and study area shall be collected and analysed for important relevant physical and chemical parameters. Soil monitoring should be carried out in at least three locations including one at the project site.

12.4.2 *Water Quality Monitoring*

Water quality monitoring shall be conducted at representative locations in the study area for surface and groundwater. Samples shall to be collected and analysed for important relevant physical, chemical and bacteriological parameters. Water quality monitoring locations should include at least three surface water (if exists in the study area) and three groundwater locations.

12.4.3 *Ambient Air Quality Monitoring*

Depending upon the project size, location and the type of activities involved, ambient air quality in respect of suspended particulate matter (SPM), respirable particulate matter (RPM), SO_2, NO_x, and CO, shall be monitored at representative locations in the site and study area at a frequency of twice a week at each location adopting a 24 hourly schedule (8 hourly for CO). The monitoring locations shall be located on the basis of predominant wind directions, land use pattern and height of the proposed stacks. At least one station shall be located at the maximum pollution deposition area due to the proposed stacks of generators. The number of air quality monitoring locations should be at least five including one at the project site.

12.4.4 *Noise Monitoring*

Ambient noise level monitoring shall be carried out at representative locations in the site and study area over a period of 24 h to obtain hourly equivalent continuous noise (L_{eq}) levels as well as day and night time L_{eq} to compare with the standards. Noise monitoring should be carried out for at least six locations including one at the project site, one at the boundary of the project site and one at the nearest residential/sensitive area.

12.4.5 *Tree Counting*

Survey shall be conducted to assess existing trees in the project site in respect of numbers, species girth size, plan for re-plantation or making good for trees being lost to be finalized.

12.4.6 *Traffic Survey*

Traffic survey for continuous 24 h has to be carried out to measure number and type of vehicles passing on the existing main roads giving access to the project.

12.5 Work Execution Procedures

Work execution procedures should be described in a manner so that there is least wastage, rework and repair and acceptable performance is achieved. In this respect, the reference to relevant Indian Standards for materials; quality assurance verification; material handling, storage, and protection; work procedures including working on materials/fabrication, placing/installation; inspection and testing procedures of completed works; and protection after completion of work, need to be specifically addressed. In addition to these considerations, the relevant works should be given specific attention as given below:

a) *Excavation and sub-structure works* — Issues related to noise and vibrations during excavation, piling, rock cutting, etc; control of damages to surroundings; prevention of collapse; and, control of excessive dewatering and sustainable use of de-watered water need to be analysed, risks identified and methodologies detailed out prior to undertaking such works.

b) *Concrete work procedures* — Soundness and stability of formwork and other enabling structures; suitability of concrete mix to the prevailing environmental conditions; avoidance to undesirable cutting, etc for laying services and embedded items; providing requisite cover to the reinforcements; proper curing; and, allowance of setting time are essential for meeting the expected performance of concrete works. In general, for concrete works, good practices [11(30)] shall be followed.

c) *Steel, aluminium and other metal works* — Noise control during cutting, welding, hammering and fabrication operations; prevention of waste; reuse of cut sections (for example cut reinforcement bars reused in other locations depending on requirement); collection and disposal of scrap; fire and injury prevention during working; prevention of collapse due to unstable installation operations; and safety of workmen are critical aspects that need special mention in procedures.

d) *Masonry works* — Wastage during on-site handling of materials; execution in proper plumb, plane and alignment to avoid wastage of finishing material for making up for making up for the defects; and, filling up of joints to attain requisite *U* and *R*-value characteristics need particular attention.

e) *Surface finishing and furnishing* — Preparation of finishing base; environmental

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conditions during and after finishing/ furnishing works; and, application procedure for surface undulations are essential considerations to realize desirable surface characteristics as well as service life of finishes and furnishings.

f) *Handling and use of chemicals* — Working conforming to the prescribed procedures; protection against spillage and human body contact; supply and use log describing quantities and authorized person(s); and, prevention of reaction which are explosive, exothermic causing fire or release of toxic fumes or creating corrosive reactions to the surrounding works, should be specifically identified and planned.

g) *Handling and use of oils and gases* — Avoidance of fire by preventing conditions leading to ignition; spillage polluting the works and sites; use of appropriate containers for storage and handling; and contingency procedures for limiting damage due to spillage and neutralizing the effects should be specifically highlighted in procedures.

12.6 Effective Use of Water

See **10.4**.

12.7 Construction Waste Management

12.7.1 Construction and demolition activities generate large quantities of solid waste. Diversion to landfill sites is one of the major issues in handling of construction waste. Increase in waste generation and improper land filling with construction wastes have major impacts like waste of land resources, affecting water bodies, groundwater pollution, etc. Construction organizations shall systematically pre-empt and identify wastes that may be generated and plan to re-use, re-cycle and handle wastes in an appropriate manner. Monitoring of waste and its disposal through an established procedure also create opportunities to prevent wastages in construction processes and lead to conservation of resources.

By proper disposal, waste materials which are likely to be dumped in landfills can be converted into value added products. Some construction waste materials can be diverted for re-use, whereas others can be recycled into another usable material. Many construction waste materials can either be used onsite or sent to other nearest sites/industries for reuse/recycle/reconversion into useful products.

One of the important approaches to reduce waste and effect waste utilization is to evolve design details such as optimizing use of materials and employing technologies aiding in the same. Durable materials and high performance technologies need lesser maintenance and deliver better service life. Proper construction waste planning is, therefore, recommended before starting the construction or demolition which involves identification, segregation, proper storage, reuse/recycling and finally the proper disposal of remnant waste materials.

12.7.2 *Identification, Segregation and Storage of Wastes*

It is very difficult and costly to reuse or recycle the waste materials which is in mixed form and not segregated at right time during the construction. Storing of segregated waste in labelled containers/bins, and monitoring of stored waste bins periodically by the trained/skilled personnel may prevent wastage. Waste should be stored within the site and such area should be chosen, where further shifting is not required.

12.7.3 *Reuse and Recycling*

Reuse and recycling not only reduces the land filling load but is also economical and an eco-friendly step in construction. Reuse increases the life of building materials. It is desirable to locate nearby recycling units for construction waste recycling to reduce the cost as well as adverse environmental impact.

Brick bats and concrete, especially from piling works, have a potential to be used as sub-grade works for paving, etc. Excavated earth and boulders may often be reused at site or used elsewhere through the network of specialist agencies. However, topsoil should be isolated, preserved and reused at the same site or at another location where there is a demand for fertile topsoil for landscaping. Wastes, such as metal and plastics, should be disposed of for re-cycling. Other wastes, such as cellulosic materials, timber, etc, which are biodegradable, should be disposed of at authorized designated locations.

12.7.4 *Handling and Disposal of Waste*

All construction wastes shall be stored or handled in such a way so as to avoid unnecessary decay or deterioration. Bio-degradable waste during construction shall be collected separately and treated with bio-methanation, organic waste compactors, etc, or subjected to composting.

Construction waste is generally inert in nature (does not contain chemical or biochemical pollution), but proper training is required to handle the construction waste because improper handling may cause accidental damage to the handling person. The person segregating the construction waste should be properly equipped for safety aspects. Spillage of construction waste during transportation should be prevented. There are different sustainable techniques of waste disposal available and should be practiced.

12.7.5 Every waste resulting from construction,

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remodelling, repair and demolition of any civil structure of individual or organisation shall be managed in accordance with *Construction and Demolition Waste Management Rules*, 2016.

12.8 Post-Construction Closeout

Project closeout is a very significant stage from the sustainability considerations. While project management closeout should ensure that the contractual obligations are complied with, the consequences of construction activities should also be appropriately determined. At this stage, the obligations of the project, in terms of physical delivery of works as enshrined in the briefing documents as well as environmental commitments towards sustainability, shall be ensured.

12.8.1 *Disposal of Structures and Infrastructure for Construction*

Building and other structures and other infrastructures may need to be demolished/reconstructed partly or completely. These, including their mechanical, electrical, plumbing installations, etc, should be disposed of in a manner so as to facilitate re-use of materials, components, installations, etc, by the same organization at another construction site or their re-cycle. In case the materials do not have reclaim value, possibility should be explored for their use as backfill materials; otherwise offsite disposal may be resorted to in an appropriate and authorized manner.

12.8.2 *Closure of Tube Wells*

Abandoned tube wells are a risk to life. These shall be closed properly. In may also be explored to reuse the same as a part of water harvesting system.

12.8.3 *Restoration of Dereliction Caused to Site*

While controlled site dereliction is a good construction practice, the site should be restored deploying appropriate methods. Project budget should include apportionment of resources towards restoration. Such restoration activities may continue for a long time even after physical completion of project, and hence, the commitment towards such efforts is essential. It shall be ensured that the areas, which are under restoration, are well protected during this period.

12.8.4 *Re-Use of Top Soil*

Re-use of top soil as a resource is an important sustainability consideration. In case the construction site does not leave adequate space for storage of top soil, it is important to identify another location in vicinity for proper storage until it can be reused at the same site or in case it is found not possible to use in the same site, it is taken to other nearby site for use as top soil. Value of top soil should not be compared in financial terms but rather as a scarce natural resource.

12.9 Heritage Buildings and New Construction

Heritage buildings should be given special attention during construction of a new building, especially if it is situated in close vicinity, complying with the requirements of proper architectural controls in accordance with **18** of Part 2 'Administration' of the Code. The following may also be considered while planning and executing such works:

a) Heritage contents, their characteristics and other building elements that need to be undertaken as scope of work.
b) Construction techniques including diversion of utility services.
c) Competence and experience of execution agency to handle such works involving the use of traditional materials and technologies.
d) Approval of structural and chemical investigation and local understanding, of the heritage structure if it has merit of cultural significance.
e) Project management processes especially pertaining to time, cost, procurement and risk assessment, risk management and risk preparedness strategy, using the sequences appropriate to traditional works.
f) Scheduling of activities including review processes and inspections by designated competent persons.
g) Planning for enabling works and safety such as scaffolds, protection measures for other adjoining works.
h) Site management including circulation diversions.
j) Contingencies for unexpected damages to works and unforeseen structural behaviour.
k) Prevention of fire, flooding and other such emergencies and disasters during works.

12.10 Alternate Use, Deconstruction, Dismantling and Demolition

Built facilities are created to facilitate certain functions. Due to changes in functional use over a period, deterioration in physical condition of building elements, etc, the productivity may decline below threshold. As a result such buildings may be rendered unsuitable in spite of previous renovations. In such situations, effort should be made to re-use of facilities with renovations or remodel for alternate use retaining most of the building and its facilities. Effort may be made to evolve a flexible design so as to make it suitable to varied functional uses.

If design configuration and residual service life is not consistent with functional requirements and particularly

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considering the safety of the building, the built facility should be de-constructed so as to retrieve as many buildings assemblies/materials/installations for reuse and recycle, as possible. While working on design details, it shall be ensured that the design should facilitate deconstruction. During the process of de-construction, least damage should be caused to the assemblies, materials and installations. In case of complex structure, such operations shall be undertaken under expert supervision and with proper enabling works.

If built facilities were not designed to facilitate deconstruction, the dismantling should be resorted to in such a manner as to maximize retrieval of materials. Demolition operations shall be planned considering safety of workers; and avoiding damage to adjoining properties; noise, vibrations and air pollution; disruption to continuance of activities in the vicinity; etc. The demolition shall be carried out in accordance with good practices [11(31)].

12.11 Disaster Risk Mitigation during Construction

Sustainable construction practices shall address risks during construction stage from natural and man-made disasters. Natural disasters such as earthquakes, landslides, cyclones, flooding, etc, shall be considered during construction planning and adequately taken into consideration in risk mitigation through the construction methods statement, generally developed by the construction project management team and/or construction agency. Reference shall also be made to Part 6 'Structural Design' of the Code for technical measures for natural disaster mitigation.

In addition to the natural disasters, the risk mitigation against man-made disasters shall also be carried out. Deep excavations causing cave-in due to the lack of proper protection, earth saturation caused due to leaking city sewers/water mains are common man-made disasters. Similarly, fire collapse of structural slabs leading to progressive collapse of slabs below, hoisting of space frames, trusses and concrete segments and operations involving coordinated lifting/hoisting using multiple cranes are some typical situations that may turn disasters. Such operations and processes should have 'fail-safe' detailing as also back-up plan to deal with disasters. Necessary resource deployment shall be part of such disaster planning.

Reference shall also be made to Part 7 'Construction Management, Practices and Safety' of the Code for safety during various construction operations.

13 COMMISSIONING, OPERATION, MAINTENANCE AND BUILDING PERFORMANCE TRACKING

13.1 General

While the guidelines covered for commissioning and handing over, operation and maintenance and building performance tracking are applicable to majority of building occupancy types, many of these are particularly suited to buildings with high energy consumption such as large office buildings, hospitals, hotels, retail malls, etc.

13.2 Commissioning and Handover

Commissioning of building services typically includes natural ventilation, renewable energy systems, metering installation, plumbing, lifts and HVAC systems commissioning, etc. Commissioning stage should record the consumption of energy (such as power consumed by fan motors) and water used by plumbing and other systems that will help in reviewing and improving the systems for efficient operation. The commissioning stage helps in identifying any remaining site activities and the training activities that need to be coordinated. It helps in bringing to attention various common problems encountered such as key pieces of hardware are missing, not installed, or defective; installation of sensors, scanners, and other monitoring devices in the wrong locations; and improper coding of the sequence of controls for equipment. These and other problems should be identified and corrected during the commissioning process. Required resources should be allocated to commission the systems after they are installed to ensure that they work as intended. A complete and thorough commissioning of the building shall be done to ensure that the systems will work as intended.

13.2.1 *Commissioning Process*

Typically, the first step in the commissioning process should involve formation of a commissioning team that comprises the owner, users, occupants, operation and maintenance (O&M) staff, and design professionals. The next step is the preparation of the project requirements, which should address building systems such as lighting, air-conditioning, water systems, etc, as well as the design intent and the functional specifications for the key building systems. The project design document should include a commissioning plan. Prior to the handover stage, the commissioning team should verify the installation of the systems, conduct functional performance testing, training of the O&M personnel, etc. A post occupancy commissioning report shall be provided to the owner and/or relevant authorities once the necessary tests have been conducted and the areas that need correction have been rectified.

13.2.2 *Handover*

During the handover stage, records of meter readings for the different building systems, and other data should be provided to the asset management team. A simple guide for occupants will help the team understand the working of the systems in the building.

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13.3 Operation and Maintenance

O&M programmes that focus on improving energy efficiency of building systems can help save energy without a significant capital investment. From small to large sites, these savings can represent significant savings each year, and can be achieved with minimal cash outlays.

Building maintenance is a wide subject covering not only maintenance of building services but also the maintenance of all other aspects including the structure itself. Effective operation and maintenance is one of the most cost effective methods for ensuring reliability, safety and efficiency of a building. Inadequate maintenance of energy-using systems is one of the major causes of energy waste. Energy losses from steam, air and water leaks, uninsulated lines, maladjusted or inoperable controls and from poor maintenance are often considerable. Also, inadequate maintenance of systems that consume water, including plumbing, HVAC and landscaping systems (as applicable), can result in excessive usage of water. Good maintenance practices result in substantial savings in consumption of energy and water, and should be considered as a resource.

Traditionally, O&M is carried out on a reactive basis, where maintenance is only provided when equipment or systems fail. On the contrary, a preventative maintenance programme, that prescribes regular checks of equipment at scheduled intervals, helps to improve system performance and extend its useful life. Predictive maintenance programmes go a step further where rather than following a set schedule of maintenance, checks are used to predict when equipment may be in need of maintenance prior to it experiencing any damage. Such predictions are based on analysis of known factors, for example 'stressors' that can impact the performance of the system. The O&M plan should be complemented by a review of the building operation with one year after the majority of the building area has been occupied. The design and construction/installation teams should also review the O&M manual with the asset management team.

13.3.1 *Requisites of an O&M Programme*

A competent O&M programme requires the participation of staff from operations, maintenance, engineering, training and administration. The successful implementation of an O&M programme requires cooperation, dedication, and participation at all levels including among managers, practitioners, and other technical staff. The O&M plan should be a living document, that is, it is amended as the other requirements change. The intention should be to update O&M document periodically as new procedures and technologies are developed and employed. A web-based version can also be implemented for incorporating updates as frequently as possible.

Revisions to the O&M programme should be considered throughout the assessment process while considering all potential energy savings, and also when capital-intensive projects are being evaluated. Changes to O&M procedures and practices should be considered beyond the scope of repair and regular maintenance. Auditors who conduct performance review of the facility should take a holistic approach, and should consider,

a) how the activities that are undertaken within the building can be used to optimize energy efficiency in existing operations, and
b) how the newly implemented measures can improve the performance of the building.

Activities related to O&M should be included in the implementation plan; responsibilities should be designated to individuals; and time lines should be outlined for completing these activities. Training of the staff and awareness programmes should be developed to ensure that there is full compliance among staff for the new procedures to ensure effective implementation of the energy efficiency programme. The O&M plan should refer to the manufacturer's recommendations on equipment operation and maintenance. O&M actions and activities should only be carried out by trained personnel.

13.4 Building Performance Tracking (Measurement and Verification)

Subsequent to the commissioning and handover stage, regular monitoring of the performance shall be carried out which will provide information on whether the set environmental performance and targets have been met or not. As part of the measurement and verification (M&V) process, an ongoing monitoring of the energy and water systems should be carried out. This will ensure ongoing accountability of energy and water consumption during the life of building. Some of the main attributes of a building performance tracking (measurement and verification) system include the following:

a) Monitoring of technical and energy performance during first three to five years of occupancy, to ensure that the performance targets during the operation of the building are in line with the expected performance parameters. Energy metering may be provided for the following applications:
    1) Lighting (interior and exterior);
    2) Air conditioning (heating/cooling);
    3) Hot water systems;
    4) Renewable energy systems;
    5) Energy meters for pumping of municipal

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water, grey water and irrigation water; and

6) Miscellaneous equipment such as elevators, computers escalators, etc.

b) Conducting an occupant survey annually for the first three years of the building. This will help in obtaining feedback from the users regarding the effectiveness of the designed systems, as well as identifying possible areas of improvement. These surveys will also provide information about any enhancements or modifications.

Monitoring the performance of plumbing, sanitation and irrigation systems in terms of the water consumed when the building is in operation is an important aspect of the performance tracking system. Metering the water consumed by these systems will help in determining whether the water consumption by the building is in an efficient manner or not. Similarly, measuring and tracking the discharge of water by the building, whether it is storm water, sewage, or otherwise, will provide information on whether the re-use of water is taking place efficiently or not (*see* **10** for design of water efficient systems).

An energy management and control system (EMCS) is one method of tracking the performance of the energy consumed by the different building systems. EMCS systems typically consist of electronic devices with microprocessors and communication capabilities and utilize widespread use of powerful, low-cost microprocessors and standard cabling communication protocols. EMCS provides a building operator, manager or engineer with basic background information and recommended functions, capabilities, and best practices that will enable the control systems to be fully optimized, resulting in improved quality of life of building occupants and users and more reliable and energy efficient facilities.

13.4.1 *Functions and Capabilities of an EMCS*

An EMCS may be known as building automation system (BAS), building management system (BMS), energy management system (EMS), and facility management system (FMS). In this Part of the Code, the EMCS referred comprises the sensors, transmitters, data acquisition and data processing performed at the user (building) level as well as data and control systems that are more global to full campus control schemes. EMCS may also have a global supervisory controller to perform high-level tasks (for example, resetting temperature set-points based on building conditions and scheduling on/off times). The hardware generally consists of a distributed computer environment with smart controllers strategically located throughout the system (buildings and base-wide network). Several network terminals or computers can be attached to these networks to provide a man-machine interface (MMI). Depending on its capabilities, EMCS can perform a wide variety of functions. At a minimum, the EMCS has a sensor(s) to measure control variable(s) (for example, temperature and flow rates), a controller with the capability to perform logical operations and produce control outputs, and a controlled device(s) that accepts the control signals and perform actions (for example, move dampers and valves).

13.5 Operator Skills and Training

Performance problems result from errors in installation and operation of complex building heating/cooling and other systems. Without the right skill sets and proper training, building operators and managers may not be able to manage the facility optimally even with the most advanced building management systems. One of the key ways to enhance building operations and maintenance performance and thereby achieving the efficiency goals of buildings/facilities is handling by well trained building operators and managers. To operate buildings efficiently, in addition to a good controls infrastructure, the following may be desirable:

a) Increasing the skill level of operators and maintenance personnel; this can be accomplished by providing the building operators with frequent proper training and incentives for performing well.

b) Providing adequate engineering supervision of work by technicians to ensure that knowledge of fundamental processes is properly applied for operation and maintenance actions.

c) Providing operators with system performance feedback; this can be achieved by providing easy-to-use system diagnostic information to correct problems and to understand the cost impacts of improper operations.

d) Providing incentives for achieving efficiency goals.

e) Educating everyone who influences the decisions relating to planning, budget, design, and procurement of energy, water and related systems.

13.6 Control-System Maintenance

Maintenance of the control system is critical in ensuring its performance after installation and commissioning. Many factors can cause degradation of the control systems performance post-commissioning such as:

a) Overrides of automatic control by operations staff, a frequent problem, generally driven by customer complaints;

b) Drift or failure of sensors;

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c) Failure of actuators;
d) Corroded or failed wires and their connections;
e) Improper changes to control schedules (sometimes temporary changes become permanent changes by oversight); and
f) Degradation or failure of controlled devices.

These problems can be prevented by good operation and maintenance practices, such as a reporting system for all overrides, periodic re-commissioning of the control system, and maintenance of the control system and the physical components it actuates. Automated fault detection and diagnostic tools, alarms, plots of trend data, and maintenance tracking systems may be used to help in identifying performance degradation, faults and the need for maintenance and for compliance of recommendations of these tools and taking action, by the maintenance personnel.

It is recommended that the control system specifications include requirements for maintenance documents and a maintenance plan. The facility should also consider contracting for maintenance support, if it is not provided in-house. In procuring maintenance support, the organization should ensure that the maintenance contract requires maintenance of all systems in a manner that ensures continuous, or nearly continuous proper operation of all controls and controlled devices. This requires frequent, periodic inspection, testing, and evaluation of systems and equipment followed by the correction of any defects found. System inspection, testing and evaluation can be automated *via* continuous monitoring tools.

ANNEX A

(*Clause* 8.1)

DESIGN STRATEGIES AS PER CLIMATE ZONES FOR VARIOUS SEASONS

A-1 SUMMER PERIOD

Design Strategy (1)	*Hot Dry Climate* (2)	*Warm Humid Climate* (3)	*Moderate Climate* (4)	*Composite Climate* (5)	*Cold Climate* (6)
Reduction in the ingress of heat during the day (by insulation, thermal mass, buffer spaces, orientation, shading, etc)	√	√	√	√	√
Introduction of naturally (through use of courtyard, wind towers, properly positioned windows, etc) or mechanically pre-cooled air, into the building with adequate air-flow during the day	√	√ (substantive increase recommended)	—	√	√
Adequacy of airflow of naturally (through the use of courtyard, wind towers, properly positioned windows, etc) or mechanically pre-cooled air during the night	√	√ (substantive increase recommended)	√(naturally only)	√	√
Reduction of the temperature variation within the building during the day/night, in comparison to temperature variation in the ambient temperature	√	—	—	√	√
Adequacy air changes, as required by the activities within building, and the density of the occupancy	√	√ (substantive increase recommended)	√	√	√

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A-2 WINTER PERIOD

Design Strategy	*Hot Dry Climate*	*Warm Humid Climate*	*Moderate Climate*	*Composite Climate*	*Cold Climate*
(1)	(2)	(3)	(4)	(5)	(6)
Reduction in the ingress of cold into the building during the day, as well as during the night (by insulation, buffer spaces, orientation, weather stripping, etc)	√	√	—	√	√ (substantive reduction recommended)
Reduction in the air changes, without compromising with the minimum requirements for the activities, as well as for the density of the occupancy	√	—	√	—	√ (substantive reduction recommended)
Reduction in the egress of heat from within the building spaces during the day as well as during the night	√	—	—	√	√ (substantive reduction recommended)
Adequacy of natural ventilation/air changes in all spaces, as per requirement of maintaining indoor air quality	—	√	—	√	—
Marginal reduction in the ingress of cold into the building during the day as well as during the night	—	—	√	—	—

A-3 MONSOON PERIOD

Design Strategy	*Hot Dry Climate*	*Warm Humid Climate*	*Moderate Climate*	*Composite Climate*	*Cold Climate*
(1)	(2)	(3)	(4)	(5)	(6)
Reduction in the ingress of heat from outside into the building (by insulation, thermal mass, buffer spaces, orientation, shading, etc)	√	√	√	√	√
Substantive increase in the airflow/velocity/ air changes during the day as well as the night	√	√	√	√	√
Reduction of humidity within the building throughout the day and night (using dehumidifiers, desiccant cooling, etc)	√	√	√	√	√
Substantive increase in the natural ventilations in all spaces	—	√	—	—	—

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ANNEX B

[*Clauses* 8.2(a), C-1 *and* D-1]

PRESCRIPTIVE METHOD FOR ENVELOPE OPTIMIZATION

B-1 ROOFS

Roofs shall comply with either the maximum assembly *U*-value or the minimum insulation *R*-value in Table 9. *R*-value is for the insulation alone and does not include building materials or air films. The roof insulation shall not be located on a suspended ceiling with removable ceiling panels.

Cool roofs with slopes less than 20° shall have an initial solar reflectance of not less than 0.70 and an initial emittance not less than 0.75.

Table 9 Roof Assembly *U*-Value and Insulation *R*-Value Requirements

(*Clause* B-1)

Sl No.	Climate Zone	24 h Use Buildings Hospitals, Hotels, Call Centres, etc		Daytime Use Buildings Other Building Types	
		Maximum *U*-Value of the Overall Assembly W/m²°C	Minimum *R*-Value of Insulation Alone m²°C/W	Maximum *U*-Value of the Overall Assembly W/m²°C	Minimum *R*-Value of Insulation Alone m²°C/W
(1)	(2)	(3)	(4)	(5)	(6)
i)	Composite	U-0.261	R-3.5	U-0.409	R-2.1
ii)	Hot and dry	U-0.261	R-3.5	U-0.409	R-2.1
iii)	Warm and humid	U-0.261	R-3.5	U-0.409	R-2.1
iv)	Moderate	U-0.409	R-2.1	U-0.409	R-2.1
v)	Cold	U-0.261	R-3.5	U-0.409	R-2.1

Table 10 Opaque Wall Assembly *U*-Value and Insulation *R*-Value Requirements

(*Clause* B-2)

Sl No.	Climate Zone	24 h Use Buildings Hospitals, Hotels, Call Centres, etc		Daytime Use Buildings Other Building Types	
		Maximum *U*-Value of the Overall Assembly W/m²°C	Minimum *R*-Value of Insulation Alone m²°C/W	Maximum *U*-Value of the Overall Assembly W/m²°C	Minimum *R*-Value of Insulation Alone m²°C/W
(1)	(2)	(3)	(4)	(5)	(6)
i)	Composite	U-0.440	R-2.10	U-0.440	R-2.10
ii)	Hot and dry	U-0.440	R-2.10	U-0.440	R-2.10
iii)	Warm and humid	U-0.440	R-2.10	U-0.440	R-2.10
iv)	Moderate	U-0.431	R-1.80	U-0.397	R-2.00
v)	Cold	U-0.369	R-2.20	U-0.352	R-2.35

B-2 OPAQUE WALLS

Opaque walls shall comply with either the maximum assembly *U*-value or the minimum insulation *R*-value in Table 10. *R*-value is for the insulation alone and does not include building materials or air films.

B-3 VERTICAL FENESTRATION

Vertical fenestration shall comply with the maximum area weighted *U*-value and maximum area weighted SHGC requirements of Table 11. Vertical fenestration area is limited to a maximum of 60 percent of the gross wall area for the prescriptive requirement.

Table 11 Vertical Fenestration *U*-Value and SHGC Requirements

(*Clause* B-3)

Sl No.	Climate	Maximum *U*-Value W/m²°C	Maximum SHGC	
			WWR ≤ 40 Percent	40 Percent < WWR ≤ 60 Percent
(1)	(2)	(3)	(4)	(5)
i)	Composite	3.30	0.25	0.20
ii)	Hot and dry	3.30	0.25	0.20
iii)	Warm and humid	3.30	0.25	0.20
iv)	Moderate	6.90	0.40	0.30
v)	Cold	3.30	0.51	0.51

Alternative overhangs and/or side fins may be applied in determining the SHGC for the proposed design. An adjusted SHGC, accounting for overhangs and/or side fins is calculated by multiplying the SHGC of the unshaded fenestration product times a multiplication (*M*) factor. If this exception is applied, a separate *M* factor shall be determined from Table 5 for each orientation and unique shading condition.

Vertical fenestration areas located more than 2.2 m above the level of the floor are exempt from the SHGC requirement in Table 11, if the following conditions are complied with:

a) The total effective aperture for the elevation is less than 0.25, including all fenestration areas greater than 1.0 m above the floor level; and

b) An interior light shelf is provided at the bottom of this fenestration area, with an interior projection factor (PF) not less than:

   1) 1.0 for *EW*, *SE*, *SW*, *NE*, and *NW* orientations;

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2) 0.5 for *S* orientation; and
3) 0.35 for *N* orientation when latitude is less than 23°.

B-3.1 Minimum Visible Transmission (VLT) of Glazing for Vertical Fenestration

To permit the use of available day lighting in place of electric lighting, glazing products used in offices, banks, libraries, classrooms with predominant daytime usage, shall have the minimum VLT, defined as function of WWR, where effective aperture is greater than 0.1, equal to or greater than the minimum VLT requirements of Table 12. Table 12 also indicates recommended VLT ranges for daylight applications in such spaces.

Table 12 Minimum Visual Light Transmission Light Transmission Requirements
(*Clause* B-3.1)

Sl No.	Window Wall Ratio	Minimum VLT
(1)	(2)	(3)
i)	0 - 0.3	0.27
ii)	0.31 - 0.4	0.20
iii)	0.41 - 0.5	0.16
iv)	0.51 - 0.6	0.13
v)	0.61 - 0.7	0.11

B-4 SKYLIGHT

Skylights shall comply with the maximum *U*-value and a maximum SHGC requirement of Table 13. Skylight area is limited to a minimum of 5 percent of the gross roof area for the prescriptive requirement.

Table 13 Skylight *U*-Value and SHGC Requirements
(*Clause* B-4)

Sl No.	Climate	Maximum *U* value ($W/m^2°C$)		Maximum SHGC	
		With Curb	Without Curb	0-2 Percent SRR	2.1-5 Percent SRR
(1)	(2)	(3)	(4)	(5)	(6)
i)	Composite	11.24	7.71	0.40	0.25
ii)	Hot and dry	11.24	7.71	0.40	0.25
iii)	Warm and humid	11.24	7.71	0.40	0.25
iv)	Moderate	11.24	7.71	0.61	0.4
v)	Cold	11.24	7.71	0.61	0.4

ANNEX C

[*Clause* 8.2(b)]

TRADE-OFF METHOD FOR ENVELOPE OPTIMIZATION

C-1 The building envelope complies with the Code, if the building envelope performance factor (EPF) of the proposed design is less than the standard design, where the standard design exactly complies with the criteria in Annex B. The envelope performance factor shall be calculated using the following equations:

$$EPF_{Total} = EPF_{Roof} + EPF_{Wall} + EPF_{Fenest}$$

where

$$EPF_{roof} = c_{roof} \sum_{s=1}^{n} U_s A_s$$

$$EPF_{Wall} = c_{Wall,Mass} \sum_{s=1}^{n} U_s A_s + c_{Wall,Other} \sum_{s=1}^{n} U_s A_s$$

$$EPF_{Fenest} = c_{1Fenest,North} \sum_{w=1}^{n} SHGC_w M_w A_w + c_{2Fenest,North} \sum_{w=1}^{n} U_w A_w + c_{1Fenest,Non\ North} \sum_{w=1}^{n} SHGC_w M_w A_w + c_{2Fenest,Non\ North} \sum_{w=1}^{n} U_w A_w + c_{1Fenest,Skylight} \sum_{s=1}^{n} SHGC_s A_s + c_{2Fenest,Skylight} \sum_{s=1}^{n} U_s A_s$$

and

EPF_{Wall}, EPF_{Fenest} and EPF_{Roof} = envelope performance factor for walls, fenestration and roofs, respectively;

A_s, A_w = area of a specific envelope component referenced by the subscript 's' or for windows referenced by the subscript 'w';

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$SHGC_w$, $SHGC_S$ = solar heat gain coefficient for windows and skylights;

M_w = multiplier for the $SHGC_w$ that depends on the projection factor of an overhang or side fin as given in Table 5;

U_s = *U*-value for the envelope component referenced by the subscript 's';

c_{Roof}; $c_{Wall,Mass}$; $c_{Wall,Other}$; $c_{Fenest,North}$; $c_{Fenest,Non\ North}$; $c_{Fenest,Skylight}$ = coefficients for the roof, wall, window and skylight class of construction. Values of *c* are taken from Table 14 to Table 18 for each class of construction.

Table 14 Envelope Performance Factor Coefficients — Composite Climate

(*Clause* C-1)

Sl No.	Building Component	Daytime Occupancy		24 h Occupancy	
		U-Value W/m² K	SHGC	*U*-Value W/m² K	SHGC
(1)	(2)	(3)	(4)	(5)	(6)
i)	Mass walls	6.01	—	13.85	—
ii)	Curtain walls, other walls	15.72	—	20.48	—
iii)	Roofs	11.93	—	24.67	—
iv)	North windows	–1.75	40.65	–4.56	58.15
v)	Non-north windows	–1.25	54.51	0.68	86.57
vi)	Skylights	–96.35	311.71	–294.66	918.77

Table 15 Envelope Performance Factor Coefficients — Hot Dry Climate

(*Clause* C-1)

Sl No.	Building Component	Daytime Occupancy		24 h Occupancy	
		U-Value W/m² K	SHGC	*U*-Value W/m² K	SHGC
(1)	(2)	(3)	(4)	(5)	(6)
i)	Mass walls	5.48	—	15.01	—
ii)	Curtain walls, other walls	6.38	—	22.06	—
iii)	Roofs	11.14	—	25.98	—
iv)	North windows	–2.40	36.57	–1.49	56.09
v)	Non-north windows	–1.86	46.79	1.187	81.79
vi)	Skylights	–96.27	309.33	–295.81	923.01

Table 16 Envelope Performance Factor Coefficient — Warm Humid Climate

(*Clause* C-1)

Sl No.	Building Component	Daytime Occupancy		24 h Occupancy	
		U-Value W/m² K	SHGC	*U*-Value W/m² K	SHGC
(1)	(2)	(3)	(4)	(5)	(6)
i)	Mass walls	6.42	—	9.60	—
ii)	Curtain walls, other walls	14.77	—	19.71	—
iii)	Roofs	9.86	—	14.11	—
iv)	North windows	–1.58	34.95	–7.29	64.19
v)	Non-north windows	–1.00	43.09	–6.48	76.83
vi)	Skylights	–96.11	305.45	–295.45	893.55

Table 17 Envelope Performance Factor Coefficient — Temperate Climate

(*Clause* C-1)

Sl No.	Building Component	Daytime Occupancy		24 h Occupancy	
		U-Value W/m² K	SHGC	*U*-Value W/m² K	SHGC
(1)	(2)	(3)	(4)	(5)	(6)
i)	Mass walls	2.017	—	3.11	—
ii)	Curtain walls, other walls	2.72	—	4.11	—
iii)	Roofs	5.46	—	5.86	—
iv)	North windows	–3.10	29.66	–11.95	62.14
v)	Non-north windows	–2.98	34.86	–11.62	68.45
vi)	Skylights	–96.21	298.82	–294.12	876.70

Table 18 Envelope Performance Factor Coefficient — Cold Climate

(*Clause* C-1)

Sl No.	Building Component	Daytime Occupancy		24 h Occupancy	
		U-Value W/m² K	SHGC	*U*-Value W/m² K	SHGC
(1)	(2)	(3)	(4)	(5)	(6)
i)	Mass walls	5.19	—	5.19	—
ii)	Curtain walls, other walls	6.76	—	6.76	—
iii)	Roofs	5.69	—	5.67	—
iv)	North windows	1.55	9.13	1.55	9.13
v)	Non-north windows	– 1.13	16.32	– 1.13	16.32
vi)	Skylights	– 93.44	283.18	– 93.44	283.18

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ANNEX D

[*Clause* 8.2(c)]

WHOLE BUILDING ANALYSIS METHOD FOR ENVELOPE OPTIMIZATION

D-1 A building complies with the whole building performance requirement when the estimated annual energy use of the proposed design is less than the standard design, even though it may not comply with the specific requirements of the prescriptive requirements given in Annex B**.** Annual energy use for the purposes of the whole building performance method shall be calculated, in kilowatt-hour (kWh), of electricity use per year.

D-2 SIMULATION GENERAL REQUIREMENTS

A simulation program may be used for the analysis of energy consumption in buildings to model the following:

a) Energy flows on an hourly basis for all 8 760 h in the year;
b) Hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set points and HVAC system operation, defined separately for each day of the week and holidays;
c) Thermal mass effects;
d) Ten or more thermal zones;
e) Part-load and temperature dependent performance of heating and cooling equipment;
f) Airside and waterside economizers with integrated control; and
g) All the standard design characteristics specified in this chapter.

The simulation program shall use hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the proposed building is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site.

The proposed design and standard design shall be calculated using the following:

1) Same simulation program;
2) Same weather data; and
3) Same building operation assumptions (thermostat set points, schedules, internal gains, occupant loads, etc).

D-3 CALCULATING THE ENERGY CONSUMPTION OF THE PROPOSED DESIGN AND THE STANDARD DESIGN

The simulation model for calculating the proposed design and the standard design shall be developed in accordance with the requirements in Table 19. The HVAC system type and related performance parameters for the standard design shall be determined from Table 20 and the following rules:

a) All HVAC and service water heating equipment in the standard design shall be modelled at the minimum efficiency levels, both part load and full load.
b) Where efficiency ratings, such as energy efficiency ratio (EER) and coefficient of performance (COP), include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modelled separately.
c) Minimum outdoor air ventilation rates shall be the same for both the standard design and the proposed design.
d) The equipment capacities for the standard design shall be sized proportionally to the capacities in the proposed design based on sizing runs; that is, the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the proposed design and standard design. Unmet load hours for the proposed design shall not differ from unmet load hours for the standard design by more than 50 h.

Components and parameters not listed in Table 20 or otherwise specifically addressed in this Part of the Code shall be identical to those in the proposed design. Where there are specific requirements in this Part of the Code the component efficiency in the standard design shall be adjusted to the lowest efficiency level allowed by the requirement for that component type.

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Table 19 Modelling Requirements for Calculating Proposed and Standard Design

(*Clause* D-3)

Sl No.	Case	Proposed Building	Standard Design
(1)	(2)	(3)	(4)
i)	Design model	a) The simulation model of the proposed design shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls b) When the whole building performance method is applied to buildings in which energy-related features have not yet been designed (for example, a lighting system), those yet-to-be-designed features shall be described in the proposed design so that they minimally comply with applicable mandatory and prescriptive requirements	The standard design shall be developed by modifying the proposed design as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modelled identically in the standard design and proposed design
ii)	Space use classification	The building type or space type classifications shall be chosen in accordance with this code. More than one building type category may be used in a building if it is a mixed-use facility	Same as proposed design
iii)	Schedules	The schedules shall be typical of the proposed building type as determined by the designer	Same as proposed design
iv)	Building envelope	All components of the building envelope in the proposed design shall be modelled as shown on architectural drawings or as installed for existing building envelopes *Exceptions*: The following building elements are permitted to differ from architectural drawings: a) Any envelope assembly that covers less than 5 percent of the total area of that assembly type (for example, exterior walls) need not be separately described. If not separately described, the area of an envelope assembly shall be added to the area of the adjacent assembly of that same type b) Exterior surfaces whose azimuth orientation and tilt differ by no more than 45° and are otherwise the same may be described as either a single surface or by using multipliers c) For exterior roofs other than roofs with ventilated attics, the reflectance and emittance of the roof surface shall be modelled d) Manually operated fenestration shading devices such as blinds or shades shall not be modelled. Permanent shading devices such as fins, overhangs, and light shelves shall be modelled	The standard design shall have identical conditioned floor area and identical exterior dimensions and orientations as the proposed design, except as noted in (a) to (d) a) *Orientation* — The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90°, 180°, 270°, then averaging the results. The building shall be modelled so that it does not shade itself b) Opaque assemblies such as roof, floors, doors, and walls shall be modelled as having the same heat capacity as the proposed design but with the minimum *U-value* required in **B-1** and **B-2** c) *Fenestration* — Fenestration areas shall equal that in the proposed design or 40 percent of gross above grade wall area, whichever is smaller, and shall be distributed uniformly in horizontal bands across the four orientations. No shading projections are to be modelled; fenestration shall be assumed to be flush with the exterior wall or roof. Manually operated fenestration shading devices such as blinds or shades shall not be modelled. Fenestration *U-value* shall be the minimum required for the climate, and the solar heat gain coefficient shall be the maximum allowed for the climate and orientation d) *Roof albedo* — All roof surfaces shall be modelled with a reflectivity of 0.30
v)	Lighting	Lighting power in the proposed design shall be determined as follows: a) Where a complete lighting system exists, the actual lighting power shall be used in the model b) Where a lighting system has been designed, lighting power shall be determined c) Where no lighting exists or is specified, lighting power shall be determined for the appropriate building type d) Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures)	Lighting power in the standard design shall be determined using the same categorization procedure (building area or space function) and categories as the proposed design, with the lighting power to be set equal to the maximum allowed for the corresponding method and category in either Table 20 or Table 21. Power for fixtures not included in the lighting power density calculation shall be modelled identically in the proposed design and standard design

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Table 19 — (*Concluded*)

(1)	(2)	(3)	(4)
vi)	HVAC system	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows: a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions, if required by the simulation model c) Where no heating system exists or no heating system has been specified, the heating system shall be modelled as electric resistance. The system characteristics shall be identical to the system modelled in the standard design d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be modelled as an air-cooled single zone system, one unit per thermal block. The system characteristics shall be identical to the system modelled in the standard design	The HVAC system type and related performance parameters for the standard design shall be determined from Table 22. Equipment performance shall meet the requirements of this Code and the relevant Indian Standards
vii)	Service hot water	The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the proposed design shall be determined as follows: a) Where a complete service hot water system exists, the model shall reflect the actual system type using actual component capacities and efficiencies b) Where a service hot water system has been designed, the service hot water model shall be consistent with design documents c) Where no service hot water system exists or is specified, no service hot water heating shall be modelled	The water heating system shall be of the same type of the proposed design For residential facilities, hotels and hospitals the standard design shall have a solar system capable of meeting 20 percent of the design load Systems shall meet the prescribed efficiency requirements of equipment, pipe insulation and incorporate heat traps in accordance with the relevant applicable Indian Standards
viii)	Miscellaneous load	Receptacle, motor, and process loads shall be modelled and estimated based on the building type or space type category These loads shall be included in simulations of the building and shall be included when calculating the standard design and proposed design. All end-use load components within and associated with the building shall be modelled, unless specifically excluded, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment	Receptacle, motor and process loads shall be modelled the same as the proposed design. The water heating system shall be of the same type of the proposed design
ix)	Modelling limitations to the simulation program	If the simulation program cannot model a component or system included in the proposed design, one of the following methods shall be used with the approval of the authority having jurisdiction: a) Ignore the component if the energy impact on the trade-offs being considered is not significant b) Model the component substituting a thermodynamically similar component model c) Model the HVAC system components or systems using the standard design's HVAC system in accordance with Sl No. (vi) Whichever method is selected, the component shall be modelled identically for both the proposed design and standard design models	Same as the proposed case

NOTE — The energy simulation results shall be reported for the proposed building and standard design and the percentage savings in annual energy consumption achieved each for interior lighting, exterior lighting, HVAC, domestic hot water and other/miscellaneous equipment consuming substantial energy. The total energy savings for all equipment, that is, total building load shall also be reported.

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Table 20 Interior Lighting Power — Building Area Method

(*Table* 19)

Sl No.	Building Area Type	LPD W/m^2
(1)	(2)	(3)
i)	Automotive facility	9.7
ii)	Convention center	12.9
iii)	Court house	12.9
iv)	Dining: bar/lounge/leisure	14.0
v)	Dining: cafeteria/fast food	15.1
vi)	Dining: family	17.2
vii)	Dormitory	10.8
viii)	Exercise center	10.8
ix)	Gymnasium	11.8
x)	Healthcare clinic	10.8
xi)	Hospital/health care	12.9
xii)	Hotel	10.8
xiii)	Library	14.0
xiv)	Manufacturing facility	14.0
xv)	Motel	10.8
xvi)	Motion picture theater	12.9
xvii)	Multifamily	7.5
xviii)	Museum	11.8
xix)	Office	10.8
xx)	Parking garage	3.2
xxi)	Penitentiary	10.8
xxii)	Performing arts theater	17.2
xxiii)	Police/fire station	10.8
xxiv)	Post office	11.8
xxv)	Religious building	14.0
xxvi)	Retail	16.1
xxvii)	School/university	12.9
xxviii)	Sports arena	11.8
xxix)	Town hall	11.8
xxx)	Transportation	10.8
xxxi)	Warehouse	8.6
xxxii)	Workshop	15.1

NOTE — In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Table 21 Interior Lighting Power — Space Function Method

(*Table* 19)

Sl No.	Building Area Type	LPD (W/m^2)
(1)	(2)	(3)
i)	Office-enclosed	11.8
ii)	Office-open plan	11.8
iii)	Conference/meeting/multipurpose	14.0
iv)	Classroom/lecture/training	15.1
v)	Lobby	14.0
vi)	For hotel	11.8
vii)	For performing arts theater	35.5
viii)	For motion picture theater	11.8
ix)	Audience/seating area	9.7
x)	For gymnasium	4.3
xi)	For exercise center	3.2
xii)	For convention center	7.5
xiii)	For religious buildings	18.3
xiv)	For sports arena	4.3
xv)	For performing arts theatre	28.0
xvi)	For motion picture theatre	12.9

Table 21 — (*Continued*)

(1)	(2)	(3)
xvii)	For transportation	5.4
xviii)	Atrium-first three floors	6.5
xix)	Atrium-each additional floor	2.2
xx)	Lounge/recreation	12.9
xxi)	For hospital	8.6
xxii)	Dining area	9.7
xxiii)	For hotel	14.0
xxiv)	For motel	12.9
xxv)	For bar lounge/leisure dining	15.1
xxvi)	For family dining	22.6
xxvii)	Food preparation	12.9
xxviii)	Laboratory	15.1
xxix)	Restrooms	9.7
xxx)	Dressing/locker/fitting room	6.5
xxxi)	Corridor/transition	5.4
xxxii)	For hospital	10.8
xxxiii)	For manufacturing facility	5.4
xxxiv)	Stairs-active	6.5
xxxv)	Active storage	8.6
xxxvi)	For hospital	9.7
xxxvii)	Inactive storage	3.2
xxxviii)	For museum	8.6
xxxix)	Electrical/mechanical	16.1
xl)	Workshop	20.5
xli)	Sleeping quarters	3.2
xlii)	Convention centre — exhibit space	14.0
xliii)	Library	
	a) Card file and cataloguing	11.8
	b) Stacks	18.3
	c) Reading area	12.9
xliv)	Hospital	
	a) Emergency	29.1
	b) Recovery	8.6
	c) Nurse station	10.8
	d) Exam treatment	16.1
	e) Pharmacy	12.9
	f) Patient room	7.5
	g) Operating room	23.7
	h) Nursery	6.5
	j) Medical supply	15.1
	k) Physical therapy	9.7
	m) Radiology	4.3
	n) Laundry — washing	6.5
xlv)	Automotive — service repair	7.5
xlvi)	Manufacturing	
	a) Low bay (<8 m ceiling)	12.9
	b) High bay (>8 m ceiling)	18.3
	c) Detailed manufacturing	22.6
	d) Equipment room	12.9
	e) Control room	5.4
xlvii)	Hotel/motel guest rooms	11.8
xlviii)	Dormitory — living quarters	11.8
xlix)	Museum	
	a) General exhibition	10.8
	b) Restoration	18.3
	c) Bank office — banking activity area	16.1
l)	Religions buildings	
	a) Worship-pulpit, choir	25.8
	b) Fellowship hall	9.7
li)	Retail	
	a) Sales area	18.3
	b) Mall concourse	18.3
lii)	Sports arena	
	a) Ring sports area	29.1
	b) Court sports area	24.8
	c) Indoor field area	15.1

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Table 21 — (*Continued*)

(1)	(2)	(3)
liii)	Warehouse	
	a) Fine material storage	15.1
	b) Medium/bulky material storage	9.7
	c) Parking garage — garage area	2.2

Table 21 — (*Concluded*)

(1)	(2)	(3)
liv)	Transportation	
	a) Airport — concourse	6.5
	b) Air/train/bus — baggage area	10.8
	c) Terminal — ticket counter	16.1

Table 22 HVAC Systems Map

(*Clause* D-3)

Sl No.	Parameter	Residential More than 3 Storeys	Non-residential		
			Less than 3 floors or less than 7 500 m^2	4 or 5 floors or less than 7 500 m^2 or 5 floors or less and 7 500 – 15 000 m^2	More than 5 floors or more than 15 000 m^2
(1)	(2)	(3)	(4)	(5)	(6)
i)	System Type	Packaged terminal air conditioner	Packaged rooftop air conditioner	Central cooling plant with constant volume AHU for each zone	Central cooling plant with constant volume AHU for each zone
ii)	Fan control	Constant volume	Constant volume	Constant volume air handler for each zone	Variable volume air handler
iii)	Cooling type	Direct expansion	Direct expansion	Chilled water	Chilled water
iv)	Heating type	Electric resistance	Electric resistance	Electric resistance	Electric resistance

NOTE — If the proposed building has an air cooled chiller/system then the budget building shall have Air cooled chiller otherwise the budget case shall have water cooled centrifugal chillers.

LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfilment of the requirements of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parantheses indicates the number of the reference in this Part.

	IS No.	*Title*
(1)	15792 : 2008	Guidelines for artificial recharge to groundwater
	15797 : 2008	Guidelines for roof top rainwater harvesting
(2)	3792 : 1978	Guide for heat insulation of non-industrial buildings (*first revision*)
(3)	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
(4)	4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
(5)	455 : 2015	Specification for Portland Slag cement (*fifth revision*)
	456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
	457 : 1957	Code of practice for general construction of plain and reinforced concrete for dams and other massive structures
	458 : 2003	Specification for precast concrete pipes (with and without reinforcement) (*fourth revision*)
	459 : 1992	Specification for unreinforced corrugated and semi-corrugated asbestos cement sheets (*third revision*)
	1332 : 1986	Specification for precast reinforced concrete steel lighting poles (*first revision*)
	1343 : 2012	Code of practice for prestressed concrete (*second revision*)
	1489	Specification for Portland-pozzolana cement:
	(Part 1) : 2015	Fly ash based (*fourth revision*)
	(Part 2) : 2015	Calcined clay based (*fourth revision*)
	1592 : 2003	Specification for asbestos cement pressure pipes and joints (*fourth revision*)
	1626	Specification for asbestos cement

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IS No.	*Title*
	building pipes and pipe fittings, gutters and gutter fittings and roofing fittings:
(Part 1) : 1994	Pipe and pipe fittings (*second revision*)
(Part 2) : 1994	Gutters and gutter fittings (*second revision*)
(Part 3) : 1994	Roofing accessories (*second revision*)
1727 : 1967	Methods of test for pozzolanic materials (*first revision*)
2096 : 1992	Specification for asbestos cement flat sheets (*first revision*)
2098 : 1997	Specification for asbestos cement building boards (*first revision*)
2117 : 1991	Guide for manufacture of hand-made common burnt clay building bricks (*third revision*)
2185	Specification for concrete masonry units:
(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
(Part 2) : 1983	Hollow and solid light-weight concrete blocks (*first revision*)
(Part 3) : 1984	Autoclaved cellular aerated, concrete blocks (*first revision*)
(Part 4) : 2008	Preformed foam cellular concrete blocks
2541 : 1991	Code of practice for preparation and use of lime concrete (*second revision*)
3115 : 1992	Specification for lime based blocks (*second revision*)
3370	Code of practice for concrete structures for storage of liquids:
(Part 1) : 2009	General requirements (*first revision*)
(Part 2) : 2009	Reinforced concrete structures (*first revision*)
3466 : 1988	Specification for masonry cement (*second revision*)
3812	Specification for pulverized fuel ash:
(Part 1) : 2013	For use as Pozzolana in cement, cement mortar and concrete (*third revision*)
(Part 2) : 2013	For use as admixture in cement mortar and concrete (*third revision*)
4098 : 1983	Specification for lime-pozzolana mixture (*first revision*)
4139 : 1989	Specification for calcium silicate bricks (*second revision*)
4926 : 2003	Code of practice for ready-mixed concrete (*second revision*)
5817 : 1992	Code of practice for preparation and use of lime pozzolana mixture concrete in buildings and roads (*first revision*)
5820 : 1970	Specification for precast concrete cable cover
6041 : 1985	Code of practice for construction of autoclaved cellular concrete block masonry (*first revision*)
6042 : 1969	Code of practice for construction of lightweight concrete block masonry
6066 : 1994	Recommendations for pressure grouting of rock foundations in river valley projects (*second revision*)
6072 : 1971	Specification for autoclaved reinforced cellular concrete wall slabs
6073 : 2006	Specification for autoclaved reinforced cellular concrete floor and roof slabs (*first revision*)
6908 : 1991	Specification for asbestos cement pipes and fittings for sewerage and drainage (*first revision*)
8229 : 1986	Specification for oil well cement (*first revision*)
9142 : 1979	Specification for artificial lightweight aggregates for concrete masonry units
9375 : 1979	Specification for precast reinforced concrete plant guards
9627 : 1980	Specification for asbestos cement pressure pipes (light duty)
9872 : 1981	Specification for precast concrete septic tanks
9893 : 1981	Specification for precast concrete lintels and sills
10049 : 1981	Code of practice for manufacture of lime based blocks
10262 : 2009	Guidelines for concrete mix proportioning (*first revision*)
10359 : 1982	Code of practice for manufacture and use of lime-pozzolana concrete blocks for paving
10360 : 1982	Specification for lime-pozzolana concrete blocks for paving
10772 : 1983	Specification for quick setting lime-pozzolana mixture
11293	Guidelines for design of grout curtains:
(Part 1) : 1985	Earth and rockfill dams
(Part 2) : 1993	Masonry and concrete dams

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	IS No.	*Title*
	11650 : 1991	Guide for manufacture of common burnt clay building bricks by semi-mechanized process (*first revision*)
	12089 : 1987	Specification for granulated slag for manufacture of Portland slag cement
	12440 : 1988	Specification for precast concrete stone masonry blocks
	12592 : 2002	Specification for precast concrete manhole cover and frame (*first revision*)
	12894 : 2002	Specification for pulverized fuel ash lime bricks (*first revision*)
	13000 : 1990	Specification for silica-asbestos cement flat sheets
	13008 : 1990	Specification for shallow corrugated asbestos cement sheets
	13757 : 1993	Specification for burnt clay fly ash building bricks
	14862 : 2000	Specification for fibre cement flat sheets
	14871 : 2000	Specification for products in fibre reinforced cement — Long corrugated or asymmetrical section sheet and fittings for roofing and cladding
	15388 : 2003	Specification for silica fume
	15648 : 2006	Specification for pulverized fuel ash for lime pozzolana mixture application
	15916 : 2011	Code of practice for building design and erection using prefabricated concrete
	15917 : 2010	Code of practice for building design and erection using mixed/ composite construction
(6)	2686 : 1977	Specification for cinder as fine aggregates for use in lime concrete (*first revision*)
	3068 : 1986	Specification for broken brick (burnt clay) coarse aggregates for use in lime concrete (*second revision*)
	3182 : 1986	Specification for broken brick (burnt clay) fine aggregates for use in lime mortar (*second revision*)
	9142 : 1979	Specification for artificial light-weight aggregates for concrete masonry units
(7)	9142 : 1979	Specification for artificial light-weight aggregates for concrete masonry units
(8)	2185	Specification for concrete masonry units:
	(Part 1) : 2005	Hollow and solid concrete blocks (*third revision*)
	(Part 2) : 1983	Hollow and solid lightweight concrete blocks (*first revision*)
	(Part 3) : 1984	Autoclaved cellular (aerated) concrete blocks (*first revision*)
	(Part 4) : 2008	Preformed foam cellular concrete blocks
	12440 : 1988	Specification for precast concrete stone masonry blocks
(9)	2572 : 2005	Code of Practice for construction of hollow concrete block masonry (*first revision*)
	6041 : 1985	Code of Practice for construction of autoclaved cellular concrete block masonry (*first revision*)
	6042 : 1969	Code of Practice for construction of lightweight concrete block masonry
(10)	1725 : 2013	Specification for stabilized soil blocks used in general building construction (*second revision*)
(11)	401 : 2001	Code of practice for preservation of timber (*fourth revision*)
	1141 : 1993	Code of practice for seasoning of timber (*second revision*)
(12)	303 : 1989	Specification for plywood for general purposes (*third revision*)
	710 : 2010	Specification for marine plywood (*second revision*)
	1328 : 1996	Specification for veneered decorative plywood (*third revision*)
	1658 : 2006	Specification for fibre hardboards (*third revision*)
	1659 : 2004	Specification for block boards (*fourth revision*)
	3087 : 2005	Specification for wood particle boards (medium density) for general purposes (*second revision*)
	3097 : 2006	Specification for veneered particle boards (*second revision*)
	3129 : 1985	Specification for low density particle board (*first revision*)
	3308 : 1981	Specification for wood wool building slabs (*first revision*)
	4990 : 2011	Specification for plywood for concrete shuttering work (*third revision*)
	5509 : 2000	Specification for fire retardant plywood (*second revision*)
	12406 : 2003	Specification for medium density

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IS No.	*Title*
	fibreboards for general purposes (*first revision*)
12823 : 2015	Specification for wood products — Prelaminated particle boards (*first revision*)
13958 : 1994	Specification for bamboo mat board for general purposes
14587 : 1998	Specification for prelaminated medium density fibre board
14588 : 1999	Specification for bamboo mat veneer composite for general purposes
14616 : 1999	Specification for laminated veneer lumber
14842 : 2000	Specification for coir veneer board for general purposes
15380 : 2003	Specification for moulded raised high density fibre (HDF) panel doors
15476 : 2004	Specification for bamboo and corrugated sheets
15491 : 2004	Specification for medium density coirboards for general purposes
15877 : 2010	Specification for coir faced block boards
15878 : 2010	Specification for coir hardboard for general purposes
(13) 2250 : 1981	Code of practice for preparation and use of masonry mortars (*first revision*)
4443 : 1980	Code of practice for use of resin type chemical resistant mortars (*first revision*)
4832	Specification for chemical resistant mortars:
(Part 1) : 1969	Silicate type
(Part 2) : 1969	Resin type
(Part 3) : 1969	Sulphur type
(14) 13077 : 1991	Guide for preparation and use of mud mortar in masonry
(15) 653 : 1992	Specification for linoleum sheets and tiles (*third revision*)
1198 : 1982	Code of practice for laying, fixing and maintenance of linoleum floor (*first revision*)
(16) 1237 : 2012	Specification for cement concrete flooring tiles (*second revision*)
1443 : 1972	Code of practice for laying and finishing of cement concrete flooring tiles (*first revision*)
2114 : 1984	Code of practice for laying *in-situ* terrazzo floor finish (*first revision*)
(17) 15622 : 2006	Specification for pressed ceramic tiles
(18) 1661 : 1972	Code of practice for application of cement and cement-lime plaster finish (*first revision*)
(19) 2547	Specification for gypsum building plaster:
(Part 1) : 1976	Excluding premixed lightweight plaster (*first revision*)
(Part 2) : 1976	Premixed lightweight plaster (*first revision*)
12679 : 1989	Specification for by-product gypsum for use in plaster, blocks and boards
(20) 14862 : 2000	Specification for fibre cement flat sheets
14871 : 2000	Specification for products in fibre reinforced cement long corrugated or asymmetrical section sheets and fittings for roofing and cladding
(21) 2095	Specification for gypsum plaster boards:
(Part 1) : 2011	Plain gypsum plaster boards (*third revision*)
(Part 2) : 2001	Coated/laminated gypsum plaster boards (*second revision*)
(Part 3) : 1996	Reinforced gypsum plaster boards (*second revision*)
8272 : 1984	Specification for gypsum plaster for use in the manufacture of fibrous plasterboards (*first revision*)
(22) 4021 : 1995	Specification for timber door, window and ventilator frames (*third revision*)
(23) 6523 : 1983	Specification for precast reinforced concrete door and window frames (*first revision*)
(24) 8183 : 1993	Specification for bonded mineral wool (*first revision*)
(25) 3677 : 1985	Specification for unbonded rock and slag wool for thermal insulation (*second revision*)
(26) 2115 : 1980	Code of practice for flat roof finish: Mud *phuska* (*second revision*)
(27) 4082 : 1996	Recommendations on stacking and storage of construction materials and components at site (*second revision*)
7969 : 1975	Safety code for handling and storage of building materials
(28) 10500 : 2012	Drinking water (*second revision*)
11624 : 1986	Guidelines for the quality of irrigation water
8188 : 1999	Treatment of Water for Cooling Towers — Code of Practice

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IS No.	*Title*
201 : 1992	Quality tolerances for water for textile industry(*second revision*)
2724 : 1964	Quality tolerances for water for pulp and paper
2725 : 1964	Quality tolerances for water for rayon- manufacturing industry
3328 : 1993	Quality tolerances for water for swimming pools (*first revision*)
4221 : 1967	Quality tolerances for water for tanning industry
4251 : 1967	Quality tolerances for water for processed food industry
4700 : 1968	Quality tolerances for water for fermentation
8914 : 1988	Quality tolerances for water for vitreous enamel industry (*first revision*)
10392 : 1982	Specification for feed water and boiler water for low and medium pressure boilers
10496 : 1983	Specification for feed water, boiler water and condensate for high pressure boilers
13891 : 1994	Quality tolerances for freshwater for fish culture
3957 : 1966	Quality tolerances for water for ice manufacture
(29) 15883 (Part 1) : 2009	Guidelines for construction project management: Part 1 General
(30) 456 : 2000	Code of practice for plain and reinforced concrete (*fourth revision*)
1343 : 2012	Code of practice for prestressed concrete (*second revision*)
(31) 4130 : 1991	Safety code for demolition of buildings (*second revison*)
(32) 6598 : 1972	Specification for cellular concrete for thermal insulation
(33) IS/ISO 817	Designation and safety classification of refrigerants (*under preparation*)
(34) 12615 : 2011	Energy efficient induction motors — Three phase squirrel cage (*second revision*)

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NATIONAL BUILDING CODE OF INDIA

PART 12 ASSET AND FACILITY MANAGEMENT

BUREAU OF INDIAN STANDARDS

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FOREWORD

There has been significant growth in the requirement of building maintenance in view of an increased output of the construction industry in terms of buildings and built environment. This has been primarily due to large scale new construction taking place all across the country. While there is a need for proper maintenance of the existing building assets, there is a growing awareness of the need to manage the condition of the nation's building stock more efficiently. Paralleling these developments has been the increased application of new technology, permitting more efficient use of data and resources. Notwithstanding this, it is still the case that much maintenance activities take place in a context that do not create a fully integrated approach to managing asset/facility performance and, thus, the full potential of many assets/facilities is never wholly realized. The likely adverse impact on safety and business continuity due to lack of a well planned maintenance strategy is also not fully appreciated as yet.

Poor detailed design affects building performance, and hence impacts maintenance cost and consequent effect is well known. There is need to look into this aspect and explore design-maintenance relationship. Many of the problems encountered in buildings stem from the development phase, where a failure to establish user requirements in sufficient detail results in the poor performance of the completed building. At the hand-over stage also there may be serious shortcomings, and more careful consideration need to be given to providing the client with a proper building model to facilitate the effective management of the property. None of these crucial developments can take place without a major shift in client attitudes, and professions working with the built environment.

Considering all the above, the National Building Code Sectional Committee decided to incorporate this new Part to NBC, namely, Part 12, to give a comprehensive approach to asset and facility management for adoption by all concerned.

This Part 12 of the Code covers provisions relating to management of building assets and associated services and deals with issues relating to maintenance of all types of facilities and fixed assets such as buildings and building services. Besides these provisions, critical activities and critical assets which need to be focused upon by facility managers have also been identified. The responsibilities of occupants for maintenance of facilities, such as, structures, equipment and exterior property have also been covered.

While outlining a process approach to maintenance management at the strategic and tactical level with links to operational activities, an attempt has been made to make the owners and occupants aware of the importance of initiating timely action to formulate strategies and policies for maintenance management. Measures that will help organizations and individuals to assist those responsible for ensuring that asset and facility continue to perform as intended, retaining their asset value at minimum cost, have been outlined. While focusing on the activities required to maintain an asset or a complete facility, it is imperative that capabilities of the Facility Managers are improved in general so that money spent on maintaining the assets yield value.

Following Indian Standards have been utilized while formulating this Part 12:

IS 15183	Guidelines for maintenance management of buildings:
(Part 1) : 2002	General
(Part 2) : 2002	Finance
(Part 3) : 2002	Labour

Considerable assistance has also been drawn from following International Standards while formulating this Part:

ISO 55000 : 2014	Asset/Facility management — Overview, principles and terminology
ISO 55001 : 2014	Asset/Facility management — Management systems — Requirements
ISO 55002 : 2014	Asset/Facility management — Management systems — Guidelines for the application of ISO 55001
BS 8210 : 2012	Guide to facilities maintenance management

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BS 8536 : 2010 Asset/Facility management briefing code of practice

BS 8572 : 2011 Guide to procurement of facility-related services

BS 8587 : 2012 Guide to facility information management

BSI PAS 55 : 2008 Publicly available specification for the optimal management of physical assets

Reference has also been made to following publications:

Maintenance Manual 2012, Central Public Works Department, Govt of India.

Solid Waste Management Rules, 2016, Ministry of Environment, Forest and Climate Change, Govt. of India

Hazardous and Other Wastes (Management and Transboundary Movement) Rules, 2016, Ministry of Environment, Forest and Climate Change, Govt. of India

All standards, whether given herein above or cross-referred to in the main text of this Part, are subject to revision. The parties to agreement based on this Part are encouraged to investigate the possibility of applying the most recent editions of the standards.

For the purpose of deciding whether a particular requirement of this Part is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this Part of the Code.

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NATIONAL BUILDING CODE OF INDIA

PART 12 ASSET AND FACILITY MANAGEMENT

1 SCOPE

1.1 This Part 12 covers provisions relating to management of building assets and associated facilities and includes various aspects relating to maintenance of all types of facilities and fixed assets, such as, buildings and building services.

1.2 This Part does not cover assets other than physical assets.

1.3 Whereas all asset and facility management services in permanent or temporary buildings, including mechanical, electrical and plumbing services relating to buildings, maintenance of landscaped areas, etc, are covered in this Part, the maintenance of bulk services required for towns and cities are not covered in this Part. This Part, however, covers all operations/efforts required to ensure that the asset/facility continues to meet the requirements which were set for it during design stage.

2 TERMINOLOGY

For the purpose of this Part, the following definitions shall apply.

2.1 Access — Approach, entry, internal circulation or exit, including in cases of emergency.

2.2 Ageing — Getting old, specifically beyond the design life of the asset.

2.3 As-built Information — Expression of the design, its working detail, construction works and/or installations, functions, operations and maintenance needs of a facility in a form suitable for use in managing that facility.

2.4 Asset — A useful or valuable thing or an item of property owned by a person or organization, regarded as having value and life of more than one year, available to meet debts, commitments, or legacies and performing predetermined functions to facilitate the users.

2.5 Asset Life — Period from asset creation to end of its functional life.

2.6 Asset Register — A central database of information about asset/facility in terms of their manufacturer, vendor, make, model, specifications, date of acquisition, initial cost, maintenance costs and requirements, additions/alterations over period, accumulated depreciation and written down value.

2.7 Asset Type — Grouping of assets having common characteristics that distinguish those assets as a group or class, for example, physical assets, information assets, intangible assets, critical assets, enabling assets, linear assets, information and communications technology (ICT) assets and infrastructure assets.

2.8 Asset/Facility Management — Integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities.

2.9 Benchmarking — Comparing performance, often between companies in similar sectors.

2.10 Biodegradable Waste — Any organic material that can be degraded by microorganisms into simpler stable compounds.

2.11 Briefing — Briefing is the process of communicating the objectives and needs of an owner, or prospective owner, of a facility to a designer in order to prepare a design for that facility. This process includes clarification and confirmation of the owner's intentions and documenting the consequent provisions for the facility to enable informed decision making primarily in design, but also in construction work and/or installation, testing and commissioning, handover and start-up of operations. A number of stages are envisaged for preparing and applying the brief during design and in later phases.

2.12 Buffer Zone — A zone of no development which shall be maintained around landfills, processing and disposal facilities of solid waste.

2.13 Building Fabric — Elements and components of a building other than furniture and services installations.

2.14 Building Information Model (BIM) — Shared digital representation of physical and functional characteristics of any built object (including buildings, bridges, roads, etc) which forms a reliable basis for decisions.

NOTE — A building information model may embody, for example, building geometry, spatial relationships, geographic information and the quantities and properties of building components.

2.15 Building Maintenance Work undertaken to maintain or restore the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

2.16 Building Management System (BMS) — Computer aided control systems, including hardware and software, to collect and monitor parameters and performance data of plant, equipment, systems and elements either at source or remotely and to enable corrective action to be initiated.

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2.17 Building Manual — Guidance to assist in making the best use of the design features, services and systems of a building or other facility.

2.18 Business Continuity Management (BCM) — Holistic management process that identifies potential threats to an organization and the impacts to business operations that those threats, if realized, may cause, and which provides a framework for building organizational resilience with the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities.

2.19 Carbon Emissions — Polluting carbon substances released into the atmosphere.

2.20 Carbon Footprint — Totality of greenhouse gas (GHG) emissions caused directly and indirectly by an individual, organization, event or product.

2.21 Cleaning — Locating, identifying and properly disposing of undesirable substances from surfaces or material.

2.22 Cleaning Services — Services undertaken to ensure the cleanliness, maintenance and aesthetic upkeep of the building/property.

2.23 Competent Person — Person, suitably trained and qualified by knowledge and practical experience.

2.24 Computer Aided Facilities Management (CAFM) — Systems, applications and tools that automate functions needed to support the core business in its efficient and effective use of facilities.

2.25 Computer Aided Maintenance Management System (CMMS) — System specifically designed to enable planning, organizing, directing and controlling maintenance programmes and to collect and collate historical data on the performance of assets so that the most effective maintenance method is selected under actual performance and environmental conditions.

2.26 Condition Monitoring — Act of measuring and recording data from operating parameters, using either human senses or instrumentation, to verify plant and equipment condition and trends. It is also the act of assessing an asset to understand how it is likely to perform in future.

2.27 Confined Space — Space which may be inadequately ventilated for any reason and may result in a deficiency of oxygen, or a build-up of toxic gases, for example, closed tanks, sewers, ducts, closed and unventilated rooms, and tanks particularly where heavier than air gases or vapours may be present.

2.28 Corrective Maintenance — Maintenance carried out after fault recognition and intended to put an item into a state in which it can perform a required function.

2.29 Crime Prevention Through Environmental Design (CPTED) — A multi-disciplinary approach to deterring criminal behavior through environmental design. CPTED strategies rely upon the ability to influence offender decisions that precede criminal acts. CPTED principles of design affect elements of the built environment ranging from the small-scale (such as the strategic use of shrubbery and other vegetation) to the overarching, including building form of an entire urban neighbourhood and the amount of opportunity for 'eyes on the street'.

2.30 Critical Activities — Activities which have to be performed in order to deliver the key products and services which enable an organization to meet its most important and time sensitive objectives.

2.31 Critical Asset — Asset having potential to significantly impact on the achievement of the organization's objectives.

2.32 De-construction — A planned selective demolition in which salvage, re-use and recycling of the demolished structure is maximized.

2.33 Deliverable — Product or service as an outcome of a process.

2.34 Design Development — Transitional phase where the basis of the design progresses towards the production of detailed design information.

2.35 Design Life (DL) — Intended/expected service life by the designer or as stated by the designer to the client to support specification decisions.

2.36 Documented Information — Information required to be controlled and maintained by an organization and the medium on which it is contained.

2.37 Domestic Hazardous Waste — Waste contaminated with hazardous chemicals or infectious waste such as discarded paint drums, pesticide cans, CFL bulbs, tube lights, expired medicines, broken mercury thermometers, used batteries, used needles, gauge and syringes, etc, generated at the household level.

2.38 Dry Waste — Waste, other than food waste, inert and including recyclable waste, non-recyclable waste, combustible waste and sanitary waste.

2.39 Dump Sites — A land utilized by urban local body for unscientific disposal of solid waste without following the principles of sanitary land filling.

2.40 Durability — Ability of a building and its parts to perform its required function over a period of time and under the influence of agents.

2.41 Duress Alarms — Duress alarms are installed to protect personnel who may be placed in danger of

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physical assault during interactions with other persons. Duress alarms are normally placed in locations where an employee may be alone with a potentially threatening person.

2.42 End-user — Recipient of facility-related services.

NOTE — Recipients include occupants and other users of a facility.

2.43 Estimated Service Life (ESL) — Service life that a building or parts of a building should be expected to have in a set of specific in use conditions, determined from the reference service life data after taking into account any differences from the reference in-use conditions.

2.44 Exterior Property – The open space on the premises under the control of owners or operators of such premises.

2.45 External Envelope — Roof and façade including openings.

2.46 Facilities Maintenance — Work needed to maintain the performance of the building structure, fabric and components, and engineering installations.

2.47 Facility — Tangible asset that supports/serves an organization.

2.48 Facility Asset Performance — Requirements in terms of measurable outcomes for meeting organizational goals.

2.49 Hazardous Waste — It shares the properties of a hazardous material (for example ignitability, corrosivity, reactivity, or toxicity), or other physical, chemical, or biological characteristics that may pose a potential risk to human health or the environment if improperly managed. Wastes may also be defined as 'hazardous' by local regulations or international conventions, based on the origin of the waste and its inclusion on hazardous waste lists, or based on its characteristics. Sludge from a waste treatment plant, water supply treatment.

2.50 House Keeping — The routine recurring work which is required to keep a structure in good condition so that it can be utilized at its original capacity and efficiency along with proper protection of capital investment, throughout its economic life.

2.51 Information Management — Processing and storage of information in a controlled manner.

2.52 Intrusion Detection Systems — An intrusion detection system (IDS) is a device or software application that monitors the activities for malicious activities or policy violations and produces reports to a management station. Intrusion detection and prevention systems (IDPS) are primarily focused on identifying possible incidents, logging information about them, and reporting attempts.

2.53 Life Cycle — The stages of an asset from acquisition through commissioning and operation to disposal.

2.54 Maintenance — An intervention on an asset to improve its operation or ensure its continued good operation (It is also the combination of all technical and associated administrative actions during the service life to retain a building, or its parts, in a state in which it can perform its required functions.).

2.55 Maintenance Management — Process of ensuring that the most effective and efficient maintenance programme is formulated and delivered to ensure that assets/facilities continue to perform their intended function. The organization of maintenance has to be within an agreed policy. Maintenance can be seen as a form of 'steady state' activity.

2.56 Maintenance Manual — Technical instructions intended to preserve an asset/facility in, or, restore it to a state in which it can perform a required function.

2.57 Maintenance Plan — Structured and documented set of tasks that include the activities, procedures, resources and the time scale required to carry out maintenance.

2.58 Maintenance Policy — Scope and course of action taken to achieve an organization's objectives.

2.59 Maintenance Programme — Arrangement of maintenance tasks in terms of their sequence, durations and resource requirements.

2.60 Maintenance Strategy — Statement of organizational approach to maintenance management.

2.61 Management System — Set of interrelated or interacting elements of an organization to establish policies and objectives and processes to achieve those objectives.

2.62 Mantrap — A small room with two doors. The first door is locked; a person is identified and authenticated. Once the person is authenticated and access is authorized, the first door opens and allows the person into the mantrap. The person has to be authenticated again in order to open the second door and access a critical area. The mantrap area can have a weight sensing floor as an additional control to prevent literal piggybacking.

2.63 Occupants — Users who spend a significant proportion of their time in or about a facility.

2.64 Operational Plan — Organization's statement of actions intended to achieve a specific business goal(s).

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2.65 Operational Strategy — Overall approach to managing production or use of a facility.

2.66 Perimeter Intrusion Detection and Assessment System (PIDAS) — A type of fencing that has sensors on the wire mesh and base of the fence. A passive cable vibration sensor sets off an alarm if an intrusion is detected.

2.67 Perimeter Security — Control and observation of areas of ingress and egress to a building and parking structure, including main lobby doors, rear plaza doors, truck docks, fire exits, and other points of access.

2.68 Physical Asset — A tangible, manmade object that has a specific function, normally within a broader system.

2.69 Planned Preventive Maintenance — Maintenance organized and carried out with forethought, control and the use of records to a plan based on the results of condition surveys.

2.70 Predicted Service Life — Service life predicted from performance recorded over time in accordance with standard laid down procedure.

2.71 Predictive Action — Action to monitor the condition of an asset and predict the need for preventive action or corrective action.

2.72 Preventive Maintenance — An intervention on an asset taken in advance of a failure to reduce the chances of failure.

2.73 Preventive Action — Action to eliminate the cause of a potential non-conformity or other undesirable potential situation (for asset/facility management).

2.74 Primary Collection — Collecting, lifting and removal of segregated solid waste from source of its generation including households, shops, offices and any other non-residential premises or from any collection points or any other location specified by the urban local body.

2.75 RASCI Chart — Responsible, accountable, supported, consulted and informed chart that is used to summarize the roles and functions performed in the procurement process and the activities within it.

2.76 Reliability Centered Maintenance (RCM) — An approach which targets intervention on assets based on the known historic performance of that or similar assets.

2.77 Repair, Renovate, Refurbish — An intervention which improves the performance and condition of an asset to upgrade or retain desired performance.

2.78 Residual Waste — Includes the waste and rejects from the solid waste processing facilities which are not suitable for recycling or further processing.

2.79 Root Cause Analysis — A thorough assessment of all of the factors influencing the occurrence of a fault or failure.

2.80 Sanitary Land Filling — The final and safe disposal of residual solid waste and inert wastes on land in a facility designed with protective measures against pollution of ground water, surface water and fugitive air dust, wind-blown litter, bad odour, fire hazard, animal menace, bird menace, pests or rodents, greenhouse gas emissions, persistent organic pollutants slope instability and erosion.

2.81 Sanitary Waste — Wastes comprising of used diapers, sanitary towels or napkins, tampons, condoms, incontinence sheets and any other similar waste.

2.82 Scope Creep — Uncontrolled changes to the agreed scope of the facility related service being provided.

2.83 Secondary Collection — Collection of solid waste deposited at secondary waste storage depots or bins for onward transportation of the waste to the processing or disposal facility.

2.84 Secondary Storage — The temporary containment of solid waste at a public place in a covered bin or container in a manner so as to prevent littering, vectors, stray animals and odour.

2.85 Service Life — Period of time after installation during which a building or its parts meets or exceed the performance requirements.

2.86 Shutdown/Outage — A period, either planned or otherwise, during which asset interventions occur.

2.87 Stabilizing — The biological decomposition of biodegradable wastes to a stable state where it generates no leachate or offensive odours and is fit for application to farm land, soil erosion control and soil remediation.

2.88 Stakeholder — Individual, organization or group with an interest in an organization, facility or project. It also applies to the person or entity with an interest in or concern about a facility.

2.89 Surveillance — Surveillance is the monitoring of the behaviour, activities, or other changing information, usually of people for the purpose of influencing, managing, directing, or protecting them. This can include observation from a distance by means of electronic equipment (such as, CCTV cameras). Surveillance is used for intelligence gathering, the prevention of crime, the protection of a process, person, group or object, or for the investigation of crime. Surveillance is often a violation of privacy, and is opposed by various civil liberties groups and activists.

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2.90 Surveillance Devices — Surveillance device can be defined as any instrument, apparatus or equipment used either alone, or in conjunction with other equipment, which is being used to conduct surveillance.

2.91 Whole Life Costing — An understanding of the full economic impact of owning an asset, covering all stages of its life cycle.

3 GENERAL ASPECTS OF ASSET/FACILITY MANAGEMENT

3.1 Asset and its Management

The physical assets represent only one of the five broad categories of asset types that have to be managed holistically in order to achieve the organizational strategic plan. The other categories are human assets, information assets, financial assets and intangible assets (reputation, morale, intellectual property, goodwill, etc). The scope of this Part is limited to maintenance of physical assets.

Asset management is the process by which an owner maximizes the value of a property or portfolio of properties from acquisition to disposition within the objectives defined by the owner.

Asset management utilizes strategic planning practices including investment analysis, operation analysis and the positioning of a property in the market place in accordance with market trends.

3.2 Facility and its Management

Facility is something that is built for a specific purpose and which is used by end users for predetermined purposes. Facilities management is the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities as well as enhances its ability to successfully control the building environment that houses people (employees, clients, visitors). Facilities management encompasses multi-disciplinary activities within the built environment and the management of their impact upon people and the workplace. It is also known as a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology.

3.3 Overview of Asset/Facility Management

Asset/Facility management is a multidisciplinary approach for designing, planning and managing in an integrated and coordinated way all non-core support services necessary for an effective and efficient execution of the organization's core activities. It involves systematic and coordinated process of planning, operating, maintaining, upgrading and replacing assets cost effectively with minimum risk and at the desired level of customer service at the lowest life cycle cost for the purpose of achieving its organizational strategic plan. It can be used to help assure that utility services are provided in a sustainable, cost-effective way to assist and help to improve the quality of life of people.

Asset/Facility Management is not an accounting exercise or a substitute for quality management. It is for everyone working in a organization that owns or operates assets. This includes those working in procurement, finance, personnel, service, planning, design, operations, administration, leadership, marketing and sales. It is neither a project management system nor just about maintenance.

It is devoted to the coordination of space, infrastructure, people and organization, often associated with the administration of office blocks, public arenas, schools, sporting complexes, convention centre, shopping complexes, hospitals, hotels, etc. Facilities management practice is applicable for all class of assets, that is, retail, residential, commercial, industrial, warehousing and hospitality, etc.

If correctly implemented, facility management can deliver safe, productive, humane and cost effective environments in different spheres of people's living, commercial activities and working. This practice also enhances the skills of people within the facilities management sector, creates career opportunities, and enables new working styles which is important in this technologically driven world. All these benefits will not only enhance the organization's image and brand name but also make the infrastructures across class of assets a safe, healthy and productive place.

Asset/facility management includes the integration of the planning and management of a wide range of services both 'hard' (for example, building fabric and building services) and 'soft' (for example, catering, cleaning, security, and mailroom), the management of an increasingly broad range of tangible assets, support services as well as people skills.

The identified core competencies of the asset/facility management are:

a) *Communication* — Communication plans and processes for both internal and external stakeholders;
b) *Emergency preparedness and business continuity* — Emergency and risk management plans and procedures;
c) *Environmental stewardship and sustainability* — Sustainable management of built and natural environments;
d) *Finance and business* — Strategic plans,

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budgets, financial analyses, procurement;

e) *Human factors* — Healthful and safe environment, security, facility management employee development;

f) *Leadership and strategy* — Strategic planning, organization, staff and leadership organization;

g) *Operations and maintenance* — Building operations and maintenance, occupant services;

h) *Project management* — Overseeing and management of all projects and related contracts;

j) *Quality* — Best practices, process improvements, audits and measurements;

NOTE — Management of only physical assets are covered in this Part.

The asset/facility management can be done either in-house or by engaging outside agency.

Asset management and facility management have overlapping aspects, these are therefore dealt with in this Part together and accordingly, in most cases the term 'asset/facility' has been used while in some other cases, the two terms have been used interchangeably.

3.3.1 *General Issues Relating to Asset/Facility Management*

Any asset/facility will have following stakeholders:

a) Owner,
b) Execution team,
c) End user, and
d) Maintenance or operation team (Operator).

All the four may be different entities or may be one. In any case it is essential to ensure that the best interests of all the stakeholders are served. This gets served when an asset/facility is maintained in such a manner that it performs the function or allows functions to be performed for which the facility was conceived.

The owner may be the operator of the asset/facility or another party may fulfil this role. In either case, it is important that the interests of the operator are taken into account from the outset. This interest extends to the needs of the end-users of the asset/facility. In larger organizations, an operations team, asset/facility management team or a facility manager is responsible for the asset/facility on a day-to-day basis. In smaller organizations, there may not be any equivalent provision. Nonetheless, someone has to provide expertise on operational matters and that may have to fall to a consultant engaged for this purpose. This person is necessary to provide comment and advice on the implications of design and construction proposals from an operational perspective as they are developed from planning to the procurement strategy through to the handover and close-out work stage.

The operator, operations team or facility manager, as appropriate, should be given authority by the owner to contribute information concerning the operational strategy and operational requirements, including performance outcomes and targets, operational costs and budgets, and the procurement of facility related services where appropriate. The owner may agree that such contributions are channeled through the owner's representative or they may be communicated directly to the design and construction team. In the latter case, the design and construction team should ensure that contributions are duly recorded and made available within the team. A responsible, accountable, supported, consulted and informed (RASCI) chart should be used to clarify responsibilities.

Effective asset/facility management, combining resources and activities, is vital to the success of any organization. At a corporate level, it contributes to the delivery of strategic and operational objectives. On a day-to-day level, effective facilities management provides a safe and efficient working environment, which is essential to the performance of any business – whatever its size and scope. Maintaining and developing services through the process of building maintenance, administration and contract management, maintaining communications infrastructure ensures that a facility gives value during its operational life.

Timely action and proper maintenance ensures continued serviceability during life of the asset/facility and gives better return on investment, ensures enhanced life of asset, continued safety and helps avoid risks of the asset/facility loosing value and requiring greater amount of effort and finances to bring it back to a serviceable stage. It ensures that the asset continues to meet the standards which were set during design stage.

3.3.2 *Strategy*

An organization should formulate a facilities maintenance strategy and policy that meets its current and likely future needs. The strategy and policy should be reviewed, at least annually, to ensure that it continues to be aligned to the organization's core business and primary processes. An organization should ensure that the needs of its stakeholders are identified and the impact of those needs is assessed and taken into account when formulating the strategy and policy. A communication plan to disseminate the strategy and policy, as well as tactical and operational actions, to stakeholders should be prepared by the organization. Details of annual, or more frequent, reviews to check on the alignment between actions and the organization's facilities maintenance strategy should be included in the plan.

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3.3.3 *Stakeholder Engagement*

Stakeholders should be involved in discussion about the arrangements for asset/facility management in general and facility-related services in particular in defining their needs and the level of performance that is acceptable. This task includes,

a) involving stakeholders, as far as practicable, in identifying their needs through, for example, the use of questionnaire-based surveys and in contributing to the drafting of service specifications and service levels;
b) identifying diversity of need such as when seeking to include people with disabilities or other individuals' specific needs;
c) prioritizing the needs of stakeholders; and
d) controlling stakeholder inputs and changes once service specifications and service levels have been agreed in order to avoid scope creep.

3.3.4 *Effective Communication*

Effective communication between the procurer and service providers (another stakeholder group) should be maintained to enable the implementation of an asset/facility management strategy (in terms of the broad approach to the procurement of services) which is both understood and capable of being acted upon. Clear and regular communication is required to develop relationships.

3.3.5 *Performance Evaluation*

It is imperative that the strategy for managing the asset/facility should be efficient and cost-effective in terms that are quantifiable. It may be advisable to set the following performance outcomes at the strategy work stage and monitored during each subsequent work stage up to operation and end of life, with post occupancy evaluation (POE) during a defined period of extended aftercare used as the basis for measuring operational performance:

a) *Environmental* — The asset/facility should meet performance targets such as those for energy use, CO_2 emissions, water consumption and waste reduction or others defined by the owner and operator.
b) *Social (that is, functionality and effectiveness)* — The asset/facility should be designed and constructed to meet the functional and operational requirements of the owner such as the overall concept, context, uses, access, visual form, space, internal environment, durability and adaptability, and in operation should meet the operator's and end-users' requirements of utility, usability, safety, maintainability, security, inclusiveness and comfort.
c) *Economic* — The asset/facility should meet performance targets for capital cost and operational cost, which should be considered side-by-side to enable whole-life costs to be calculated.

Outcomes and targets should be specific to the project and should be verified in each work stage.

3.3.6 *Statement of Needs*

Deliverables in the briefing process should include a statement of needs. A statement of needs embodies the owner's objectives and the extent to which they are likely to be satisfied by the facility. A functional brief is the interpretation of the statement of needs in the form of defined scope of work as a basis for design.

Internal and external stakeholders should be identified at the start of the briefing process and their interest in the facility should be assessed and documented. A stakeholder impact analysis should be undertaken to determine how, and the extent to which, stakeholder interests may impact on the facility in terms of its design, construction work and/or installation, testing and commissioning, handover and start-up of operations.

A statement of the owner's primary activities and primary processes should be prepared. This statement should provide details of how the facility is expected to contribute to the fulfilment of the owner's primary activities and should describe the processes to be carried out in or from the facility.

The space efficiency of the facility should be calculated, where applicable, and used to assess the owner's space provision over the anticipated lifetime of the facility. Allowance for growth and/or reduction in the demand for space and its phasing over the lifetime of the facility should be incorporated in the assessment of this provision.

Results of the stakeholder impact analysis used in assessing stakeholder interests in the facility should be made available to the designer if prepared by the owner or a third party. The results should show the nature, extent and relative importance of all expressed needs. Any prioritization should be made explicit. The statement should express the needs of the owner both in general terms and specifically in relation to the facility.

The statement of needs should be used to inform the provision of an operational facility. Information and data on the expected use of the facility, including technical solutions, should be prepared against criteria given in the statement of needs. The information and

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data should be grouped as follows:

a) Primary activities and processes to be accommodated by the facility;
b) Operational demands and support processes for users; and
c) Technical solutions, including the appraisal of options for satisfying identified needs.

This information is used, amongst other things, in planning the layout and arrangement of spaces and functions within the facility. There can be different ways of satisfying an identified need and these have to be made clear and supported by information and data for decision-making.

3.3.7 *Importance of Asset/Facility Management System*

Systems asset/facility management are vital for organizations that are dependent on the function and performance of their physical assets in the delivery of services or products, and where the success of an organization is significantly influenced by the stewardship of its assets. Asset/facility management is important because it can help organizations to,

a) reduce the total costs of operating their assets;
b) reduce the capital costs of investing in the asset base;
c) improve the operating performance of their assets (reduce failure rates, increase availability, etc) and ensure continued serviceability during life of the asset;
d) reduce the potential health impacts of operating the assets;
e) reduce the safety risks of operating the assets;
f) minimise adverse environmental impact of operating the assets;
g) maintain and improve the reputation of the organization;
h) improve the regulatory performance of the organization;
j) reduce legal risks associated with operating assets;
k) gives better return on investment (important from financers point of view), enhanced life of asset, ensures continued safety; and
m) it ensures that the asset continues to meet the standards which were set during design stage – the strategy for managing the asset/facility should be efficient and cost-effective in terms that are quantifiable.

The key to good asset/facility management is that it optimizes these benefits. That means that asset/facility management takes all of the above into account and determines the best blend of activity to achieve the best balance for all of the above for the benefit of the organization. Asset/facility management is explicitly focused on helping organizations to achieve their defined objectives and to determine the optimal blend of activities based on these objectives.

4 ORGANIZATIONAL STRUCTURE OF AN ASSET AND FACILITY MANAGEMENT SYSTEM

The organizational strategic plan is the starting point for development of the asset/facility management policy, strategy, objectives and plans. Monitoring and continual improvements within the asset/facility management system is very important.

Organization setup for large facilities will be guided by the factors given below.

4.1 Scope of Work to be Carried Out

In general, asset/facility management will require carrying out necessary activities in various disciplines involved for covering all relevant aspects. For each discipline, the number of persons required at field level and supervisory levels will depend on the quantum of assets to be managed.

4.2 Competence of Staff at Various Levels

Asset/facility management work will need personnel with adequate and relevant expertise in each of the concerned disciplines at various levels.

4.3 Organization Roles at Various Levels

The top management has to ensure that the personnel at various levels are aware of their roles and responsibilities and an information communication system is in place to see that all activities specified for asset/facility management have been duly carried out at all levels.

4.4 Facility Manager

Normally functions of facility management are entrusted to a dedicated functionary termed as Facility Manager. He can be assisted by various skilled and unskilled persons as per facility requirements.

4.4.1 *Functions of Facility Manager*

Facility Manager is primarily concerned with operational planning and control of the activities covered under asset/facility management. This will involve various items as given under **4.4.2** to **4.4.4**.

4.4.2 *Persons Reporting to Facility Manager*

They should be aware of their roles and responsibilities and procedures to be followed. Facility Manager has to see that adequate resources are made available to

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them for carrying out the required activities. Where necessary, their competence is to be developed further so that they may carry out the present and future assignments successfully.

4.4.3 *Control Mechanisms*

The facility manager should put in place certain control mechanisms to ensure that,

a) there is documentation to enable verification that the activities required were duly carried out and completed as required;
b) there is documentation to enable verification that the risk management processes required were duly carried out and completed as required; and
c) efforts are made to determine emerging risks and plan changes to asset/facility management well in advance, if required.

4.4.4 *Management of any Change*

During operational phase, there may be changes due to supply chain constraints in respect of materials or labour, or there may be competing demands on resources. New assets may also have to be managed. There may be a change in processes and so on. Efforts have to be made to foresee the changes and take timely action to avoid any disruption in asset/facility management processes.

4.5 Outsourcing

Certain items under the facility manager may have been outsourced. Facility Manager has to supervise those items with effective monitoring in order to ensure that the concerned agencies are discharging their responsibilities properly and performance is as planned, which should be supported by necessary documentation. The control of risks which cannot be transferred to outside agencies should be maintained with the Facility Manager.

5 METHODOLOGY

During the planning of the asset/facility management system, the resources required for the activities planned should be determined. These resources may be grouped broadly in the following two categories:

a) In-house; and
b) Outsourced.

The costs of activities required for asset/facility management should also be incurred under above two categories.

5.1 In-House Activities

Following aspects should be kept in view while planning the activities required for asset/facility management as in-house activities:

a) Cost to be incurred on salary and establishment expenses of regular staff will be more or less fixed depending upon the number of staff in various categories and the infrastructure required for them by way of office accommodation, tools and plants, equipment, etc. This expenditure will not vary much unless the number of staff or the quantum of equipment is varied depending on the work load.
b) Generally, the quantum of works to be carried out is decided keeping in view, in addition to technical requirement, the availability of funds. Cost incurred on works will depend on the actual quantum of work carried out and is, therefore, variable.

5.2 Outsourced Activities

The procurer should determine the extent to which, if any, facility-related services are to be provided from within the organization and those services that are to be outsourced. Where both occur, account should be taken of the need to integrate the two sources of service delivery and the resources and costs that may be involved in managing such an arrangement. Consideration should be given to the interfaces between separate services, including any obtained from within the organization, so that end-users experience seamless service delivery.

5.2.1 *Precautions to be Taken During Outsourcing*

The advantage of managing activities with in-house resources is that the organization has direct control over the operations. However, when activities are outsourced, such direct control is not automatic. The organization shall assess the associated risks and shall ensure that outsourced processes and activities are controlled. There has to be a clear demarcation between the activities that have to be outsourced and the activities to be managed by the organization in-house. Arrangements have to be made for sharing the knowledge and information between the organization and the agencies with whom contract has been entered into for providing certain activities. Therefore, in case of outsourcing of certain activities, the organization shall lay down responsibilities and authorities within the organization for controlling such outsourced activities including monitoring of their performance.

5.3 Processes to be Adopted

Adequate staff having necessary training in carrying out various operations for ensuring required levels of cleanliness, serviceability, hygienic conditions, safety

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and security of occupants under guidance of facility manager should be deployed. The Facility Management team should draw up plans for achieving the desired standards. It should also keep track of best practices developed elsewhere and is exposed to latest developments in this field.

6 RESOURCES REQUIREMENT FOR ASSET/ FACILITY MANAGEMENT

6.1 Resource Assessment

A facility, and the individual assets that it comprises, should be maintained to deliver the most effective outcomes in terms of minimal cost and risk. Assets should be classified into risk categories, for example, small, medium, severe and critical, according to their potential impact on the core business of the organization in the event of failure in performance. The condition of assets should be determined and a decision made as to the most effective option for their maintenance.

The organization shall determine and provide the resources needed for the establishment, operation, and further improvement of the asset/facility management system; meeting the asset/facility management objectives and implementation of the activities specified in asset/facility management system. Information technology will help in making better use of resources, reduce risk of failure of essential services, and make available information for better future planning.

6.2 Resource Plan

A maintenance resource plan should be prepared for assets operating under normal (operating) conditions. This plan should be modified, where necessary, to reflect operating conditions within the facility that fall outside specified design requirements and/or tolerances. The plan should be capable of aligning with changes in demand for, or modes of, service delivery. For an existing facility, a condition assessment of the assets should be undertaken before preparing the maintenance resource plan, wherever practicable. The cost of implementing the plan should be estimated and adequate provision made within budgets. Once implemented, the plan should be monitored for effectiveness and performance, with adjustments made where appropriate to ensure that the requirements set out are met.

6.3 Need Assessment

An organization should align its service needs, including service dependency, utilization, location, capacity and functionality, and maintenance planning with the required level of facility asset performance. Where a new facility is being procured, an organization should ensure that adequate provision is made during the design and construction phases to incorporate these requirements. Maintenance should be planned to take account of the maintenance cycle of each element/sub-element and inspections should be made at regular intervals (as determined by the properties of each element/sub-element and its anticipated service life). An organization's production and operational requirements should be integrated into the maintenance plan. Annual programmes of maintenance should take into account subsequent years' programmes so that additional costs or abortive works are minimised. Decisions to replace or repair components should be taken after due consideration of whole-life costs.

6.4 Adequacy of Resources

6.4.1 The resources available may be compared with the resources required. In case of shortfall in availability as compared to requirement, the shortfall may be met by one or more of the following options:

a) Augmenting in-house resources;
b) Augmenting outsourced resources; and
c) When resources cannot be augmented, say, due to non-availability of requisite funds, postponing the requirements which are not so urgent.

6.4.2 Following factors affect the choice of the category of resource required for various activities:

a) *Competence of staff* — It is to be seen whether the requisite competence is available with the staff available in-house, or it is necessary to arrange the same by outsourcing. Where required, the competency needs should be met by provision of training to the available persons, or hiring or contracting of competent persons. The following shall be taken care of,
   1) The organization shall determine the required level of competence of persons doing work under its control that affects its asset performance, asset/facility management performance and asset/ facility management system performance.
   2) The organization shall ensure that the persons engaged on its works are competent on the basis of appropriate education, training or experience.
   3) Where required, action should be taken to see that the concerned persons acquire the requisite competence by further training, etc.
   4) Adequate documented information shall be kept as evidence of competence of concerned persons.

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5) The organization shall periodically review current and future competency needs.
6) Staff is aware of their job requirement and expected deliverables.

b) Persons doing work under the organization's control, who can have an impact on the achievements of the asset/facility management objectives, shall be aware of,

1) the asset/facility management policy;
2) their contribution to the effectiveness of the asset/facility management system, including the benefits of improved asset/facility management performance.
3) their work activities, the associated risks and opportunities and how they relate to each other.
4) the implications of not conforming to the asset/facility management system requirements.

c) *Tools, plant and machinery* — Certain maintenance operations may require tools, plants and machinery, which may or may not be available in-house. In case of non-availability in-house, it has to be decided whether the same should be procured or the work outsourced.

7 PROCUREMENT OF ASSET/FACILITY RELATED SERVICES

7.1 Roles, Responsibilities and Accountabilities

One of the functions of asset/facility management is to determine which procurement option, or combination of options, for the delivery of maintenance-related services best fits the core business and primary processes of an organization. It is important for organizations to understand the full maintenance requirements and the capability and capacity required to deliver these services.

Procurement of facility-related services should be regarded as a distinct function within the procurer's organization and, as such, should be covered by a designated role. Formal systems, processes and procedures should be assessed to determine whether or not arrangements covering facility related services have been included and, if so, how these may apply.

The procurer should determine where responsibilities and accountabilities rest with respect to defined roles in the procurement of facility-related services. Where tasks to be performed fall outside existing roles, the organization should consider designating additional personnel for this purpose. The need for expert advice from external sources to supplement any lack of internal skills and competence should be ascertained. Where found necessary, additional roles should be defined and incorporated alongside those existing. The procurer should identify all roles that are connected with the function of procuring facility-related services and ascertain their nature and the relationship between them. Where the procurer is unable to fulfil required roles, the appointment of a managing agent (or other consultant) should be considered.

7.2 Planning for Procurement

A plan of the procurement process should be prepared to identify the stages involved and activities within them. The plan should take the form of a schedule in which stages, planned activities and their resources, decision points and milestones are shown against a time-scale.

Planning for procurement is a project in its own right. Resources include finance, budgets, human resources, consumables, equipment and information technology. Milestones cover commencement dates, completions and deadlines. Approvals and other key decisions are better considered as activities having durations and not as milestones since they are rarely, if ever, instantaneous events. The plan should complement existing processes and procedures, and align with the requirements of corporate governance. The procurement plan should identify:

a) Stages and decision points in the procurement process;
b) Criteria for decision-making;
c) Activities within stages and their sequence;
d) Sources of information and data to be used in activities;
e) Individuals and external organizations to be involved in activities and their roles;
f) Other stakeholders who may be involved;
g) Resources needed to support the activities; and
h) Deliverables at each stage and the form they should take.

The plan should incorporate the tendering process and procedures to be adopted.

7.3 Pre-qualification

A request for proposal (RFP) or a pre-qualification quotation (PQQ) should be prepared by the procurer and reflect, as a minimum, the following:

a) Legal form and ownership of the service provider;
b) Areas of specialization, competences and technical skills;
c) Proposed approach to service delivery (that is, method of work);

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d) Extent of subcontracting;
e) Relevant track-record (based on evidence of similar contracts);
f) Financial capacity and dependency;
g) Organizational organogram ;
h) Health, safety, security and sustainability policies, procedures and practices;
j) Commitment to provisions on access, inclusion and equality;
k) CSR policy and initiatives;
m) Alignment with the procurer's business process and systems; and
n) Basis for assessing overall suitability (including criteria, scoring and any weightages to be applied).
p) Training infrastructure

The RFP/PQQ may be undertaken in two parts: firstly, through a preliminary evaluation which is used to determine and filter out any service providers that are clearly unsuitable; and, secondly, through a detailed evaluation aimed at objectively assessing the ability of prospective service providers. Any preliminary evaluation should enable the procurer to quickly establish the suitability of service providers, enabling them to focus attention on those best qualified to deliver the service.

NOTE — Standard procedures for call of tenders may be as well established by respective organizations, for example, ones under two/three envelope system.

The procurer should determine the number of service providers that it wishes to invite to submit an RFP/PQQ. A maximum and minimum number should be set. The procurer should determine if, at the end of the RFI stage, it lacks information to specify all of its facility-related services and required levels of performance. In such a case, it should make arrangements to gather that information before proceeding to a request for proposal (RFP).

7.4 Financial Appraisal

All prospective service providers, irrespective of specialization or size, should be treated fairly and with equal diligence during the financial appraisal process. As a minimum consideration, the following should be undertaken:

a) Inspection of the financial accounts for the past three years of trading (in the absence of audited statements, other information that demonstrates the service provider's financial standing should be sought); and
b) Assessment of the service provider's ability and capacity to deliver the service at the current estimated contract value.

Where the procurer considers that its knowledge of the market is underdeveloped, it should investigate the availability of prospective service providers and the extent to which they may cover the identified scope of facility related services. The procurer should engage in direct enquiries with service providers and/or the trade associations or other bodies that represent them. Market testing should represent a genuine attempt to engage existing and prospective service providers in discussion about approaches to service delivery.

The procurer should consider the benefits of seeking indicative cost estimates to guide decision-making.

7.5 Centralized *Versus* De-centralized Management of Service Contracts

Where the procurer has both centralized and de-centralized management with respect to procurement, it should state its position and policy in regard to services that may be procured locally and those that may only be procured centrally and *vice-versa*. Note should be taken of the arrangements for day-to-day management of service contracts and authorities for contract awards, approval of payments and significant changes in the scope of contracts or their value. Where there is a requirement for pre-qualification for the purpose of inclusion in a list of tenderers, policy in this regard should be made clear both centrally and locally.

7.6 Geographical Location and Limits

By examining needs in regard to the provision of facility-related services, in particular attributes of service, the procurer should be able to achieve a clear understanding of what is important in service delivery. The procurer should consider the extent to which the local market is able to offer the planned services and the geographical limits that are acceptable when considering the suitability of a prospective service provider.

7.7 Single/Multiple Service Contracts

The procurer should explore the combinations of services that can be delivered by prospective service providers with regard to the defined scope and the relationships and interfaces between the services. Account should be taken of the ability of service providers based on evidence of performance and/or reference sites.

7.8 Local, Regional and National Service Providers

The procurer should determine the extent to which the market locally, regionally or nationally has the capacity to satisfy needs. Account should be taken of the specialization, number and size of service providers

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able to offer the planned services. Informal enquiries directed to prospective service providers may reveal the extent to which they are in a position to undertake new work, although care should be exercised when making judgments as to their capacity to do so.

7.9 Award of Works and Monitoring

The work shall normally be awarded to lowest responsible bidder whose bids are found to be responsive and is capable of delivery. Proper monitoring system shall be put in place to ensure quality work, as per work schedules and within budget estimates.

8 CLASSIFICATION OF ASSET/FACILITY MANAGEMENT

8.1 Typically asset/facility management can be classified into two areas of 'hard' and 'soft' services. The scope is extremely varied and services are likely to include hard services and soft services as given under **8.1.1** and **8.1.2**, respectively.

8.1.1 *Hard Services*

Hard services basically include building fabric maintenance, building services maintenance, such as plumbing, heating, ventilation and air conditioning (HVAC), electrical installations, lifts and escalators, etc.

MEP equipment provide essential service and make the building/facility safe and workable it is most essential that all the systems installed in any building/facility are maintained in good running/operating condition. Shortcoming in maintenance can lead to disruption of essential service and lead to impacting adversely the working within the facility therefore downtime should be minimised. All these services have to be carried out as per the type and usage of the facility.

For large or sensitive installations/facilities, it will be desirable to co-opt the facility management team at planning and design stage and utilize their inputs during the lay-out/design of building fabric and services, which can ultimately lead to easier and better functioning. Selection of materials, system, which have proved to be easier to maintain should be considered while making selection at project execution stage.

Some of these hard services, which are covered in this Part include,

a) building fabric maintenance (including addition/alteration and refurbishment) (*see* **10**);
b) building services maintenance:
    1) Plumbing and drainage (*see* **11**);
    2) Air conditioning, heating and mechanical ventilation (HVAC) services (*see* **12**);
    3) electrical installations (*see* **13**);
    4) lifts and escalators (*see* **14**); and
    5) fire fighting-detection and suppression (*see* **15**); and
c) Roads and pathways (*see* **16**).

8.1.2 *Soft Services*

Soft services, such as housekeeping, pest control, waste management, security, valet services, office support services, etc, are as essential a part of asset/facility management as maintaining hard services.

All these soft services have to be carried out as per the type, usage of the facility and may vary considerably. For instance services and service standards for a hotel, hospital or shopping malls/complexes may be quite different from those required for a standalone residence. A considered call on this has to be taken by the owner and the standards required to be achieved have to be communicated to the facility management team.

Some of these soft services, which are covered in this Part include,

a) environment, health and safety (*see* **17**);
b) landscaping and horticulture waste management (*see* **18**);
c) housekeeping (*see* **19**);
d) pest control (*see* **20**);
e) security management (*see* **21**); and
f) solid waste management (*see* **22**).

8.2 Asset/facility management in respect of common areas in a building and built environment should also take care of the provisions of **9.13**.

8.3 Various services, whether hard or soft, require understanding of different aspects, methodologies and management of maintenance, which have been detailed in **9**.

9 BUILDING MAINTENANCE — METHODS AND MANAGEMENT

9.1 General

Any building (including its services) when built has certain objectives and during its total economic life, it has to be maintained in proper condition to meet those objectives. Maintenance is a continuous process requiring a close watch and taking immediate remedial action. It is interwoven with good quality of housekeeping. It is largely governed by the quality of original construction. The owners, engineers, constructors, occupants and the maintenance agency are all deeply involved in this process and share a responsibility. Situation in which all these agencies

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merge into one is ideal and most satisfactory. There are two processes envisaged, that is, the work carried out in anticipation of failure and the work carried out after failure. The former is usually referred to as preventive maintenance and the latter as corrective maintenance. The prime objective of maintenance is to maintain the performance of the building fabric and its services to provide an efficient and acceptable operating environment to its users.

Maintaining a building is expensive; it costs many times more to run a building over its lifetime than to build it, yet maintenance is often not accorded the priority it warrants. A poorly maintained building will be a drain on resources and will impair building use, whereas a well maintained building will function smoothly and represent an appreciating asset to its owners. A professional approach is therefore required to building maintenance.

Though the building may be designed to be very durable it needs maintenance to keep it in good condition. Whereas construction stage lasts for a short period, maintenance continues for comparatively very large period during the useful life of building. Inadequate or improper maintenance adversely affects the environment in which people work, thus affecting the overall output. In the post construction stage the day to day maintenance or upkeep of the building shall certainly delay the decay of the building structure. Maintenance management of building is the art of preserving over a long period what has been constructed

9.1.1 The objective of maintenance is,

a) to preserve building and services, machinery in good operating condition;
b) to restore it back to its original standards; and
c) to improve the facilities depending upon the development that is taking place in building and services engineering.

9.1.2 Maintenance in general term can also be identified in the following broad categories:

a) *Cleaning and servicing* — This is largely of preventive type, such as checking the efficacy of rain water gutters and servicing the mechanical and electrical installations. This covers the house keeping also.
b) *Rectification and repairs* — This is also called periodical maintenance work undertaken by, say, annual contracts and including external replastering, internal finishing, etc.
c) *Replacements* — This covers major repair or restoration such as reproofing or re-building defective building parts.

9.2 Maintenance Methods

An organization should determine which method or combination of methods best satisfies its operational needs in maintenance in accordance with its facilities maintenance strategy and policy. Each method should be assessed in terms of the extent to which it satisfies (or does not satisfy) the criteria defined as part of the facilities maintenance strategy. When taking into account asset criticality and monitoring capacity within the facility, the benefit of combining methods should be evaluated.

There are a number of methods of maintenance; these can be grouped into two broad categories (*see also* Fig. 1):

a) Planned maintenance, which includes planned preventive maintenance and shutdown maintenance. Preventive maintenance further includes condition-based maintenance, reliability centred maintenance (RCM) and total productive maintenance (TPM); and
b) Unplanned maintenance, which includes corrective maintenance, breakdown maintenance and emergency maintenance.

9.2.1 *Planned Maintenance*

9.2.1.1 *Planned preventive maintenance or scheduled maintenance*

This method allows maintenance activities to be organized and carried out with forethought, control and records to a predetermined plan, based on the results of condition surveys. This method aims to avoid or to mitigate the 'consequences of failure' and to minimise maintenance-induced failures and their associated costs. It is based on the criticality of failure to the organization and is also known as scheduled maintenance.

Planned preventive maintenance is further classified into following categories:

a) *Condition-based maintenance* — This method of maintenance is based on the results of condition monitoring of building, plant, equipment, systems and elements to avoid loss of function or failure. Condition-based maintenance is performed by selecting and monitoring a parameter which, for example, indicates plant condition. Data are collected and analysed and required maintenance is determined from the findings. This work can be carried out continuously, periodically or on demand in real time and is often used for remotely monitoring plant condition.
b) *Reliability centred maintenance* — Reliability centred maintenance is a systems-based method used to determine maintenance tasks

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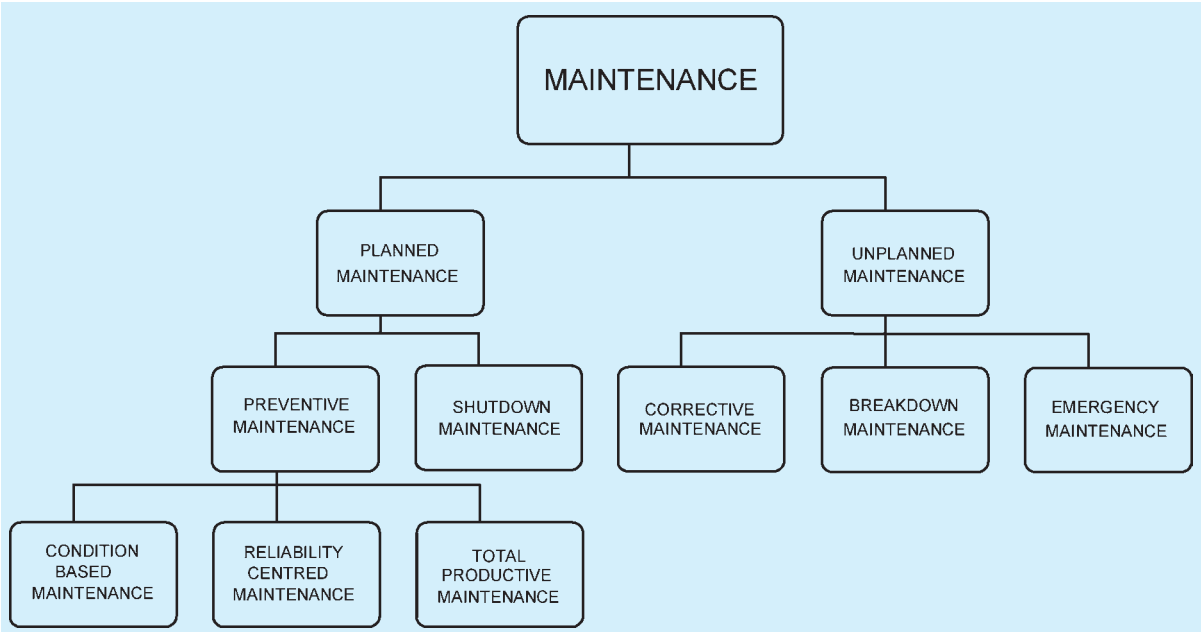


FIG. 1 MAINTENANCE METHODS

needed to ensure that a facility asset or system continues to function in order to fulfil its purpose as designed in its present operating condition. The method can involve the implementation of asset condition monitoring, based on the advance provision of an asset register.

c) *Total productive maintenance* — Total productive maintenance is a systematic approach to improving maintenance effectiveness, which operates at the tactical level and normally builds on the successful implementation of strategic methods. The method also involves the implementation of asset condition monitoring, based on the advance provision of an asset register.

9.2.1.2 *Planned shutdown maintenance*

This method is normally used for continuous process production and manufacturing facilities, where a detailed plan is produced for all assets for work to be carried out during a total shutdown.

9.2.2 *Unplanned Maintenance*

9.2.2.1 *Corrective maintenance*

Maintenance initiated as a result of the observed or measured condition of plant, equipment, systems, elements, before or after a functional failure, can be used to resolve the problem and ensure correct functional performance. This work can be planned or unplanned.

9.2.2.2 *Breakdown maintenance*

Breakdown maintenance relates to the task of restoring an asset so that it can fulfil its original function after failure. This method may result in high replacement costs over the lifetime of the asset, but has a low initial maintenance resource requirement. It is sometimes used for simple facilities that have few operatives and no critical environments to support.

9.2.2.3 *Emergency maintenance*

This maintenance method results from a sudden, unforeseen occurrence requiring immediate corrective work to be carried out to restore to function and to avoid potentially serious consequences.

9.3 Cost Effectiveness

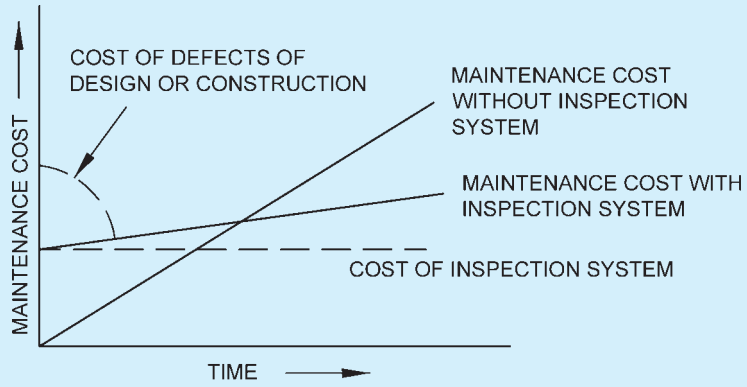
The facility manager has to work out the cost effectiveness of the method adopted taking into account the resources availability, criticalness of services and cost trade off to determine the frequency and level of maintenance to be ensured. Impact of various factors on costs involved and degree of maintenance services achieved is shown in Figs. 2 to 4.

9.4 Aspects Influencing Building Maintenance

9.4.1 Maintenance of the buildings is influenced by the following factors:

a) *Technical factors* — These include age of building, nature of design, material specifications, past standard of maintenance and cost of postponing maintenance.

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NOTES

1 In general maintenance classication may be as:

a) Major repair or restoration,

b) Periodic maintenance, and

c) Routine or day-to-day maintenance.

2 A system which is based on planned inspections and maintenance will have higher overhead costs than the one that is not, but the planned inspection lead to lower maintenance expenditure.

FIG. 2 COST RELATIONSHIP BETWEEN PLANNED AND UNPLANNED SYSTEM

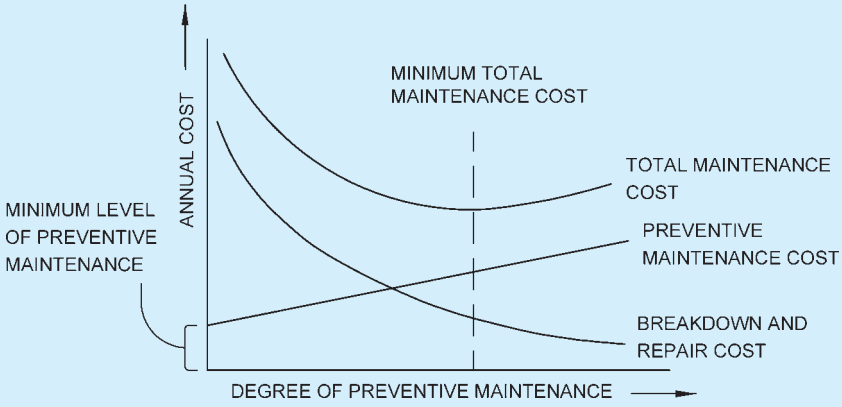


FIG. 3 TRADE-OFF BETWEEN REPAIRS AND PREVENTIVE MAINTENANCE

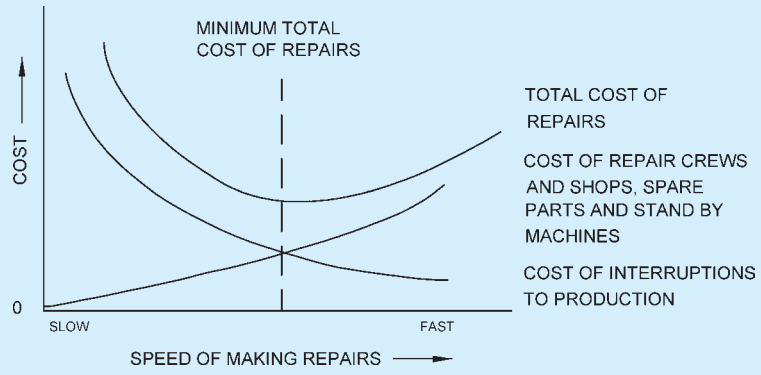


FIG. 4 SPEED OF MAKING REPAIRS

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b) *Policy* — A maintenance policy ensures that value for money expended is obtained in addition to protecting both the asset value and the resource value of the buildings concerned and owners.

A maintenance policy should be developed to support the preparation of operational plans in accordance with the maintenance strategy. The policy should outline the scope and course(s) of action that should be taken to achieve an organization's goals. The maintenance policy should embody the principle of best value for money to protect both the asset value and the resource value of the facility. The policy should cover,

1) the organization's anticipated future requirements for the facility, taking into account the facility's physical performance and functional suitability, for example:
   i) The use of the facility, that is, anticipating likely upgrades and the effect on the life cycles of existing materials, components and engineering installations;
   ii) A change of use for the facility and the effect of any conversion work on the life cycles of existing materials, components and engineering installations; and
   iii) The anticipated date of conversion, renovation or refurbishment work.
2) any cycles of maintenance determined in accordance with (a);
3) the method of maintenance, taking account of cycles of maintenance together with the requirements of the organization with respect to the use of the facility and any special requirements to which this may give rise;
4) holding spare parts and other items to replace those that are beyond repair or which have exceeded their useful life; and
5) the means for reporting on performance achieved.

c) *Financial and economic factors* — The planning and control of finance is an important aspect of maintenance management not only for the control of maintenance but also to demonstrate that the owners are getting value for money and that the maintenance proposals justify the funds requested.

Financial considerations start with the development of maintenance programmes and the preparation of budget proposals. They also include the preparation of the detailed maintenance programme following the allocation of budget funds. These will involve decisions regarding optimum repair reaction time and the choice of the most appropriate method of execution (directly employed).

d) *User* — the maintenance requirements of buildings and their various parts are directly related to the type and intensity of use they receive and the people who use these facilities especially those with disabilities, elderly and children in particular.

9.4.2 *Other Factors Affecting Maintenance*

9.4.2.1 *Health and safety*

9.4.2.1.1 *General*

The management of occupational health and safety has to be viewed as an integral component of facilities maintenance management and not as a separate function or as an add-on.

An organization should assess risks and other hazards at all stages in a facility's life cycle. Identified risks should be monitored and, wherever possible, their potential impacts should be mitigated. An organization should implement a formal system of risk management, including establishing and maintaining a risk register. Periodic reassessment of risks should be undertaken to update the risk register and associated risk mitigation.

9.4.2.1.2 *Initial review*

An initial review should be undertaken to provide information on the appropriateness, efficiency and effectiveness of existing health and safety management systems. Where no formal, or a minimal, health and safety management system exists (such as when an organization is newly established or when carrying out new activities) the initial review should be used as a base from which to develop a new system.

9.4.2.1.3 *Risk control and corrective actions*

An organization should implement risk control, as an integral part of its risk management, to ensure that control measures remain in place and that they remain efficient and effective. The risk management system should allow, as a minimum, for the following:

a) Identification of health and safety hazards arising from maintenance and other work determined by workplace inspections, behavioural observations, tours, and formal and informal discussions with the workforce;
b) Identification of people who may be at risk

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from maintenance, for example, maintenance personnel, occupants, visitors, passers-by, trespassers, persons with disabilities, elderly people and children;

c) Evaluation of the risks to which individuals and/or an organization may be exposed;

d) Devising ways to eliminate, reduce and/or control risks, for example guarding and fencing, method statements, safe systems of work, permit-to-work, training and supervision;

e) Monitoring and recording the effectiveness of risk control measures and systems, for example inspections, observations, safety tours and checklists;

f) Taking coordinated corrective action;

g) Providing feedback to the workforce and other stakeholders;

h) Training, together with health and safety checks, of operatives; and

j) Auditing and reviewing the system and, therefore, health and safety performance.

9.4.2.2 *Environmental factors*

9.4.2.2.1 *External*

An organization should assess the extent to which external environmental factors can influence the condition of the structure, fabric, engineering installations, fixtures and external finishes, and take such factors into account when drawing up maintenance plans. This should also include control of moisture. Swimming pool structures are vulnerable to the effects of chlorine used in water.

9.4.2.2.2 *Internal*

Humidity, temperature and pollution are factors that can adversely affect the condition of the structure, fabric, engineering installations, fixtures and internal finishes. The effects of intermittent heating and condensation can be particular problems.

An organization should assess the extent to which internal environmental factors, as well as the level of maintenance, influences the condition of the structure, fabric, engineering installations, fixtures and internal finishes. These factors should be taken into account when maintenance plans are drawn up. Factors that have a damaging effect on physical conditions, for example control of moisture, static electricity, as well as any unintended consequences for maintenance personnel, occupants and other users of the facility, should also be taken into account.

9.4.2.2.3 *Materials and components*

When drawing up maintenance programmes and plans, including inspection schedules, the likely maintenance cycle of each element/sub-element (in accordance with the known quality of the materials and components employed and their manufacturers' recommendations where available) should be incorporated. The following need special attention:

a) Potentially hazardous materials and components such as:
   1) Those containing asbestos;
   2) Lead, which may be present in some paint or be used for pipes carrying potable water;
   3) Materials that are either highly combustible or give off large quantities of smoke and fumes when involved in an established fire or in confined spaces (for example electrical risers); and
   4) Areas that should operate under a permit-to-work system.

b) Types or methods of construction that, under certain circumstances, may become dangerous.

c) Finishes and decorations, including their protection and treatment, where required.

9.5 Influence of Design

9.5.1 The physical characteristics, the life span and the aesthetic qualities of any building depend on the considerations given at the design stage. All buildings, however well designed and conscientiously built, will require repair and renewal as they get older. For better performance of the building envelope the following ways help to minimise troubles at later stage.

a) Due attention be paid to maintenance requirements of the facility from the planning stage. The agency which is likely to be entrusted with the work of subsequent maintenance and upkeep of the facility should be involved from the design stage itself. Their inputs will be very valuable in ensuring economical maintenance during the lifetime of the facility. This aspect needs greater attention as the defects that are built in at planning stage are difficult to be addressed at subsequent stages.

b) Detail and choose materials during construction so that the job of maintenance is less onerous.

c) Specifications adopted should be practical and based on local practices. Durability considerations and maintenance of various areas should be kept in view.

d) In addition to initial costs and life, type of

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finish achieved and fire and life safety requirements should be built in at the time of design.

e) Detailing of components should be done to ensure that they are conducive to effective operation and maintenance

f) Accessibility for maintenance purposes of areas and services requiring maintenance is taken care of. It is necessary that service personnel are able to reach the service easily, safely, have adequate working space, safe working conditions and adequate lighting provisions. Cleaning of façade and replacement of glass panes needs to be kept in view while finalizing exteriors.

g) In addition to designing a building for structural adequacy, consideration should also be given to environmental factors such as moisture, natural weathering, corrosion and chemical action, user wear and tear, pollution, flooding, subsidence, earthquake, cyclones etc.

h) Design phase should cover such items as the owner's anticipated future requirement for the building taking account of the building's physical performance and its functional suitability. This may lead to decisions regarding,

   1) a change of use for the building and the effect of any conversion work on the life cycles of existing components or engineering services; and

   2) availability of replacements.

j) The present use of the building anticipating any likely upgrading and their effect on the life cycles of existing components or engineering services.

9.5.2 During construction stage it should be ensured that suitable construction techniques are adopted, adequate quality control measures are taken, special attention is paid to services and testing of lines, effective supervision throughout and sound remedying of defects is ensured.

Need of good workmanship needs no emphasis. Proper detailing of elements and various fittings and fixtures will ensure good workmanship and quality work which in turn will not only give longer life to the facility but will ensure their long term functional service.

9.5.3 A list of common causes for maintenance problems is given in Annex A for guidance. However, no such list is likely to be entirely comprehensive.

9.6 Maintenance Planning

9.6.1 *General*

Maintenance plans should be driven by and support the intended outcomes stated in the facilities maintenance policy and strategy and should be fully aligned with them. Maintenance plans should be prepared in consultation with stakeholders, taking account of the following as a minimum:

a) Organization's requirements for production and operational demands and constraints;

b) Organization's financial circumstances and/or taxation position; and

c) Feedback data on maintenance outcomes, including associated costs. Multi-year programmes of maintenance should be put in place where appropriate, that is, for long-term planning, finance or other expediency. Programmes should state a review date for assessing progress and performance.

When formulating maintenance plans, alternate maintenance methods should be evaluated. The links between the selected maintenance method(s), maintenance performance, facility asset performance and service delivery should be established through metrics, such as, key performance indicators (KPIs), based on a practical and effective maintenance process.

9.6.2 *Assessment of Maintenance Planning*

An organization should assess the benefits of maintenance planning, basing the assessment on the following:

a) Contribution to the organization's goals;

b) Satisfaction of stakeholder interests;

c) Effectiveness of the facility in supporting the organization's operational plans;

d) Availability and reliability of the facility at minimal cost;

e) Capital and tax planning;

f) Asset/facility management strategy;

g) Protection of the value of facility assets;

h) Provision of data on facility asset performance;

j) Provision of data for maintenance benchmarking;

k) Provision of data for continual process improvement;

m) Provision of data on environmental performance;

n) Basis for service life planning;

p) Contribution to energy management;

q) Contribution to business continuity management;

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r) Basis for service level agreements;
s) Transparency and sound governance in financial reporting;
t) Identified security risks;
u) Awareness environmental sustainability;
v) Improvement of outsourcing and collaboration agreements;
w) Contribution to the facilities management strategy;
y) Contribution to total quality management; and
z) Contribution to procurement and supply chain management.

9.6.3 *Maintenance Planning Process*

While taking up maintenance planning, following should be kept in consideration:

a) Facility assets required to support the core business and the delivery of services should be defined;
b) Required level of facility asset performance, including performance indicators, should be agreed;
c) Condition and sufficiency of facility assets for their intended purpose should be audited;
d) Scope of the maintenance required should be identified through gap analysis;
e) An appropriate maintenance method from those available should be selected;
f) Resources required for the chosen maintenance method should be assessed;
g) Maintenance plans and budgets should be prepared to cover the required scope of services over the short, medium and long term;
h) A tactical plan for delivery of maintenance should be formulated;
j) Resources to deliver the scope of maintenance should be provided;
k) Maintenance plans and programmes of work are implementable;
m) Performance monitoring, review and control of maintenance plans and programmes of work should be carried out.

Information and data gathered from this process should be used to re-inform the organization's need for, and use of, facility assets during this and any future iterations, of this process.

9.6.4 *Financial Management*

Maintenance budgeting is directed to keeping building in appropriate condition by the most economic means and each aspect of maintenance policy bears on cost. In maintenance budgeting, there are two prime elements relating to what to budget for and how to assess its cost.

Financial control is an important aspect of maintenance management; this ensures that maintenance proposals justify the funds requested and that organizations obtain best value for money.

A maintenance strategy, and its associated maintenance programme(s), should include estimates of the cost of known work and provision for work that may be required but where the extent is unknown. These estimates should be used as the basis for preparing budgets for maintenance in line with an organization's overall financial planning and management accounting requirements. Budgets should include, but are not limited to, repair/replace decisions, the optimization of planned preventive maintenance, surveying/ inspection costs and whole-life costs. Budget proposals should be presented in a way that identifies,

a) the impact on capital value;
b) the costs and benefits that accrue from the funds required;
c) the risks and associated costs of not carrying out maintenance programmes in accordance with the maintenance strategy; and
d) the costs and benefits of repair against refurbishment and against replacement and the basis of calculation, for example, net present value (NPV).

In the case of outsourced contracts, the contract sums and the costs associated with the management of the contracts, should be prepared. An audit should be carried out in each financial year to ascertain the extent to which best value for money has been obtained from the funds expended in the previous year on maintenance and to determine if any changes are needed to improve value for money.

It will be a good practice to carry out during the following financial year, a technical audit to ascertain the extent to which value for money was obtained from the funds expended in the previous year and what improvements in management may be made to improve cost benefits.

Guidelines relating to estimation of expenditures for maintenance as in **9.11.2** may be used.

For details, *see* good practice [12(1)].

9.7 Maintenance Work Programmes

The programming of maintenance work can affect an owner or his activities. Following aspects need consideration:

a) Maintenance work should be carried out at

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such times as are likely to minimise any adverse effect on output or function.

b) Programme should be planned to obviate as far as possible any abortive work. This may arise, if upgrading or conversion work is carried out after maintenance work has been completed or if work such as rewiring is carried out after redecoration.

c) Any delay in rectifying a defect should be kept to a minimum only if such delay is likely to affect output or function. The cost of maintenance increases with shortening response times.

d) Maintenance work, completed or being carried out should comply with all statutory and other legal requirements.

9.7.1 *Maintenance Guides*

An owner responsible for a large number of buildings may have established procedures for maintenance. When an owner is responsible for the maintenance of only one building or a small number of buildings, the preparation of a guide tailored to suit each particular building, can offer significant advantages. Such a guide should take into account the following:

a) Type of construction and residual life of the building, and

b) Environment and intensity of use.

The guide may form part of a wider manual covering operational matters.

9.7.2 *Feed Back*

9.7.2.1 Feedback is normally regarded as an important procedure of providing information about the behaviour of materials and detailing for the benefit of the architect/ engineer designing new buildings, which will result in lessening maintenance costs. It is an equally valuable source of information for the persons responsible for maintenance. Every maintenance organization should develop a sample way of communicating its know-how, firstly for benefit of others in the organization and secondly for the benefit of the building industry as a whole. There should be frank and recorded dialogue on an on-going basis between those who occupy and care for buildings and those who design and construct them.

9.7.2.2 Feedback should aim at the following:

a) User satisfaction, particularly from diversity of users, such as women, elders and person with disabilities;

b) Continuous improvement, and

c) Participation by all.

9.7.2.3 *Source of information*

The information on feedback can be obtained from the following:

a) Occupants,

b) Inspections,

c) Records, and

d) Discussions.

9.8 Means of Effecting Maintenance

9.8.1 *Responsibility*

Some maintenance work will be carried out by the occupier of a building or by the occupier's representative. In the case of leasehold or similar occupation not all maintenance may be the responsibility of occupier. Responsibility of common areas, as need to be clearly defined (*see* **9.13**).

9.8.2 The owner/occupant is primarily responsible for ensuring meeting minimum requirements of maintenance and upkeep as specified in **9.12**. Maintenance work sub-divided into major repair, restoration, periodical and routine or day-to-day operations may be undertaken by one of the following:

a) Directly employed labour,

b) Contractors, and

c) Specialist contractors under service agreement or otherwise.

9.8.3 The merits of each category for typical maintenance work shall be considered because optimum use of resources appropriate to tasks in a given situation is an important element of policy.

9.8.4 The success of contracting out depends on the nature of the services, conditions in which contracting is undertaken (the tendering process), how the contract is formulated and subsequent monitoring of service quality. The important consideration in the decision to contract out is whether a contractor can ensure a socially desirable quantity and quality of service provision at, a reasonable cost to the consumers.

9.9 Access for Maintenance

9.9.1 *General*

All maintenance activities including any preliminary survey and inspection work require safe access and in some situations this will have to be specially designed. Maintenance policy, and maintenance costs, will be much influenced by ready or difficult access to the building fabric and to building services. Special precautions and access provisions may also need to be taken for roof work or for entry into confined spaces such as ducts or voids.

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9.9.2 *Access Facilities*

Permanent accessibility measures should be provided at the design stage only for all the areas for safe and proper maintenance. It is a matter on which those experienced in the case of the building can make an important contribution at design stage in the interest of acceptable maintenance costs.

A wide variety of temporary access equipment may appropriately be provided for maintenance work, ranging from ladders to scaffoldings or powered lift platforms.

Wherever possible, it is better to provide permanent access facilities, such as fixed barriers, ladders, and stairways. When such permanent access facilities are provided necessary arrangement may be included in maintenance plans for their regular inspection, maintenance and testing.

All personnel employed for carrying out maintenance should be provided with the necessary protective clothing and equipment and instructed in its use.

When physical access is not possible in situations such as wall cavities, drains, etc, inspections may be made with the aid of closed circuit television or optical devices such as endoscopes.

9.9.3 *Access to Confined Spaces*

Following should be ensured for facilitating maintenance in confined spaces:

a) *Ventilation* — Special precautions need to be taken when entering a confined space. Such confined spaces should be adequately ventilated, particularly before being entered, to ensure that they are free from harmful concentrations of gases, vapours other airborne substances and that the air is not deficient in oxygen.

b) *Lighting* — Good lighting is necessary in order that maintenance work can be carried out satisfactorily. This is particularly important in confined spaces. When the normal lighting is inadequate it should be supplemented by temporary installations. These should provide general and spot illumination as appropriate.

9.10 Performance Management

9.10.1 *General*

Performance management involves monitoring, controlling and improving the efficiency and effectiveness of maintenance management and applies to both internal and outsourced arrangements. Various models, methods and tools are available to assist in the measurement of performance and in indicating where improvement is required; examples include, but are not limited to, value management.

Performance management can be used as a means to foster efficient and effective working relationships between the parties of a contract or agreement relating to maintenance and/or its management, with the aim of achieving continual improvement in performance. It is not intended to be used as the basis for penalizing contractors or service providers, but instead to encourage better performance. Requirements for performance management should be formulated as part of the maintenance strategy and policy and communicated to all affected stakeholders.

An organization should establish a performance management system based upon service level agreements. Where a quality management system exists, the relationship between that and the performance management system should be made clear. In such cases, information and data should be capable of being entered once into either system and should be accessible from both.

9.10.2 *Quality Control*

Quality of construction has to be ensured during planning stage and construction stage of the facility as already emphasized by making suitable provisions for use of durable materials, proper specifications, adequate detailing with emphasis on works required to be done after construction for maintenance and upkeep. All maintenance should ideally be inspected while it is being undertaken and immediately after completion to ensure that it complies with requirements. Records and accounts rendered for maintenance work carried out should be checked for completeness and accuracy.

9.10.3 *Inspections*

Maintenance is intended to ensure that the facility remains fit for purpose in terms of satisfying organizational goals. This requirement is met, in part, through an effective inspection regime and forward-looking maintenance reporting.

9.10.3.1 The facility should be inspected to determine the quality of the internal environment and the condition and performance of the structure, fabric, engineering installations, fixtures and finishes. Inspection intervals should take into account the properties and anticipated service life of elements/sub-elements.

Regular inspections are actual part of the procedures for the maintenance of buildings. They are needed for a variety of purposes and each purpose requires a different approach if it is to be handled with maximum economy and efficiency. A more detailed inspection covering all parts of a building is needed to determine

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what work should be included in cyclic and planned maintenance programme.

Inspections should be carried out carefully as unrecorded dangers may exist. If any area or task is suspected of being hazardous, suitable precautions should be taken.

9.10.3.2 *Frequency of inspection*

Inspection should be carried out at the following frequencies:

a) *Routine* — Continuous regular observations should be undertaken by the building user as part of the occupancy of building. Feedback resulting from this type of observation should be encouraged. Consultation with occupants and other users of the facility to determine the existence of any maintenance matters that may require action and, where such work has been undertaken, measurement of users' satisfaction with the outcomes.

b) *General* — Visual inspections of main elements should be made annually under the supervision of suitably qualified personnel at appropriate times. That informs an organization's budget for maintenance programmes and other maintenance.

c) *Detailed* — The frequency of full inspection of the building fabric by suitably qualified personnel should not normally exceed a 5 year period. An inspection should be carried out by using a checklist made up of facility elements/sub-elements and arranged in way that supports safe working

9.10.3.3 *Inspection schedule*

The preparation of a specific schedule should be encouraged. Once prepared, it can be used for subsequent inspections.

9.10.3.4 *Inspection of engineering services*

Engineering services generally have a shorter life expectancy than building fabric and because of their dynamic function should be subjected to more frequent inspections and maintenance.

Inspection of services should be carried out for three purposes as follows:

a) To check, if maintenance work is required,

b) To check, if maintenance work is being adequately carried out, and

c) For safety reasons to comply with statutory requirements and if required, with recommendations of other relevant organizations.

The frequency of inspections for purpose (a) will depend upon types of plant and system manufacturer's recommendations and subjective judgment. Frequencies for purpose (b) should be carried out on an annual basis.

9.10.3.5 *Method of inspection*

The limited life of building services means it is important to record their residual life so that their replacement can be budgeted for, and inspection methods should be arranged accordingly.

A checklist of items of plant to be inspected should be considered. Detailed procedure of how inspections should be carried out are necessary because a simple visual inspection is unlikely to show whether plant operating correctly and efficiently.

Inspections frequently necessitate the use of appropriate instruments by competent persons. An example of this is the inspections carried out to check compliance with statutory requirements.

When instruments are used it is important that adequate training is provided in the use of the instruments and the interpretation of the results.

9.10.3.6 Records of all inspections should be kept. Inspection report for buildings may be prepared in the format as given in Annex B.

9.10.3.7 *Reporting*

A maintenance report should be prepared. Information gained from inspections should be collated into two groups:

a) The degree of urgency needed to carry out repairs; and

b) A comparison of maintenance plans, including work of a planned preventive nature.

Attention should be paid to the requirements defined in the maintenance policy. Each item should be carefully assessed when postponing apparently non-urgent work so that it does not result in a major defect or failure over the longer term. The anticipated life of the facility, or any element of it, should be taken into account.

Anticipated failures and defects expected to lead to failure should be highlighted in reports. The resulting information should be arranged in three categories: those matters requiring immediate attention, those that can be placed into a maintenance programme and those which can be postponed but which should continue to be monitored and reviewed.

The maintenance report should address all maintenance requirements not covered by planned preventive maintenance for a period of five to ten years. Where contracts run over longer periods, maintenance plans

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may extend beyond this limit. The following points should be included, as a minimum, in the maintenance report:

1) Location;
2) Name of element (for example, roof);
3) Name of sub-element (for example roof covering – tiling);
4) Existing condition (for example excellent, satisfactory, adequate, poor or unsafe);
5) Prioritization of the element (for example, the redecoration of a customer-facing reception area will have a higher ranking than a storage room);
6) Anticipated phasing of maintenance; and
7) Cost of maintenance.

9.11 Standard Norms for Maintenance Management

9.11.1 *Labour Management*

9.11.1.1 Since the types of assets and facilities, requirements and levels of maintenance vary widely from asset to asset, the same may be established between the parties concerned depending on the type of the asset and the complexities involved. Typical indicative norms for employment of workmen for day to day maintenance of buildings is given at Annex C.

9.11.1.2 Multidisciplinary skill among the workers should be encouraged.

Multidisciplinary training programmes should be organized for the workmen to impart them knowledge of various skills. After suitable tests, they should be entrusted with multidisciplinary responsibilities. This approach of multidisciplinary skill will help in improving the quality of maintenance and shall also result in speedy attendance of maintenance complaints requiring attention of two/three disciplines at a time. For details see good practice [12(2)].

9.11.1.3 Organizations should ensure that suitable expertise is available for maintenance and its management at all levels within the organization. Where this expertise is not available in an organization, external resources should be employed instead. Persons responsible for managing the maintenance of facilities, including engineering installations, should possess appropriate management ability and technical competence.

9.11.2 *Recommendatory Expenditures for Maintenance*

A major part of expenditure on asset/facility management is incurred on maintenance, which is determined as follows:

a) Maintenance for day-to-day services,
b) Annual repairs, and
c) Special repairs.

Plinth area maintenance rates, that is annual financial yardstick established for building maintenance on plinth area basis for civil, electrical/mechanical works may be taken as per existing provisions in works departments at central or state level or any other prevalent rates. Special considerations may be taken into account for hilly areas, coastal areas or other areas with severe aggressive climate.

These rates may be multiplied by approved city and year maintenance cost index factor to set the present values for particular city for particular time period. Weightages for various components may be determined based on the usage and applied to work out cost index factors for maintenance works.

NOTE — Typical weightages for building maintenance works may be:

a)	Aggregate	3.50
b)	Cement	9.00
c)	Lime	15.00
d)	Paint	25.00
e)	Sand	4.00
f)	Timber	9.00
g)	Unskilled labour	23.50
h)	Skilled labour	11.00
	Total	100.00

However, the wages shall be governed by *Minimum Wages Act*, 1948 along with the statutory provisions like PF, ESI, Bonus, etc, and other prevalent mandatory regulations of the respective States/Union Territories.

9.12 Responsibility of Occupants for Maintenance of Facilities

The provisions of **9.12.1** to **9.12.5** shall govern the responsibilities of occupants for maintenance of facilities, such as, structures, equipment and exterior property.

9.12.1 *Responsibility*

The owner of the premises shall maintain the structures and exterior property in compliance with requirements given in **9.12.2** to **9.12.5**, except as otherwise provided for in this Code. Occupants of a building/premises/dwelling unit are responsible for keeping in a clean, sanitary and safe condition, that part of the building/premises/dwelling unit which they occupy and control.

9.12.2 *Exterior Property Areas*

The owner/occupant shall maintain the following:

a) *Vacant structures and land* — Vacant structures and premises thereof or vacant land shall be maintained in a clean, safe, secure and sanitary condition so as not to cause a blighting problem or adversely affect the

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public health or safety.

b) *Sanitation* — Exterior property and premises shall be maintained in a clean, safe and sanitary condition. The occupant shall keep that part of the exterior property that such occupant occupies or controls in a clean and sanitary condition.

c) *Sidewalks and driveways* — Sidewalks, walkways, stairs, driveways, parking spaces and similar areas shall be kept in a proper state of repair, and maintained free from hazardous conditions.

d) *Weeds* — Premises and exterior property shall be maintained free from weeds or plant growth in excess of height specified by Authority. Noxious weeds shall be prohibited.

Upon failure of the owner or agent having charge of a property to cut and destroy weeds after service of a notice of violation, any duly authorized employee of the Authority or contractor hired by the Authority may be authorized to enter upon the property in violation and cut and destroy the weeds growing thereon, and the costs of such removal shall be paid by the Owner or agent responsible for the property.

e) *Exhaust vents* — Pipes, ducts, conductors, fans or blowers shall not discharge gases, steam, vapour, hot air, grease, smoke, odours or other gaseous or particulate wastes directly upon abutting or adjacent public or private property or that of another *tenant.*

f) *Accessory structures* — All Accessory structures, including *detached* garages, fences and walls, shall be maintained structurally sound and in good repair.

9.12.3 *Exterior and Interior Structure*

The exterior and interior of a structure shall be maintained in good repair, structurally sound and sanitary so as not to pose a threat to the public health, safety or welfare. Following measures shall be taken:

a) *Protective treatment* — Exterior surfaces, including but not limited to, doors, door and window frames, cornices, porches, balconies, decks and fences, shall be maintained in good condition.

b) *Interior surfaces* — Interior surfaces, including windows and doors, shall be maintained in good, clean and sanitary condition.

c) *Structural members* — All structural members shall be maintained free from deterioration, and shall be capable of safely supporting the imposed dead and live loads.

d) *Roofs and drainage* — The roof and flashing shall be sound, tight and not have defects that admit rain. Roof drainage shall be adequate to prevent dampness or deterioration in the walls or interior portion of the structure. Roof drains, gutters and downspouts shall be maintained in good repair and free from obstructions. Roof water shall not be discharged in a manner that creates a public nuisance.

9.12.4 *Rubbish and Garbage*

9.12.4.1 *Accumulation of rubbish or garbage*

Exterior property and premises, and the interior of every structure, shall be free from any accumulation of rubbish or garbage.

9.12.4.2 *Disposal of rubbish and garbage*

Every occupant of a structure shall dispose of all rubbish and garbage in a clean and sanitary manner by placing such rubbish, garbage in an approved rubbish/ garbage disposal facility or approved containers.

9.12.4.3 *Containers*

The operator of every establishment producing garbage shall provide, and at all times cause to be utilized, approved leak proof containers provided with close-fitting covers for the storage of such materials until removed from the premises for disposal.

9.12.5 *Pest Elimination*

9.12.5.1 *Infestation*

Structures shall be kept free from insect and rodent infestation. Structures in which insects or rodents are found shall be promptly exterminated by approved processes that will not be injurious to human health. After pest elimination, proper precautions shall be taken to prevent re-infestation.

9.12.5.2 The responsibility of pest elimination in several cases of occupancy shall be as below:

a) *Single owner* — The owner of any structure shall be responsible for pest elimination within the structure prior to renting or leasing the structure and the occupant of a one-family dwelling or of a single-tenant non-residential structure shall be responsible for pest elimination on the premises.

b) *Multiple occupancy* — The owner of a structure containing two or more dwelling units, a multiple occupancy, a rooming house or a non-residential structure shall be responsible for pest elimination in the public or shared areas of the structure and exterior property.

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c) *Occupant* — The occupant of any structure shall be responsible for the continued rodent and pest-free condition of the structure.

Where the infestations are caused by defects in the structure, the owner shall be responsible for pest elimination

9.13 Common Area Maintenance

Maintenance of common areas in any building, group of buildings, should be responsibility of all those who share and use the common areas.

9.13.1 *Common Areas and Equipment*

The common area of a building or project includes all space contained in building premises that are not exclusive to any specific occupant(s) and which benefits, or is intended to benefit, all users/ occupiers of the building, in common and without distinction.

Common area of a multiple building campus/project is proportionately loaded on to the individual segments within the overall campus. Common area of such campuses will include driveways, ramps, walkways, pavements, corridors, entrances, vestibules, stairways, atriums, refuge area, terraces (with or without common rights of access) landscapes, common toilets, loading and unloading docks, dedicated property management office, parking areas, external peripheries, façade and elevation elements and utility areas such as DG room, plant room, etc.

Common equipment will include all types of pumps for water supply, fire fighting, etc; lifts and escalators; firefighting system; HVAC plant and equipment; E&M equipment like electric panels, DG sets, transformers, lightning protection system, earthing system, etc.

9.13.2 *Maintenance of Common Areas*

One way to arrange for funds to carry out this function is to levy a common area maintenance (CAM) charge on all the users. The value of CAM to be charged can be decided by the owner or it can be collectively decided by the users. Normally, CAM is charged on pro-rate basis, that is, on the ratio of area in actual occupation of each user *vis-a-vis* the total area. While computing the CAM charges it is normal practice to include expense incurred towards providing common facilities to all occupiers of a building/facility like cost of housekeeping services; energy consumption of fixtures and equipment provided for the common areas, annual maintenance contracts, if any; of equipment, spares and consumables and charges for property management services, all expenses towards maintaining regulatory and statutory compliance as applicable to the building or the project, insurance of building and equipment, sinking fund and expenditure incurred on annual maintenance of common areas, etc.

9.14 Maintenance from Accessibility Consideration

All maintenance and refurbishment in public buildings and built environment shall take into account improving accessibility for persons with disabilities and care taken that accessible design features are properly maintained during maintenance activities (*see* **B-25** of Part 3 'Development Control Rules and General building Requirements' of the Code). Periodic access audits shall be carried out at least once in three years to ensure that the requisite accessible features as per Part 3 'Development Control Rules and General Building Requirements' of the Code are provided in the building and its built environment and maintained in good condition on an ongoing basis.

10 BUILDING FABRIC MAINTENANCE

10.1 This constitutes maintenance of elements and components of a building other than furniture and services installations.

10.2 Prevention of Cracks, Repairs, Retrofitting and Seismic Strengthening of Buildings

Cracks in buildings are of common occurrence. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component can be caused by externally applied forces, such as dead, imposed, wind or seismic loads, or foundation settlement or it can be induced internally due to thermal movements, moisture, chemical action, etc. The buildings affected by earthquake may suffer both non-structural and structural damages. Non-structural repairs may cover the damages to civil and electrical items including the services in the building. Repairs to non-structural components need to be taken up after the structural repairs are carried out. Care should be taken about the connection details of architectural components to the main structural components to ensure their stability. The main purpose of the seismic strengthening is to upgrade the seismic resistance of a damaged building while repairing so that it becomes safer under future earthquake occurrences.

10.2.1 Prevention of cracks, repair work, seismic strengthening and retrofitting of an existing building shall be done in accordance with Part 7 'Construction Management, Practices and Safety' of the Code.

10.3 While demolishing a damaged building or existing unsafe building, safety precautions as given in Part 7 'Construction Management, Practices and Safety' of the Code shall be observed.

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11 MAINTENANCE OF PLUMBING AND DRAINAGE SYSTEMS

11.1 General

Plumbing fixtures shall be properly installed and maintained in working order, and shall be kept free from obstructions, leaks and defects and be capable of performing the function for which such plumbing fixtures are designed. Plumbing fixtures shall be maintained in a safe, sanitary and functional condition. Where it is found that a plumbing system in a structure constitutes a hazard to the occupants or the structure by reason of inadequate service, inadequate venting, cross connection, back-siphonage, improper installation, deterioration or damage or for similar reasons, the same should be attended to immediately.

11.2 Plumbing System

Plumbing system is a system installed in a building for the distribution and use of potable water and the removal of waterborne wastes. It covers the system that operates toilets, sinks, showers, bathtubs, etc, as also laundry facilities in buildings for washer, utility sinks, and drains that may be installed.

11.3 Drainage System

Water outputs in a building include,

a) storm water,
b) grey water,
c) black water, runoff, and
d) evaporation and leaks.

These are discussed in **11.3.1** to **11.3.4**.

11.3.1 *Storm Water*

Storm water should be reclaimed to a great extent though properly designed rainwater harvesting. Excess storm water needs to be drained off through properly designed drainage system. Outlet for it shall be identified and checked for its carrying capacity and final disposal so as to avoid inundation and unhygienic conditions.

11.3.2 *Grey Water*

It is the waste water collected from indoor sources, other than toilets, such as showers and hand basins, washing machines and requires treatment such as screening, oil and grease removal (if kitchen wastewater is also included in the source), filtration and disinfection. Grey water comprises 50-80 percent of residential wastewater. If grey water is filtered properly, reusing it for irrigation and further conveyance is safe from a health perspective.

11.3.3 *Black Water*

It is the discharge from the toilet and contains significant nutrient concentrations. The microbial contamination associated with black water demands it to be treated to a very high level, especially with respect to disinfection.

11.3.4 *Evaporation and Leaks*

Evaporation can account for a significant water loss in building systems that rely on evaporative cooling towers. Leaks can also account for a significant quantity of water use if they are not detected and corrected in a timely manner. In taking a strategic approach to improving water performance, all inputs, uses, and outputs should be considered.

11.4 Plumbing and drainage system shall be designed in accordance with Part 9 'Plumbing Services, Section 1 Water Supply and Section 2 Drainage and Sanitation' of the Code. Good practices as given in these Sections of the Code attempt to minimise risk by specifying technical standards of design, materials and workmanship.

11.5 Only licensed/registered plumbers with specified qualifications should be permitted to carry out work of plumbing and installations. Such works shall be inspected by competent person to check their adequacy and functionality. For guidelines for registration of plumbers including the minimum standards for qualifications for the grant of licences, reference may be made to good practice [12(3)].

No person should be permitted to construct, install, extend or materially alter any plumbing system without making formal application to, and receiving formal approval from, the concerned authority. Except where the authority shall agree in writing to other dispositions, only a licensed plumber shall be authorized to be responsible for the construction, repair, alteration or removal of pipes, valves, drains or other appurtenances of any drinking-water supply or drainage system (including storm drainage discharging into a public sewer or watercourse) in any building or on any land. Only a licensed plumber may make a connection to a public water main or to a public sewer, and he shall be responsible for giving notice to the water and sewerage authorities of the intention of making such connection for satisfying any requirements of those bodies.

11.6 Restoration and Recycling of Waste Water

All wastewater can potentially be recycled within a building system. Wastewater exiting the building under grey water or black water should be recycled in various possible ways.

11.7 Rain Water Harvesting

It is essential to provide rain water harvesting or storage systems to capture the runoff from the roof surfaces. For details, reference shall be made in Part 9 'Plumbing Services, Section 2 Drainage and Sanitation' of the Code.

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11.8 Common Problems

The maintenance of water supply and sanitary system in buildings requires thorough knowledge about the design, specifications and the materials used within the building and for external connections. If the defects are not attended timely, these may result in unhygienic conditions and ultimate structural failures too. Availability of as-built drawings for services is of great help in taking up repair and restoration works.

The faults in these services occur due to defective system and misuse. The common problems in water supply and sanitary system are as follows:

a) Leakage in internal pipes;
b) Blocked drains and leaking joints;
c) Damaged floor drains;
d) Overflowing cisterns;
e) Blocked waste pipes;
f) Defective or improperly fixed fittings;
g) Inadequate pressure;
h) Maintenance of appliances;
j) Noise in plumbing system;
k) Odour in piping system;
m) Seepage through floor joints of wet areas;
n) Heading up of water on terraces; and
p) Damaged or cracked appliances.

Early detection of leakage seepage is possible with use of thermal cameras which are available and can detect the early signs of leakages, etc, and can actually photograph the same showing location and its intensity.

As steady drip which comes out drop by drop can waste as much as 9 000 litre of water every three months, use of good fittings and urgent attendance to leakages/ drippings can hardly be overemphasized.

11.9 Precautionary Measures

a) *Avoid chemical drain-clearing products* — Clogged drains are the most common home plumbing problem. Chemical products used to clear clogged drains, may harm the drainage system. They can actually erode cast-iron drain pipes, and because they typically don't remove the entire clog, the problem is likely to recur, resulting in their repeated use. Drain should therefore be cleaned by removing chunk of hair and grease by using flexible drain cleaning devices (snake).
b) *Prevent future clogging* — Clogs aren't just nuisances. Backed-up water puts added pressure on wastepipes, stressing them and shortening their lifespan. Therefore, avoid plug-ups by watching what goes down the drains. Keep food scraps out of kitchen drains, hair out of bathroom drains, and anything but sewage and toilet paper out of toilets.
c) Install screens over drains in showers and tubs, and pull out hair every few weeks to prevent build-ups. Scrape food into the trash before doing dishes, even if there is a disposal and never put liquid grease down the drain; pour it into a sealable container to put in the garbage after it cools.
d) *Reduce the pressure* — High water pressure stresses pipes, and increases the likelihood of a leak. It drastically reduces the life of plumbing system. It makes pipe joints, faucets, and appliance valves work harder.
e) *Soften the water* — If the water has a high mineral content, known as hard water; it can shorten plumbing's lifespan. A white build up on showerheads and faucets is a tell-tale sign of hard water. To effectively deal with hard water install a water softener.
f) *Keep sewer lines or septic tank clear* — Snake main sewage cleanout every few years to remove messy sewage backups. Always detect and fix problems quickly. Even small leaks can make pipes corrode more quickly, and cause significant water damage. Water test and/or smoke tests on the drainage of the plumbing system should be carried out before accepting the system and allowing final finishing works.

11.10 Maintenance of Plumbing and Drainage Systems

11.10.1 *General*

Proper maintenance ensures that all fittings and fixtures are kept in acceptable working condition so that their utility is not sacrificed.

Even little leaks in plumbing can lead to big problems. It is therefore necessary to be alert to signs of impending plumbing failures, such as, leaking faucets, damp cabinets, leaking toilets or dripping refrigerators; all signal problems that need prompt attention. Problems should be repaired early. A leaking faucet isn't just annoying; the moisture it releases puts wear on sink fixtures and can encourage the growth of mold and mildew. A licensed plumber should be called to get repairs done in a professional manner.

Design of various areas has to be such that all appliances and areas needing frequent maintenance are easily approachable and adequate working space is available to maintenance personnel.

Shaft shall be of adequate size to allow workmen to

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carry out their functions properly. Working platforms and easy access to the shafts and working platforms should be ensured. Specific provisions are required to be made for maintaining services in multistoried buildings.

Checking of roofs, drains, traps on regular basis should be carried out as part of preventive maintenance to ensure that they are clean and functional. Users and cleaning personnel have to be educated not to throw solid waste into WC's, traps and drainage system.

It is good practice to lay-down a periodical drill for doing some of the maintenance works required to be done on regular basis such as white washing, painting, drain de-silting, roads re-carpeting, cleaning of traps, manholes, cleaning of tanks, etc. A small inventory of items which are often required should be kept in store for immediate use.

For effective maintenance it is necessary that the buildings are inspected on regular basis and corrective measures taken as per the outcome of inspection. Special attention is required to be paid to inspection of storm water drainage works, roofs before monsoon. This can help in preventing problem from getting worse.

Checking of roofs, drains, traps on regular basis should be carried out as part of preventive maintenance to ensure that they are clean and functional. Users and cleaning personnel have to be educated not to throw solid waste into WCs, traps and drainage system.

Special attention is to be paid to inspection of storm water drainage works, roofs before monsoon.

All fittings and fixtures should be checked regularly. For monitoring on an annual and bi-annual basis, a check list will be helpful for checking plumbing problems or potential plumbing problems.

11.10.2 *Maintenance of Plumbing Systems*

11.10.2.1 All water mains communication pipes, service pipes and pipes used for distribution of water for domestic purposes shall be thoroughly and efficiently disinfected before being taken into use and also after every major repair. The method of disinfection shall be subject to the approval of the Authority. The pipes shall also be periodically cleaned at intervals, depending upon the quality of water, communication pipes and the storage cisterns shall be thoroughly cleaned at least once every year in order to remove any suspended impurities that may have settled in the pipes or the tanks.

11.10.2.2 Storage tanks shall be regularly inspected and shall be cleaned out periodically, if necessary. Tanks showing signs of corrosion shall be emptied, thoroughly wire brushed to remove loose material (but not scraped), cleaned and coated with suitable anti-corrosive material not liable to impart taste or odour or otherwise contaminate the water. Before cleaning the cistern, the outlets shall be plugged to prevent debris from entering the pipes. Tanks shall be examined for metal wastage and water tightness after cleaning.

11.10.2.3 Record drawings showing pipe layout and valve positions shall be kept up to date and inspection undertaken to ensure that any maintenance work has not introduced cross-connections or any other undesirable feature. Any addition or alterations to the systems shall be duly recorded from time-to-time.

11.10.2.4 Any temporary attachment fixed to a tap or outlet shall never be left in such a position that back-siphonage of polluted water may occur into the supply system.

11.10.2.5 All valves shall periodically be operated to maintain free movement of the working parts.

11.10.2.6 All taps and ball valves shall be watertight, glands shall be made good, washers shall be replaced and the mechanism of spring operated taps and ball valves shall be repaired, where required.

11.10.2.7 All overflow pipes shall be examined and kept free from obstructions.

11.10.2.8 The electrical installation shall be checked for earth continuity and any defects or deficiencies corrected in the case of hot water supply installations.

11.10.3 *Maintenance of Drainage Systems*

11.10.3.1 *General*

Domestic drainage system shall be inspected at regular intervals. The system shall be thoroughly cleaned out at the same time and any defects discovered shall be made good.

11.10.3.2 *Cleaning of drainage system*

a) Sewer maintenance crews, when entering a deep manhole or sewer where dangerous gas or oxygen deficiencies may be present, shall take safety precautions required and follow the following procedures:
   1) Allow no smoking or open flames and guard against sparks.
   2) Erect warning signs.
   3) Use only safety gas-proof, electric lighting equipment.
   4) Test the atmosphere for noxious gases and oxygen deficiencies (presence of hydrogen sulphide is detected using lead acetate paper and that of oxygen by safety lamps).
   5) If the atmosphere is normal, workmen

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may enter with a safety belt attached and with two men available at the top. For extended jobs, the gas tests shall be repeated at frequent intervals, depending on circumstances.

6) If oxygen deficiency or noxious gas is found, the structure shall be ventilated with pure air by keeping open at least one manhole cover each on upstream and downstream side for quick exit of toxic gases or by artificial means. The gas tests shall be repeated and the atmosphere cleared before entering. Adequate ventilation shall be maintained during this work and the tests repeated frequently.

7) If the gas or oxygen deficiency is present and it is not practicable to ventilate adequately before workers enter, a hose mask shall be worn and extreme care taken to avoid all sources of ignition. Workers shall be taught how to use the hose equipment. In these cases, they shall always use permissible safety lights (not ordinary flash lights), rubber boots or non-sparking shoes and non-sparking tools;

8) Workmen descending a manhole shaft to inspect or clean sewers shall try each ladder step or rung carefully before putting the full weight on it to guard against insecure fastening due to corrosion of the rung at the manhole wall. When work is going on in deep sewers, at least two men shall be available for lifting workers from the manhole in the event of serious injury; and

9) Portable air blowers, for ventilating manhole, are recommended for all tank, pit or manhole work where there is a question as to the presence of noxious gas, vapours or oxygen deficiency. The motors for these shall be of weather proof and flame-proof types; compression ignition diesel type (without sparking plug) may be used. When used, these shall be placed not less than 2 m away from the opening and on the leeward side protected from wind, so that they will not serve as a source of ignition for any inflammable gas which may be present. Provision should be made for ventilation and it should be of the forced type which can be provided by a blower located at ground level with suitable flexible ducting to displace out air from the manhole.

b) The following operations shall be carried out during periodical cleaning of a drainage system:

1) The covers of inspection chambers and manholes shall be removed and the side benching and channels scrubbed;

2) The interceptive trap, if fitted, shall be adequately cleaned and flushed with clean water. Care shall be taken to see that the stopper in the rodding arm is securely replaced;

3) All lengths of main and branch drains shall be rodded by means of drain rods and a suitable rubber or leather plunger. After rodding, the drains shall be thoroughly flushed with clean water. Any obstruction found shall be removed with suitable drain cleaning tools and the system thereafter shall be flushed with clean water;

4) All subsoil drains shall be periodically examined for obstruction at the open joints due to the roots of plants or other growths;

5) The covers of access plates to all gullies shall be removed and the traps plunged and flushed out thoroughly with clean water. Care shall be taken not to flush the gully deposit into the system;

6) Any defects revealed as a result of inspection or test shall be made good;

7) The covers or inspection chambers and gullies shall be replaced, bedding them in suitable grease or other materials; and

8) Painting of ladders/rings in deep manholes and external painting of manhole covers shall be done with approved paints.

11.10.3.3 *Operation and maintenance of sewage treatment plant (STP)*

a) *Operational checks for STP* — More and more campuses are now being served by STPs for treatment of waste water and reusing it for various purposes. Maintenance of STPs and their operation is an essential activity for proper functioning of facilities where such plants are provided.

The methods of checking operational aspects of the STPs are given in Annex D.

b) *Operation and maintenance considerations*

1) Typically, in small plants, the filter press may be sized for a single batch operation

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per day. In large plants, three batches per day, one per shift, is the norm.

2) Fresh sludge (not more than a day old), kept fully aerated and mixed (agitated).
3) Dewaters easily in the filter press. Hence, sludge shall not be stored in the holding tank for longer durations.
4) The desired quantity of polymer needs to be added 15 - 30 min before the dewatering operation. Filter press operation is carried out over 3 - 4 h, or when filtration ceases.
5) After every dewatering operation, the filter clothes shall be thoroughly cleaned, so that clogging in the pores of the woven polypropylene filter fabric is avoided. Periodic cleaning of filter cloth with hypo solution will also prolong the life of cloth.
6) When the filtration process becomes excessively slow, it is time to replace the filter cloth with a fresh set.
7) Normal maintenance as prescribed by the manufacturer may be practiced for the high pressure helical screw pump. Care shall be taken not to damage the rubber stator of the screw pump by dry running of the pump. It is generally preferable to locate the pumps such that positive suction is enabled.

c) *Miscellaneous considerations*

1) Genset backup power to run the entire STP in case the mains electricity line fails.
2) Adequate illumination in STP if in a room, or basement.
3) Totally covered, underground STPs are neither operator-friendly, nor maintenance-friendly.
4) Adequate exhaust and ventilation system to be provided for operator comfort, health and hygiene.
5) Without proper exhaust/ ventilation in enclosed spaces, carbon dioxide accumulates, gets converted to carbonic acid and corrodes metallic parts in the STP. Carbonic acid also depresses *p*H of the wastewater, thus affecting treatment performance.
6) Provide safe and comfortable access to all units in STP for monitoring, operation, and maintenance.
7) Prepare and maintain a standard operating procedure for the STP and train all operators to follow those procedures.
8) Prepare and maintain an operating log book for all activities in the STP.
9) Prepare and maintain a mechanical checklist for routine preventive maintenance.
10) Prepare and maintain a history sheet for each critical equipment in the STP.
11) Prepare and maintain a chemicals/ consumables stock register.
12) Periodically check and validate all log books, checklists, etc.
13) Provide a water meter at the outlet of each type of water treatment system for respective uses to monitor average daily throughput of the STP.
14) *Ventilation system* — Required air changes should be provided to ensure good ventilation. The air change is calculated based on the open/vacant head space of the underground/ basement room. There shall be a fresh air fan (forced draft) and an exhaust fan (induced draft), with two separate ducting systems.
15) If the induced draft fan is designed for a slightly higher capacity than the fresh air fan, then the room will always be under a slight negative pressure, and gases will not escape the room as fugitive emissions.

d) *Abnormal conditions*

1) *Excess flow to STP* — At times due to malfunction of the flushing systems in the toilets, excessive inflow to the STP may be encountered. Similar is the situation during heavy rainfall. This upsets normal operation by flooding the collection tank; submerging the pumps and causing excessive flow to aeration tank. The remedies and recommended operational procedures for these situations are as follows:
2) *Remedy*
   i) Make all toilets' flushing systems fail proof.
   ii) Raise manhole levels and make covers water tight in the conveyance system.
   iii) Replace existing lift pumps by submersible pumps.
3) *Operation*
   i) Keep collection tank near empty at all times in order to accommodate

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sudden excessive inflows.

ii) If level continues to rise to near pump level, start both pumps.

iii) If level continues to rise, switch off both pumps and activate standby external portable pump to save the duty pumps.

4) *MLSS washout due to excess flow* — Consequent to high inflow conditions due to reasons cited in (1) above, mixed liquor suspended solids (MLSS) washout from the system may occur. In order to quickly put the system back to normal, it is recommended that controlled transfer of MLSS from the digester tank (to a maximum extent of 50 ml/l of MLSS per day) to the aeration tank be done so that the design level of MLSS is reached within 4-5 days of washout. For this purpose, the aerobic digester tank should be operated at near full conditions.

5) *p*H *variations in inflow* — Although *p*H variations in domestic sewage are not a cause for concern, it is possible that due to accidental spillage/ excessive usage of cleaning chemicals in the toilets may result in *p*H variations.

11.11 Attention to Wet Areas

In case of wet areas, planning for good maintenance has to be done even before execution. Bathroom, kitchen, water closet and to a lesser extent *Verandah*, balconies and sunshades may be termed as wet areas of a buildings which are more vulnerable to water due to their functional requirements. These wet areas are one of the main source of leakage and dampness in a building which leads to unhygienic conditions affecting badly the health and comfort of the inhabitants and seriously deteriorating the stability of the building. The causes of dampness and leakage may be due to defective design, sub-standard material, improper execution and incorrect usage by the occupant. For provisions on methods to be employed in a building under construction for preventing dampness and leakage arising out of the wet areas, reference shall be made to the good practice [12(4)].

Problem of leakage and dampness in building already in use require different considered approach in the analysis of the cause and remedial measures.

11.12 Selection, installation and maintenance of sanitary appliances shall be done in accordance with good practice [12(5)].

12 MAINTENANCE OF HEATING, VENTILATION AND AIR CONDITIONING (HVAC) SYSTEMS

12.1 The aspects of operation and maintenance of HVAC services and guidelines on good operating practices, maintenance requirement, its frequency, etc, in order to improve the performance of the equipment, reduce failure risk, increase life and effective use of the equipment, and save on energy consumption are covered hereunder. HVAC services include,

a) individual units;
b) plants and pumps;
c) ducts, grills and other air conveyance systems;
d) smoke extraction system; and
e) fire dampers.

For effective management of the asset, component wise operation and maintenance protocol need to be observed. It is necessary to understand basic operating logic that can be implemented manually, or through a building management system.

12.2 Selection of Equipment/Systems

Selection of equipment/systems should be made after careful consideration keeping in view the specific requirements of the facility and after duly computing the heat loads and other relevant factors. At the stage of handing over of the HVAC system by the vendor, the facility manager shall check the system running with internal loads, and also check that uniform temperature, within allowable tolerances, is being maintained throughout the air conditioned area.

12.3 The HVAC vendor shall handover the system with complete air and water balancing, along with a commissioning report. There are various types of HVAC systems available and these are selected, depending upon the intended use and economic viability. Whichever be the system installed, the same has to be maintained properly to obtain optimum output.

12.4 Guidelines on maintaining of equipment issued by the manufacturer shall be followed and regular servicing shall be got done through trained/accredited service providers to ensure proper results.

12.5 Operation of the system should be done by first switching on the indoor unit fan, and then the condensing unit. Normally most modern packaged and ductable split units have an inbuilt sequencing and only an on/off switch needs to be operated. In order to save energy consumption and to prevent discomfort to occupants, it is advisable to set the temperature in accordance with Part 8 'Building Services, Section 3 Air Conditioning, Heating and Mechanical Ventilation' of the Code. It is advisable to switch on the HVAC

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units a little before facility/office starts working to lower the indoor temperature for achieving comfort levels.

12.6 Regular cleaning of filters is the most important maintenance aspect for HVAC systems. A schedule for air filter cleaning shall be established and followed and a log should be maintained for same. Frequency of cleaning of filters should be determined keeping in view the usage, location and recommendation of the manufacturers.

12.7 Cleaning the condenser coil for air conditioning (AC) units and checking all operating pressures to ensure that there are no gas leaks and that the system is working properly should be got done through skilled technicians at regular intervals to ensure proper working of all systems.

12.8 Maintaining and operating of central HVAC plant should be done as per guidelines of the manufacturers and suppliers as it has a number of components. The components of a central air conditioning system include, chillers, pumps, air handling units, chilled water pipe systems, control valves, electrical systems, ducts, cooling towers and water softening systems. All these components are important and shall be maintained properly and as per protocol prescribed by the manufacturer/design consultant.

12.8.1 *Operation of Central AC Plants*

12.8.1.1 It is important to follow laid down sequence either manually, or through BMS - first, switch on the air handling units (AHUs), followed by chilled water pumps, followed by cooling tower fan, followed by condenser water pumps, followed by chiller. Following measures shall be adopted:

a) The chilled water temperature shall be set as per design set point. However, the set point can be increased in winter or during night operation by 1°C to 3°C, to save energy. This set point change may be done when loads are less, during winter/night, especially in non-monsoon months as per the advice of the HVAC system designer. Room thermostats for common areas may be set at universal comfort condition of 24°C, and individual area thermostats at temperature between 24°C and 25.5°C, depending upon individual comfort.

b) All AHU should be maintained properly to ensure that there is no loss of energy because of clogged filters. The basic maintenance protocol is similar (in terms of filter cleaning) as a ductable split. In addition, a regular maintenance visit by HVAC vendor is recommended, to check strainer, pressure drops, etc.

c) All pumps shall be checked regularly to look for leakages, current consumption, temperature and operating pressure, etc.

d) Cooling tower sump water should be checked monthly and laboratory analysis of the water shall be carried out to ensure that the total dissolved solid (TDS) level is below 500 ppm (or as per chiller supplier's recommendation). Blow down or bleed off from the sump, with continuous replenishment of soft water, to maintain TDS levels is recommended. Where possible, the bleed off from sump of cooling tower may be led to water softening plant for treatment and recirculation.

e) Cleaning of air-conveyance system such as ducting, grills, diffusers, is important to ensure that desired level of hygiene is maintained. This is most important in hospitals and public places.

12.8.1.2 The most important aspect is to continuously monitor the plant. It is advisable that this monitoring be done through a BMS and continuously seek refinement of the programmed logic, till the user is satisfied. A BMS does not substitute a scheduled maintenance operation but it helps to check and document sensor readings making it perform better and improve the life of the system. Readings through this system can be evaluated every quarter, to obtain annually a calibration of components like flow meters and gauges. The BMS can also provide measurement and verification of plant capacity and efficiency. It is also recommended to do a quarterly random check of few sample reports, and compare with physical readings. In addition, the BMS shall be interlinked with all safety and alarms, such as fire and access control. The BMS shall maintain a log of basic parameters like operating hours of each major component of HVAC plant, with records of in/out temperatures, and operating pressures. These logs shall be scrutinized at least once in a month by the operations team, to check for anomalies if any, in order to detect adverse operating conditions, and prevent failures.

12.9 Periodicity/Frequency of Servicing

Depending upon the type of facility, type and specification of equipment installed, usage and other operational and financial constraints, the optimum frequency of carrying out servicing should be determined. A regular record of all maintenance and service operations shall be maintained and periodically reviewed.

Daily logs of operation with timings, and readings of important parameters should be maintained. It should be ensured that logs are always up to date in real time.

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Back log being filled later shall be prohibited.

12.10 In addition to above, the requirements for operation and maintenance of HVAC systems as laid down in Part 8 'Building Services, Section 3 Air conditioning, Heating and Mechanical Ventilation' of the Code shall also be complied with.

13 MAINTENANCE OF ELECTRICAL INSTALLATIONS

13.1 Electrical installations in building have to be installed and constantly maintained in proper working condition to ensure efficient use of electricity including safety from fire and shock. Electrical system maintenance is very important as it also helps in ensuring smooth operation of all plants and equipment. The coverage is limited to maintenance of internal electrical installations starting from receiving of electric supply within premises. It covers HV panels, HV switches, transformers, LV panels, floor panels, earthing, internal electrical distribution systems, light fixtures/switches/MCBs, lightning arrestors, street lighting systems, facade lighting and transformers.

13.2 Planning of Electrical Maintenance Work

The authorized person shall have complete knowledge of the electrical appliances to be worked upon, to ensure safety. Repetitive nature of jobs require lesser pre-planning, whereas infrequent nature of jobs may need careful planning.

Planned routine maintenance will facilitate continued safe and acceptable operation of an electrical system with a minimum risk of breakdown and consequent interruption of supply. As far as the electrical equipment/installations are concerned, for the interval between the maintenance required, recommendation of the manufacturer should be followed. The manufacturer should be requested to specify minimum maintenance frequency under specified conditions. These intervals depend greatly upon the design of the equipment, the duty that it is called onto perform and the environment in which it is situated. At least annual health check up of all E&M equipment shall be carried out. Following two types of maintenance are envisaged:

a) *Routine maintenance* — Routine maintenance of the electrical equipment goes along with the regular inspections of the other equipment. Inspections shall reveal the undue damage and excessive wear to the various components. Examination of the equipment shall reveal need for conditioning of the contact system, lubrication and adjustment of the other relevant mechanisms.

b) *Post fault maintenance* — When there is a breakdown in the system and certain parts are identified for the replacement and then the maintenance/repair of the defective part away from the operating environment is covered under post fault maintenance.

13.3 Uninterrupted and hazard free functioning of the electrical installations are the basic requirements of maintenance. The equipment should be restored to correct working conditions. Special attention should be paid to the items and settings that may have been disturbed during the operational phase. Loose and extraneous equipment or wiring give rise to potential safety hazards. All covers and locking arrangements should be properly checked and secured to achieve original degree of protection.

13.3.1 Following maintenance procedures shall be adopted:

a) All transformers shall be provided with a linked switch with fuse or circuit breaker of adequate capacity. These should be checked annually to ensure the safety of the transformers. Where oil type transformers are used, timely de-hydration of oil and topping up shall be done to ensure proper functioning.

b) Regular servicing of all circuit breakers shall be ensured so that they function properly and provide desired safety.

c) The supply of energy of each motor or a group of motors or other equipment/apparatus meant for operating one particular machine should be controlled by a suitable linked switch, or a circuit breaker, or an emergency tripping device with manual reset of requisite capacity, placed in such a position as to be adjacent to the motor or a group of motors; or other apparatus readily accessible to and easily operated by the person in charge and so connected in the circuit that by its means all supply of energy can be cut off from the motor or group of motors or apparatus from any regulating switch, resistance of other device associated therewith. It should be ensured that at time of working on these equipment, this switch remains in off position to ensure safety of workers.

d) All insulating materials should be chosen with special regard to the circumstances of its proposed use ensuring that their mechanical strength is sufficient for its purpose and so far as is practicable of such a character or so protected as to maintain adequately its insulating property under all working conditions in respect of temperature and moisture.

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e) Adequate precautions shall be taken to ensure that no live parts are so exposed as to cause danger.

f) Where energy is being supplied, transformed, converted or used, the consumer, supplier or the owner of the concerned installation should be responsible for the continuous observance of the provisions in respect of his installations.

g) List of authorized person should be displayed on HV, LV, lift machine room because of likelihood of lots of hazards in these areas. Proper signage shall be displayed to discourage unauthorized personnel in these areas.

h) Lock out and tag out (LOTO) processes:

1) Inform all affected employees that more than one group/person is doing servicing /maintenance on same equipment/ location.

2) Have person in charge for each group for locked out and tag out to perform the servicing or maintenance.

3) Authorized employee has to identify the type and magnitude of the energy and inform all concerned.

4) Person in-charge has to fill the declaration form owning his overall responsibility to place lock out/tag out.

5) The person in-charge has to impart the necessary information to each person of the various sources of hazardous energy and the method of isolation.

6) Equipment is to be disconnected from the energy source.

7) Each person in-charge has to provide his/ her lock, on behalf of the group and tag out.

8) Key of the lock shall be kept with the person executing the job.

13.3.2 *Maintenance of UPS/Inverter*

Following maintenance procedures shall be adopted:

a) UPS/Inverter for emergency lighting system backup shall be checked at regular intervals.

b) Life safety systems; emergency lighting and fire alarm systems that are required to be provided with an emergency power supply from batteries shall be checked by switching off power supply to see their operations. A log book for backup time shall be maintained.

13.3.3 *Maintenance of Battery*

Storage batteries are provided for various functions such as for UPS/Invertors, DG sets, lift ARD, etc. Wherever batteries are installed, two flame proof exhaust fans shall be provided in battery room (one should run on fire indication and timer as well) to exhaust gases (during battery charging) and smoke (in case of fire) from battery room. Flame proof light fixtures will only be used in battery room. Lift automatic rescue device (ARD) and other critical system battery should be replaced after every 18 months to avoid ARD failure. All fittings and fixtures in battery room shall be flame proof.

Appropriate gas detectors can be installed in battery rooms to detect and warn about buildup of harmful gasses. These detectors should be regularly monitored and inspected to ensure proper functioning

13.3.3.1 *Standard operating procedures for maintenance of dry cell battery*

a) Check the batteries as per the schedule and make record.

b) Clean the battery terminal on regular basis.

c) Avoid charging of batteries on boost mode. Float mode of charging is best way to increase the life of the battery.

d) Check the charger for auto cut after charging. Overcharging is very harmful for the batteries.

e) Check for deposition of any sulphate on battery terminal, if found, clean with hot water and apply petroleum jelly.

f) Avoid high temperature in battery room.

g) For the performance of the batteries, voltage shall be checked on each battery terminal after determination of individual battery terminal.

h) Replace the battery, if voltage is found to be less than the specified voltage.

13.3.3.2 *Standard operating procedures for maintenance of lead acid battery*

a) Do the routine checks of lead acid batteries.

b) Check the distilled water level in the batteries. Never overfill the water.

c) Always keep the chargers in auto charge mode. Avoid boost charging.

d) Never add new electrolyte in the batteries.

e) Never add raw water to the batteries, it may contain minerals that can contaminate the electrolyte.

f) Check for the sulphation.

g) Check all the cells with the help of cell tester.

h) Check the gravity of the batteries on regular basis.

j) Battery terminals to be checked and tightened.

k) Maintain the cross ventilation in battery room.

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13.3.4 *Earth Pits and Earthing Installations*

Earth pit should not be located near pavements, roads and near the building and minimum distance from the wall to the pit should not be less 1.5 m. Earth wires running along various sub-circuit shall terminate at the main distribution panel. Resistance of earthing pits shall be checked at least once in a year. Earthing pit record shall be maintained.

13.3.5 *DG Set and its Auxiliary Operation*

DG sets should be maintained and operated only by trained technicians. Adequate stock of diesel should be maintained to ensure that the DG sets are able to provide backup power for duration of mains failure. If more than one DG set is installed then where possible DG sets should be synchronized to ensure that optimum power output is received. It should be ensured that DG sets are not operated beyond their designated power rating and also not below desired power rating. In this regard recommendation of DG set manufacturers shall be followed.

Regular checks shall be got carried out from authorized technicians/service providers. Adequate safety precautions shall be taken while operating the DG sets. All exhaust systems shall be checked at regular intervals to ensure that DG exhaust does not get blocked or is allowed to pollute sensitive areas.

13.3.6 *Emergency Lighting*

13.3.6.1 Just like fire extinguishers, smoke alarms and other life safety equipment, emergency lighting fixture is required in commercial, industrial and institutional buildings for times when emergency situations arise, so that people are able to find their way out of a building. These are often referred to as egress lighting.

Modern emergency lighting is installed in virtually every commercial and high occupancy residential building. The lights consist of one or more parabolic aluminized reflector (PAR 36) sealed beams or wedge base lamps. All units have a reflector to focus and intensify the light they produce. This can either be in the form of a plastic cover over the fixture, or a reflector placed behind the light source. Most individual light sources can be rotated and aimed for where light is needed most in an emergency, such as towards fire exits. Advance feature fixtures usually have a test button which temporarily overrides the unit, and causes it to switch on the lights and operate from battery power even if the main power is still on. Modern systems are operated with relatively low voltage, usually from 6-12 V. This reduces both the size of the batteries required as also the load on the circuit to which the emergency light is wired. Batteries are commonly made of lead-calcium/maintenance free and can last for 10 years or more on continuous charge. Fire safety aspects may require a minimum of 90 min on battery power during a power outage along the path of egress.

To indicate that a power outage has occurred, some models of emergency lights can only be shut off manually after they have been activated, even if the main building power has come back on. The system will stay lit until the reset button on the side of the unit is pressed. As there are strict requirements to provide required lighting along the path of egress, emergency lighting should be selected carefully to ensure compliance thereof as per this Code.

An emergency lighting installation may be either a central standby source such as a bank of lead acid batteries and control gear/chargers supplying slave fittings throughout the building, or may be constructed using self-contained emergency fittings which incorporate the lamp, battery, charger and control equipment. Self-contained emergency lighting fittings may operate in 'maintained' mode (Illuminated all the time or controlled by a switch) or 'non-maintained' mode (Illuminated only when the normal supply fails).

Another popular method involves battery backup ballasts that are installed within or adjacent to existing lighting fixtures. Upon sensing power loss, the ballasts switch into emergency mode turning the existing lighting into emergency lighting without the need of wiring separate circuits or external wall mounts.

For remote mounted emergency lighting, wiring from the central power source to emergency luminaries should be kept segregated from other wiring, and constructed in fire resistant cabling and wiring systems. Minimum illumination levels in escape routes and open areas should be kept as per the requirements of this Code. When non-maintained fittings are used, they shall be supplied from the same final circuit as the main lighting circuit in the area.

Emergency lighting fixtures/exit lights can use non-electrical photo luminescent lighting technology with advantage to save energy.

Smoke injures or kills more people than heat from the fire, hence the electrical emergency lighting should be designed and properly marked to effectively help people find the exits or installed near floor level for ease of evacuation in smoke.

13.3.6.2 *Procedures for maintenance of emergency lighting fixtures*

The testing intervals for the system shall be determined based on the type of usage. More frequent testing shall be done in case of buildings where large public gathering takes place. In any case, this should not exceed six months. However, units that are not

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operational between the test intervals should be checked out and repaired on an ongoing basis.

a) *Half yearly procedures*

1) Replace any faulty lamps prior to the test procedure. When replacing a faulty lamp it may also be required to replace the lamp starter also.
2) Operate the fitting from their battery supply by turning off their normal lighting power supply. This is generally done by turning off the electrical switchboard circuit that is controlling the exit and emergency lighting (*see* Note 1).
3) The light shall remain illuminated for at least 90 min.
4) Replace any faulty lamps or fittings (*see also* Note 2).
5) Turn on the normal lighting power supply and check that the battery charger indicator light on the fitting functions correctly.
6) Record details of the test and correct operation of the system. Record the replacement of faulty lamps and the replacement of fittings.

NOTES

1 On some older installations this may also affect general lighting, as the exit lights may be wired on the same electrical circuit. In these cases coordination with building occupants is required to ensure occupant safety during testing.

2 Depending upon the nature of the fault at fixture, fittings can be repaired or replaced as considered expedient and economical.

b) *Yearly procedures*

1) Carry out the half yearly procedures.
2) Clean down all light emitting and reflecting surfaces.
3) Record details of the test, cleaning and correct operation of the system.
4) Record the replacement of faulty lamps and the replacement of any fittings.

In addition to the above, a regular programme of inspection should be implemented by the building tenants to check that all maintained exit and emergency lights are operating as required.

The emergency lighting system should include adequate facilities for testing and recording the system condition. Appropriate testing should be carried out to ensure towards maintaining compliance of the system. These need to be appropriate for the specific site and should be considered as part of the system design. The tests include function test and discharge test.

13.3.7 In addition to above, the procedures for maintenance of electrical equipment to ensure their smooth functioning as given in Annex E as also provisions of Part 8 'Building Services, Section 2 Electrical and Allied Installations' of the Code shall also be complied with.

14 OPERATIONS AND MAINTENANCE OF LIFTS AND ESCALATORS

The essential requirements for the operation and maintenance and also inspection of lifts and escalators to ensure their safe and satisfactory performance are covered hereunder. Generally lifts designed for passenger usage should not be used for movement of goods, etc.

14.1 Acceptance

The purchaser should accept the lift installation only on completion of testing and commissioning with all necessary standards and documents, for example third party insurance cover of passengers and belongings, licence from the regional lift inspectorate along with lifts handing over certificate, etc.

It shall be ensured that two numbers of door open keys, operation manual, auto attendant keys and machine room keys are handed over to the owner.

14.2 Guarantee and Servicing

To ensure the continuance of satisfactory and safe operation, the purchaser (or building occupier) should arrange for the completed lift to receive regular servicing by competent persons at such intervals as the type of equipment and intensity of operation demands. Beyond free maintenance period, a comprehensive maintenance contract with the lift/escalator manufacturer is desirable and need to be entered into.

The maintenance contract shall be all inclusive including cost of manpower/supervisor/engineer as required, regular servicing, intermediate service calls, repairs and replacement of worn parts. If the owner decides to exclude provision of some major parts from the scope of maintenance contract, such exclusions should be clearly mentioned in the contract. However, this list should be bare minimum so that lift installation is not out of commission for delay in procurement of parts.

The building owner should ensure that the equipment is properly used, and that unauthorized persons are not permitted to enter the lift shaft, pit or machine rooms. Particular attention should be paid to ensure that lifts are not overloaded or misused specially when they are used in connection with furniture and equipment removals, and internal redecoration and other similar

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activities, which may be undertaken within the building.

14.3 Statutory Examinations

Lifts in certain premises (residential and commercial) are required by statutory regulations to be examined at intervals, as specified by the state Lift Acts, by a competent person, who is required to report on a prescribed form. Such reports should normally be kept in a register. Statutory examinations are not a substitute for servicing; the provision of statutory examinations and reports may be specially included in a service contract or may be arranged separately.

14.4 Service Contract (Annual Maintenance Contract)

Generally this is a document which is made in interest of lift purchaser and manufacturer within agreed terms and conditions by both parties. This document has the contact details of both parties with escalation matrix for all the related communications. Service contract period depends on purchaser and manufacturer's mutual decision. Generally service contracts are made for 12 months.

There are two types of service contracts, namely,

a) *Comprehensive contract* — This covers all the man, material and machine required for meeting the best performance of the lift or its connected equipment. Normally car enclosures, door panes, false ceilings, car gates, lights with fixtures, hand rails, mirrors, starters, chokes, floor coverings and carpets, others architectural features, hoistway enclosures, landing gates, door frames, external wiring, fans and batteries, etc, are not included. However all terms and conditions, inclusions and exclusions shall be fully clarified and documented. Manufactures normally do not cover damages caused by mishandling and acts of God (such as natural disaster, riot, blackout, brownout, flood, fires and earthquakes). Service level agreement (SLA) for rectification of deficiencies shall also be amply documented.

b) *Non-comprehensive contract* — A non-comprehensive contract does not have the provisions to cover the parts of lifts; in such cases manufacturer provides the parts on chargeable basis as per industry norms, wherever required. In this type of contract, manufacturer has to provide the services for attending call backs and preventive maintenance and rescue operation in case of man entrapments.

14.4.1 *Manufacturer's Responsibilities*

Manufacturer is liable to fulfill all the requirements of the purchaser with reference to lifts as given in **14.4.1.1** and **14.4.1.2**.

14.4.1.1 *Deployment of manpower*

The lift maintenance contractor shall deploy adequate quantum of skilled technicians/supervisor/engineer with proper PPE (Personal Protective Equipment) to attend to servicing/maintenance/repairs/rescue operation as required.

When the lift number is substantial or lift service is critical like hospitals, the maintenance contract may provide for manning the lift control room by a skilled and trained staff to attend to emergency calls from the lifts and to attend to emergency rescue operation, or any emergency situation.

The lift manufacturer shall train few earmarked personnel like security staff pertaining to safe method of rescuing trapped persons.

14.4.1.2 *Statutory approvals and compliances*

Lift manufacturer will provide all the required liaison to obtain the lifts licence form the competent authority, lift insurance. Annual equipment safety certificates should also be obtained from competent authority as may be required.

14.5 Equipment's Operations

Operation of some important lifts equipment that shall be kept functional and needs to be monitored is described below:

a) *Emergency alarm operation* — This is a general bell and situated inside the shaft at ground floor in conception with car operating panel (COP). It shall be ensured that this is in working condition at all the times and shall be pressed in an emergency situation.

b) *Intercom/Press to talk operation* — This is also an important and necessary equipment and shall generally be located in lift car and parallels connected to lift lobby/control room and machine room. Intercom shall be hung on car panel or located on COP with a symbol to make easier identification for users.

c) *Emergency lights* — There shall be a provision of emergency lighting in cab to ensure proper illumination in it in case of main supply failures or emergency.

d) *Door open and door close (DO and DC) operation* — A door open button shall be available in the COP towards the car gate to reverse the closing motion and hold the door. Door closing button shall also be provided in COP next to DO button. DC shall operate when user wish to close the door before its

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normal dwell time.

e) *Auto attendant mode operation* — There shall be a key operated switch in the COP and shall be operated by the attendant to take lift in manual control.

f) *Automatic rescue device (ARD) operation* — This shall be provided in accordance with Part 8 'Building Services, Section 5 Lifts, Escalators and Moving Walks : 5A Lifts' of the Code. In the event of power interruption, ARD which is powered by an internal battery shall operate within 15 - 20 s, enabling the arrival of lift to the nearest floor at slow speed and open the doors to let the passengers evacuate. Condition of the ARD batteries shall also be checked regularly as per manufacturer guidelines and entry of the same shall be made in ARD's battery log card. ARD batteries should be replaced if their condition is found unsatisfactory. Poor condition of batteries adversely impacts the functioning of ARD and compromises on safety of the lift.

g) *Over speed governor (OSG) operation* — OSG is a safety device which is engaged with lift car or counter weight. It is an automatic device which brings the lift car or counter weight to rest by operating the safety gear in the event of the speed in a descending direction exceeding a predetermined limit.

h) *Door safety (Sensor) operation* — This is a very important safety function located at the front edge or back edge of car door. This is known by different names, such as, as door sensor, door screen, etc. Door sensor shall protect full height of the door, covering at least 1 600 mm of car door height from bottom. Selection of the type of sensor to be supplied should be such that even slightest encumbrance will ensure that the doors do not close.

j) *Fireman lift operation* — It is a mandatory requirement and shall be implemented in all the lifts, individual or in group, with minimum of 1 or 2 h (or as may be prescribed by competent authority) fire rating. Two way (ON/OFF) fire switch shall be common to all in case of group of lifts, and individual fire switch for single lift, to evacuate the lift at ground floor, protected in a box with glass in front with suitable level indication that it is a fireman switch. When the switch is on, all the landing calls for all the floors shall become inoperative and the lift shall be on car control only after reaching at parking floor which is generally at ground, and shall park at with open door condition. Fireman lift should work only when the door close button is pressed continuously. In this exercise all the landings and car calls will not respond and remain inoperative.

NOTE — Fireman's lifts shall be clearly identified with the word 'FIREMAN LIFT' at all the landing floors.

Maintenance and routine check of fire lift shall be carried out as per the schedule given below:

Frequency	*Requirement*
Weekly check	Operating the fire switch by building maintenance staff that should check that the lift returns to the parking floor with its door open
Monthly check	Simulate failure of the primary power supply. Building maintenance staff should operate the fire switch and observe its operation by entering few calls
Half yearly check	Inspection and testing of the operation sequence of the lift should be made
Annual check	A full operation test of the lift should be performed at least once in a year. A record of this test should be retained and maintained

k) *Lift full load operation* — In case of lift full load, all the landing call shall be inoperative and only car calls made from inside the cab shall be active to satisfactorily serve the users. This full load setting should match with the full load setting agreed for the lift.

14.6 Preventive Maintenance

Modular based preventive maintenance method shall be implemented to ensure safety, availability of lifts. Maintenance modules are categorized into modules and the effectiveness is monitored through site audits. For keeping proper records, manufacturer should generate the reports and log cards. Manufacturer shall provide a schedule of plan preventive maintenance (PPM) to the user. Preventive maintenance profile should be as per the prescribed format, a typical example of which is given in Annex F.

14.7 Checks

14.7.1 *Checks for Lifts*

a) *Daily checks* — Lifts and connected parts should be checked by user on daily basis as per the typical check list given in **G-1**.

b) *Monthly checks* — Lifts and connected parts

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should be got checked by user on monthly basis as per the typical check list given in **G-2**.

14.7.2 *Checks for Escalators*

a) *Daily checks* — Escalators and connected parts should be checked by user on daily basis as per the typical check list given in **G-3**.

b) *Monthly checks* — Escalators and connected parts should be got checked by user on monthly basis as per the typical check list given in **G-4**.

14.8 Call Backs

Every call back or complaint related to lift should be reported by user to manufacturer on 24 × 7 basis. Manufacturers normally provide a toll free number to the users with 24 × 7 serviceability and an acknowledgement number is issued to the user.

14.9 Man Entrapments Rescue Operation

Lift rescue operation is an important function and responsibility of the lift technician/ manufacturer engineer/trained person to ensure safe and smooth lift rides. Following measures are taken in such eventualities:

a) *Automatic rescue device* (*ARD*) — In the event of intermittent power, the lift should automatically restart once supply is restored or ARD shall start working within 15 s to 20 s. When there is power shut down, the lift moves to nearest floor to let the passengers out provided there is no fault in the system. Passengers get trapped only when there is any electro-mechanical fault in lift.

b) *Rescue operation procedure*

1) As soon as the call is received from lift car about the trap (by intercom or by hooter noise), facility management team shall call the call centre of the service provider/lift agency and register call while simultaneously informing rescue team of service provider available in the building.
2) The passengers shall be informed (using intercom) that they are going to be rescued soon, so nobody should get panicked and nobody should try to open the car door. It will be better to reach the floor and knock the door during rescue operation to ensure presence.
3) Communication shall be continuous with the passengers in the lift to avoid the panic situation while entrapment.
4) Respective lift machine room shall be reached immediately and the level of lift shall be checked from the rope marking with reference to floor level marking; also the shaft light of the respective lift should be switched on;
   i) One should also try to reset the lift by switching off the main incomer panel and switch it on again after 10 s.
   ii) If there will be any fault which may get resolved after reset then lift will operate and come to the level and the doors will open to let the passengers out from lift.
5) If lift is found to be at level and or near level as per the rope level marking;
   i) Main supply should be cut off from main incomer panel of that particular lift and ARD shall also be switched off.
   ii) The floor where the lift car has landed shall be reached; then the landing doors should be opened manually by hand (not by inserting de-locking key); lift doors will open smoothly if the lift is on level and the passengers may be taken out and rescued.
6) If lift is out of level as per rope level marking, services team shall not try to rescue by any means. They shall follow up with service provider and wait until the arrival of lift agency's rescue team for rescue operation. Communication shall be continuous with the passengers in the lift [*see* Sl No. (3)].
7) If lift agency/service provider does not reach within 10 min, building manager and service provider shall be informed for further action.
8) After the successful rescue operation, the lift shall be shut down 'Lift Under Service' signage shall be put in front of the landings. The service agency shall then be informed for their investigation and corrective actions. Lift should not be operational until it gets fully checked and confirmed by lift agency for its safe working.

14.10 In addition to above, the requirements of ARD, fireman's lift and other lift equipment and also procedures for maintenance of lifts and escalators as given in Part 8 'Building Services, Section 5 Lifts, Escalators and Moving Walks' of the Code shall also be complied with.

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15 MAINTENANCE OF FIRE FIGHTING SYSTEMS

15.1 Maintenance of fire detection and suppression systems in any facility is a very important task for the facility manager. All owners shall arrange to deploy adequate number of trained people to man the systems and also ensure adequate budgetary support to enable proper maintenance and upkeep of the systems.

15.2 Besides properly maintaining all systems, such as fire detectors, sprinklers, first aid fire equipment, yard hydrants, fire tanks, fire pumps, etc, it is imperative that all fire exits and staircases are kept free from any form of obstruction to allow easy egress of occupants in case of any fire incident.

15.3 At the time of commissioning of any facility proper testing of all fire detection and suppression systems shall be done in accordance with relevant Indian Standards and proper record of same shall be maintained. Wherever lift lobbies, staircases, lift wells or any other such location has been designed to remain under pressure from firefighting point of view it is imperative that necessary pressure fans, etc, are kept properly maintained so that there is no failure in this regard. Security guards/lift operators shall be guided to ensure that, wherever doors have been provided to maintain differential pressures are closed to ensure proper functioning.

15.4 Similarly smoke extraction fans, fire dampers in HVAC systems shall be periodically (at least a fortnightly check is desirable) run and tested to ensure that they function properly in case of any emergency.

15.5 The facility manager shall hold regular mock firefighting drills so that people are made aware of the systems installed, the location of nearest exits, etc.

15.6 Maintenance of fire extinguishers shall be carried out in accordance with the good practice [12(6)]. Periodic inspection, testing and refilling shall be got done from competent and trained persons as per provisions given in the above mentioned good practice and as per recommendations of the manufacturers. Proper records of this activity shall be maintained. All fire detection systems shall be strictly maintained in accordance with the good practice [12(7)]. Facility manager shall ensure that during any fit out or refurbishment, no detector is subjected to any interior decoration treatment such as painting, alteration of exterior cover to conform to the environment.

15.7 A log book should be maintained for recording details, including causes of all the alarms (genuine, test or false), faults service tests and routine inspections, servicing/repairs, etc, as and when done. Period of disconnection/non-operation should also be shown.

15.8 Checks shall be made every day to ascertain that the fire panel indicates normal operation and if not, then any fault indicated should be recorded in a log book and corrective action taken and record of that should also be maintained. It shall be ensured that any fault warning recorded the previous day has received attention. The control panel shall be manned regularly so that in case of any incident, immediate action can be initiated.

15.9 Success of any firefighting system will depend upon timely and proper functioning of the fire pumps. Regular maintenance of these pumps shall be done in accordance with the good practice [12(8)]. Checking of jockey pumps shall be a daily exercise. Adequate stock of diesel shall be maintained in a safe location to ensure that pumps can be operated for design duration.

15.10 Other fire installations such as external fire hydrants, hose reels, etc, shall be checked periodically and shall be maintained. External fire hydrants shall be inspected, checked and maintained in accordance with the good practice [12(9)]. Internal fire hydrants and hose reels on premises shall be maintained in accordance with the good practice [12(10)]**.** Automatic sprinkler system shall be maintained in accordance with the good practice [12(11)].

15.11 Fire Water Reservoirs/Tank

It shall be ensured that fire water tank reservoirs are always full and free from any foreign materials. The water level shall be recorded weekly. Reservoirs shall be cleaned at least once in a year or more frequently depending upon quality of water and sludge formation shall be prevented.

Records of inspection, testing and maintenance operations and reports of hydraulic pressure tests of extinguishers and other equipment shall be maintained as per history sheet.

15.12 All maintenance operations shall be carried out as a well-planned exercise to ensure that the facility is not subjected to unnecessary risk.

a) *In case of planned shut down*:

   1) Authorities shall be kept informed before shutting of the installation for any reason, whatsoever.
   2) A thorough assessment of the risk shall be undertaken before a part or total shut down to ensure that there is no incident of fire during shut down.
   3) The heads of all the departments, tenants, RWAs shall be notified in writing that the installation shall remain inoperative and they shall exercise abundant caution during the period.

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b) *In case of unplanned shut down* — When the installation is rendered inoperative as a matter of urgency or by accident, the measures stated above for planned shutdown shall be implemented with least possible delay.

15.13 Fire Drills

Carrying out regular and periodic fire drills, at intervals as may be prescribed, is essential to ensure preparedness of personnel and testing of equipment to ensure that all systems function smoothly in case of any exigency.

15.14 All assets used for firefighting and fire prevention can be equipped with sensors. These sensors shall be capable of monitoring the health of the equipment. Sensors should log the status and send to the central database at monitoring station or BMS, where provided.

15.15 Staircases, fire exits, refuge areas, passages, open surroundings inside or outside the premises should be kept clear of goods.

16 ROADS AND PATHWAYS MAINTENANCE AND UPKEEP

16.1 General

Like other facilities, great care in planning and construction stage is very important for roads/ pavements/paths for their subsequent maintenance and upkeep. It is to be ensured that the roads are well planned and foot paths/pavements provided are at a standard height (usually 150 mm) above the road surface so that they do not cause obstruction to the vehicles and are easily manoeuvrable. All services required at the time of construction including those anticipated in future should be taken care of in the planning stage itself and adequate provisions shall be made for them from the very beginning. This will ensure that the roads are not required to be dug/cut time and again for laying of such services and also the laying of services will be efficient and economical once these are thought of and incorporated well in advance.

16.2 External Services

Special attention needs to be paid to the drainage of the area as storm water drains, more often than not, remain unplanned in the early stages of any project and the areas get inundated during rains causing inconvenience to the users. Proper survey and outlets for the rain water shall be ensured while taking up the work of the residential or commercial complexes. Need for rainwater harvesting systems has already been explained and emphasized (*see* **11.7**). These provisions have to be taken into account while designing roads/ pavements and paths. All external services should be planned and coordinated before execution. Care has to be taken to ensure that the sewer lines do not run above water lines and also do not cross potable water lines as far as possible.

16.2.1 *Ease of Movement*

While laying out foot paths/walk ways and cycle tracks traffic studies shall be carried out, junctions and crossings shall be well planned. It should be ensured that foot paths/walkways are easily approachable and are user-friendly especially to elderly people and persons with physical disabilities. A simple test for the same can be to make a person walk with a trolley and he should be able to move around without having to lift the trolley at any point.

Action at design stage should be taken to develop a safe and effective network of cycle paths. Footpaths and cycle paths are provided to assist the community with walking and cycling activities. Walking and cycling need to be encouraged as modes of transport as they,

a) enhance fitness, health and general life enjoyment;
b) reduce traffic congestion;
c) reduce greenhouse gas emissions; and
d) reduce public expenditure on new roads and car parking facilities.

Damage to paths mainly arise from aging infrastructure, vehicle overrun or through tree roots lifting the paths.

16.3 Maintenance Requirements

Materials used for footpaths and walkways need not be very costly but should be of good quality and durable so that the maintenance needs remain minimal. Attention needs to be paid to regular cleaning of drains and walkways for which the time schedule can be drawn up depending upon the usage and expectations.

All roads present maintenance problems in varying degrees depending upon the specifications and standard of execution at construction, change in traffic intensity/ pattern, climatic conditions natural calamities. In the case of concrete roads, the repairs to the roads are more or less as those applied to any other concrete works.

Road layouts indicating location of culverts, cross drainage and other underground services shall be prepared and kept available with the facility manager and exhibited in office. Different types of roads like gravel, bituminous, or concrete roads should be indicated along with length of the each stretch. A register of roads indicating total length of different types of roads shall be maintained. Similarly, a register of drains/culverts and cross drainage works shall also be maintained indicating type, length/span, etc.

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16.4 Inspections

The minimum frequency of inspections of road conditions shall be specified. Permanent surface evaluation based on surface condition like cracking, patching, riding quality, road roughness and skid resistance will form the basis for taking periodic maintenance decisions. The data collected as a result of inspection should be recorded methodically. The condition of road assets, including community paths and pedestrian areas should be regularly inspected, with focus on areas with high pedestrian usage. Priority for inspections should be given to intensively used areas.

During inspections following observations should be carefully noted:

a) Carriageway and crust conditions;
b) Berms — gullies and erosion;
c) Road side drains;
d) Road protection works — retaining walls pitching on slopes, weep holes;
e) Safety aspects:
    1) Cuts on roads,
    2) Over hanging branches of trees shall be above 4.5 m,
    3) Vertical clearance from power lines, and
    4) Berms should not be lower than 25 mm from carriageway;
f) Maintenance of the bituminous road surfaces:
    1) Surface defects on account of defective quantities of bitumen;
    2) Cracks — longitudinal, edge and hairline cracks; and
    3) Bleeding on account of binder moving upwards and collecting on the surface.

Maintenance of walkways, roads and paths should specifically ensure proper maintenance of accessibility features provided, to facilitate movement of people with disabilities.

16.5 Routine Road Maintenance

Following shall be attended to as part of routine maintenance activity:

a) Periodic inspections should be carried out;
b) All patch repairs and rectification of undulations shall be attended well in time;
c) Shoulders and the side drains to be kept in camber/cleaned;
d) Proper signage to be provided;
e) Soil erosion to be avoided; and
f) Vegetative cover should be established on cut/fill slopes.

16.5.1 *Permanent Maintenance Management System* (*PMMS*)

Permanent maintenance management system is used for managing or directing and controlling maintenance resources in a scientific manner for optimum benefits for major road system. Matching of resources time materials and labour equipment, funds, design and timely decision-making is an integral part of PMMS. The required data of assets to be maintained should be collected and made available to the facility manager who will be able to identify requirements of funds, labour, materials and equipment for maintenance works based on the methodology to be adopted.

16.6 Environmental Concerns

Environmental concerns are also to be looked into to reduce the vehicle operating costs and levels of emission from road traffic. Urban roads have unique features which need to be accounted for in the maintenance norms so as to ensure that the maintenance is carried out in right perspective. These features include traffic signals, pedestrian walkways, cycle tracks, street furniture, footpath, service lanes, streetlights, etc. Even removal of dead animals becomes a part of maintenance. These roads are subjected to continuous flow of traffic thereby giving only very limited working hours for maintenance purposes hence high level of mechanization is required. Proper monitoring of the maintenance works needs no emphasis. While carrying out design work for the roads and pavements it shall be ensured that there are no deficiencies left in the crust thickness.

17 HEALTH AND SAFETY REQUIREMENTS

17.1 Personal Protective Equipment (PPE)

17.1.1 Many hazards exist in work environment which cause thousands of injuries and health problems every year. Working at a site involving constructional work/maintenance work can pose a serious/fatal threat to the personnel involved if appropriate PPEs are not used. PPEs are protection gears used by individuals to reduce the consequence of specific risks in the work place, for example, safety helmet, safety shoes, gloves, etc.

All the PPE shall be suitable for the industry need and comply with the requirements of relevant Indian Standards. There shall be zero tolerance and no compromise on the safety at all the times. All PPE shall be maintained in optimum condition to ensure longer sustainability and durability and stored properly in easily accessible locations

17.1.2 PPE being the basic requirement, shall be supplied to all the employees, labour, contractors vendors and suppliers to protect themselves as well as

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others. Respective units as field and factory shall incorporate specialized PPE for operation in their respective operational control procedures.

17.1.3 *Responsibility*

Each one in the premises involved in work environment shall be equally responsible to ensure use of the PPE as per HSE Manual and safety code. The need and importance of safety measures shall be explained to each worker on day-to-day activities at work place.

17.1.4 *General Requirements*

a) Use PPE properly according to the nature of work.
b) Awareness of the correct way to use PPE. This may be done by training, reading and discussion on the usage of manual of specialized PPE.
c) Regular checking, cleaning and maintenance of PPE. PPE shall be maintained in good shape and condition to ensure that the purpose is served.
d) Information to be given to supervisor regarding need to repair and replace PPE.

Each establishment shall prepare and notify safety requirements and guidelines for use of PPE. Non-adherence to the guidelines so prepared should be treated as an offence. If any personnel are noticed for non-compliance, it shall be reported to line manager or work manager for appropriate disciplinary action. This shall be a general practice to impart refresher training to all the employees meeting their other training needs as tool box talk before starting any task.

17.1.5 *Use of PPE for Specific Areas*

a) *Maintenance of electrical installations* — All personnel are required to observe the following procedures for PPE use:
    1) PPE use is mandatory when contact with exposed electrical sources is likely. Only use PPE that is designed for the work being performed. Inspect and test all PPE prior to use.
    2) Use a protective outer cover (for example, leather), if the work being performed may possibly damage the PPE's insulation.
    3) Wear non-conductive headgear, if there is danger of electrical burns or shock from contact with exposed, energized equipment. Wear eye and/or face protection, where there is danger of flying objects, flashes or electrical arcs produced by an electrical explosion.
b) *Maintenance of E&M services* — All workers employed in maintaining MEP equipment shall be supplied with proper PPE and should be trained to use them properly. Working on machines and plants without proper PPE should be strictly discouraged. Some of the PPE usage which shall be ensured are:
    1) Use of insulated gloves for electrical maintenance;
    2) Use of safety shoes for all kinds of maintenance;
    3) Use of safety helmets if it is a construction site;
    4) Suitable 'wet floor/wet area' displays to be provided at the time of wet service;
    5) Disconnect main power supply while attending to any service requirement on the respective equipment;
    6) Always check with line tester that supply is disconnected;
    7) Use safety belt and harness if working on building vertical faces;
    8) Ensure limit switch, fan guard and marine light inside AHUs;
    9) Ensure adequate lighting at all times during service;
    10) Use only competent and trained service agencies/personnel;
    11) Ask service provider's service representative to display identity card before commencing service, to prevent sabotage/industrial espionage; and
    12) Use genuine/reliable spares.

17.2 Maintenance Tools

17.2.1 A list of recommended tools should be maintained. Out of the list, tools relevant to the specific maintenance activity may be used. All tools and other equipment which are used shall be stored properly and be easily accessible. Wherever tools are to be used for working on hazardous areas, they shall be procured from reputed manufacturers to ensure safety of the workers.

17.2.2 *Portable Electrical Tools*

a) Portable electrical tools (especially metal body) should be connected through 30 mA earth leakage circuit breaker (ELCB) only to avoid any injury due to any leakage current.
b) Portable electrical tools should be double insulated because with regular use, the portable tools insulation gets weak and during the work technician may get injured due to electrical shock.

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c) Portable electrical equipment shall be regularly examined, tested and maintained to ensure that the equipment and its leads are in good order.

d) Register shall be maintained for inspection, recording the testing dates and results of the equipment.

e) All portable appliances shall be provided with three core cable and three pin plug. The third pin of the plug shall invariably be earthed.

f) It shall be ensured that the metal part of the equipment shall be effectively earthed.

g) All connections to portable equipment or machines from the panel/distribution board/ extension board shall be taken using three core double insulated PVC flexible copper wires in one length. No joints shall be allowed in this flexible wire. In case single length of wire is not sufficient for a particular location then the supply can be tapped by providing another extension board comprising of switch and socket.

h) Flexible cables for portable lamps, tools and apparatus shall be regularly examined, tested periodically and maintained to ensure safety.

17.3 Good Practices

Besides ensuring use of appropriate PPE, tools and trained manpower, there are some other aspects which each facility management team should follow. These aspects include the following:

a) Always ensure that the service provider checks the operation logs, to verify whether plants were operating as they should be.

b) Always ensure that the vendor prepares a service report and duly signs it.

c) Always ensure that service report is signed by an authorized person representing the owner.

d) Always ensure that all components of the plant are maintained as per protocol.

e) Always ensure that there is a physical meeting between operator and service provider, at the time of each quarterly service.

f) Never allow unauthorized personnel to enter plant rooms, sub-stations or other installations where machinery or other equipment are installed.

g) Do not allow wearing of loose clothes by operators and technicians as it can be a potential hazard.

h) Maintain all plant rooms, sub-stations, electrical panel rooms, etc, neat and clean. Remove all unwanted materials from these areas as it may hinder operations in times of emergency.

j) Senior supervisors, facility managers shall review maintenance operations and records regularly to ensure that proper schedules are being followed and that servicing, etc, of equipment is being done on time.

k) Constant emphasis shall be given on safety aspects.

m) Regular onsite training will help maintenance personnel to improve their performance

n) All maintenance manuals, documents related to equipment, service records shall be kept in a convenient place to allow quick and easy access.

p) Wherever a special service request is received, a follow up on the same shall be done after action has been taken to resolve it. This will help in generating confidence of end users in the facility management team and will also ensure that the personnel tasked with resolving the request perform properly.

q) Some operations are required to be carried out on a 24 × 7 basis. In all such places, proper provision for a rest room shall be provided.

r) Many installations may need deployment of large work force for maintenance and operations. In all such places it will be desirable to provide a proper rest room for the workers or an area for the purpose may be designated so that they can be approached quickly, whenever a need arises.

18 MAINTENANCE OF LANDSCAPING AND HORTICULTURE WORKS

18.1 General

Landscape maintenance specifications and management plan is the key to aesthetic environment and pleasant surroundings. Well maintained and manicured green areas not only enhance the value of the asset but also provide relief to the users. The objective is to provide regular time defined services as per the landscape maintenance specifications laid down for the property. This covers hardscape as well as softscape, which are explained below:

a) Hardscape are primarily the design elements that are solid and remain unchanged as the years go by, examples are rocks, walkways, retaining walls, paver patios, outdoor kitchens, water features, fountains, decks, podiums, driveways, etc.

b) Softscape are elements that are fluid and change with time. It is the living animated part of a landscape, comprising of elements such

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as soil, plants, shrubs, trees, flowers, vegetables, vines, turf, etc.

Maintenance of hardscape and softscape should be ensured as planned. Maintenance of walkways, roads and paths should specifically ensure proper maintenance of accessibility features provided, to facilitate movement of people with disabilities.

18.2 Maintenance of Plants

The fundamental principle of maintenance of in-door and out-door plants means using the right plant and the right place in the property. Indigenous plants, or others well adapted to local conditions, should be used wherever possible. Plant growth rate, size at maturity, life span, brittleness and requirements of light, water and soil *p*H are important factors in selecting plants, along with their colour, texture, fragrance and seasonal characteristics. Matching plant requirements with site realities and correctly placing appropriate plants helps avoid expensive and time consuming problems.

In case of indoor plants, it is necessary to choose the right location with good light and away from heat, vent and air conditioner. In case of a location with abundant sunlight, in-door plants should be placed in east west facing windows, whereas in case of locations with less sunlight, they should be placed in a north facing window. It is essential to give right amount of water as both too much water and not enough water can be the primary reason for a plants death. Plants should be given plenty of moisture depending on its type. In-door plants should be kept free of pest and dust. Over-time in-door plants become sickly and poor looking as a result of dust build up and insect pest infestation. They shall be cleaned with a rag and organic insecticide soap every few months. Unhealthy growth should be removed. In case of out-door plants/trees, it shall be ensured that they are getting enough sunlight. They should be watered on regular basis. Insects, snags and snails should be killed with organic insecticides. Care of planted area shall be done in accordance with **18.5.1**.

18.3 Regular, weekly maintenance services, as outlined in the landscape maintenance specifications, should be provided and weekly and monthly checklists should be maintained. All landscape areas, including irrigation systems, should be examined on a weekly basis, looking for problems or potential problems so that timely action can be taken. This is essential as the plants once damaged can only be replaced which will require extra financial burden.

18.4 Following documents needs to be maintained in suitable formats for effective monitoring:

a) Landscape maintenance plan;
b) Weekly and monthly monitoring checklists;
c) Attendance register for the garden maintenance team;
d) Records to be maintained for gardening consumables purchased in a month;
e) Weekly checks on the gardening tools and tackles; and
f) AMC for mechanized equipment.

18.5 Methodology and Processes to be Adopted

18.5.1 *Care of Planted Area*

a) *Trees* — Trees shall be maintained in a healthy, vigorous growing condition, free from disease and large concentrations of pests. Pruning of trees should be done only in appropriate months. Timely action, to remove dead, diseased, broken, dangerous, or crossing branches, to be undertaken as part of the regular maintenance to encourage a high-branching structure. All non-structural branches between the ground and a point half the tree's total height should be removed (for very tall trees branches higher than 6 m above the ground should not be removed). Trees planted for screening purposes, such as those at rear perimeters of many sites shall not be pruned except as needed to remove dead, diseased, broken, dangerous, or crossing branches. The cutting blades on pruning shears, clippers, blades, saws, etc, shall be sterilized after pruning each tree to minimise the possibility of spreading disease.

   A vertical clearance of 2.90 m (114 inches) is required above all parking spaces. A vertical clearance of 2.0 m (80 inches) is required above all walkways. Trim trees to remove all limbs within these areas.

b) *Shrubs and vines* — Shrubs and vines shall be pruned weekly or as needed to keep them in healthy, vigorous condition, free from disease and large concentrations of pests. Works to be carried out under guidance of a competent professional. Shrubs should be allowed three months to rejuvenate prior to pruning or replacing.

c) *Groundcover* — Groundcover shall be maintained in a healthy, vigorous growing condition. Groundcover shall be planted at 200 mm spacing from the building to encourage quick coverage. Prior to planting replacement groundcover, the soil shall be tilled to a depth of 150 mm to prepare it for the new plants. The groundcover should be kept trimmed back from sidewalks, curbs, and paved areas on a weekly basis. Vertical edges

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should not be created when pruning groundcover. The edges should be cut at an angle for a more natural appearance and healthier plants.

d) *Weed control* — Weeds in planted areas, sidewalks, curbs, gutters, or pavement shall be removed or killed weekly as the weeds emerge.

e) *Mulch and/or rock layer* — Soil mulch and/or rock layer shall be cared for, as needed to create and maintain an even and uniform appearance over the visible soil surface of each planter area. Replacement rock shall be of the same size and colour as existing decorative rock on site. In the event no rock is existing, the decorative rock used shall have a maximum diameter of 20 mm and a minimum diameter of 10 mm.

f) *Fertilizer* — When applying granular fertilizers to drip-irrigated areas, the fertilizer shall be washed in by hand or rainfall before turning on the drip system. Running the drip system immediately after application will push the fertilizer away from the emitters, resulting in a high concentration of fertilizer at the edge of the wetted zone. This highly-concentrated fertilizer can kill or damage plants. It is recommended that granular fertilizers be applied to drip-irrigated areas only in early spring, just prior to a moderate rainfall.

g) *Lawns* — Lawns shall be kept in a healthy, vigorous condition, free of disease and pests. Lawn height shall not exceed 130 mm at any time, preferred is 3 inches. Lawns should be mowed, edged and trimmed weekly or as required to maintain an even, well-groomed appearance. Visible lawn clippings should be removed and disposed off-site in a legal manner. It is encouraged to use mulching mowers which cut clippings into small pieces that sift down into the lawn. Weeds shall be controlled in lawn areas as described in (d).

18.5.2 *Irrigation — Water Application and Scheduling*

18.5.2.1 Hand watering should be done, as needed to supplement natural rainfall and maintain plantings in a healthy, stress-free condition, to ensure that plants receive adequate water regardless of weather conditions. Irrigation shall be done by the use of the permanent irrigation systems. Hand watering should also be done, as needed to supplement the permanent irrigation systems.

Watering times shall be adjusted each week. Plantings shall not be over-watered. Multiple-start times and short run times should be used to prevent run-off. Drip systems should be left on for sufficient time to allow for saturation of the root zone. Shorter runs with drip irrigation do not provide sufficient water penetration for healthy root development. Multiple-start times with drip systems should be avoided, if possible. Run-off should not be allowed from any irrigation.

18.5.2.2 *Irrigation system scheduled maintenance*

Irrigation system scheduled maintenance shall include the following:

a) Each valve zone shall be observed for signs of damage on a weekly basis during the irrigation season.

b) The irrigation system should be maintained, including cleaning of filter screens yearly or more often as needed, and flushing pipes, as part of regular maintenance.

c) Drip irrigation systems need periodic flushing to remove sediment and shall be performed as per the required frequency. Drip systems shall be flushed at least once a year. Ends of drip lines should be opened and run for at least 15 min at full flow to flush. It may be necessary to install flush outlets in order to flush the drip system.

d) For safety, sprinklers shall not be installed on risers above the ground level, even if the risers are flexible. Spring-operated, pop-up style, sprinkler heads should always be used. Sprinkler heads are available with pop-up heights up to 300 mm above ground level. If the existing sprinklers are mounted on above-ground risers, the replacements shall be pop-up type sprinklers.

e) The entire irrigation system should be inspected weekly for items such as dry spots and missing or malfunctioning irrigation components. It shall be checked for leaking valves, water running across sidewalks, water standing in puddles, or any other condition which hampers the correct operation of the system or the public safety. The team shall carefully observe plant materials for signs of wilting, indicating a lack of water.

18.5.3 *General Cleaning*

While it is essential to maintain all hardscape and softscapes properly it is also essential to ensure general cleaning up of these areas. Cleaning up and litter removal from, all walks, kerbs, and gutters, on weekly basis should suffice. However, frequency may be determined depending upon the usage of the facility. In no case shall trash, litter, or leaves be blown or swept onto the property of others. All trash, litter, leaves, etc, shall be collected, hauled away, and disposed of legally.

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Under no circumstances shall dry leaves be burned. Wherever possible, composting of horticulture waste should be resorted to.

18.5.4 *Chemicals, Pesticides and Herbicides*

All chemicals shall be used in accordance with label directions and the manufacturer's recommended dosage and handling methods and handled in accordance with all applicable regulations. Nothing in this clause shall be construed to be the advice of, or to substitute for the advice of, a pest control adviser whose advice should be sought for use of registered chemicals.

Pesticides shall not be applied within one hour of the start of operating hours for businesses at the site. In the event that it is not possible to complete the application by 1 h prior to business hours (that is, 24 h operations), applications shall be made at times when customer presence is minimal. Areas to be treated shall be blocked off and warning signs posted.

18.5.5 In addition to above, the maintenance requirements as given in Part 10 'Landscape Development, Signs and Outdoor Display Structures, Section 1 Landscape Planning, Design and Development' of the Code shall also be complied with.

18.5.6 *Reports*

The weekly landscape maintenance checklist shall be complete in respect of all applicable items on the checklist. It shall be submitted to authorized representative each week for review. The monthly landscape maintenance checklist needs to be prepared for month on month requirements as per the season during the year. A typical checklist for landscape areas is given at Annex H.

19 HOUSE KEEPING

19.1 It is an established fact that a 'clean' facility enhances the appeal, productivity of occupants and the value of the facility. Janitorial service standards cover basic features of operations required to be carried out to keep the facility clean. Housekeeping or janitorial services will include, where required, ensuring desired levels of hygiene.

19.2 Methodology and Processes to be Adopted

19.2.1 Adequate staff, having necessary training in carrying out cleaning operations for ensuring required levels of cleanliness, under guidance of trained janitorial supervisor should be deployed. Having trained teams for carrying out these operations will result in better standards being achieved with lesser manpower. The facility management team should draw up plans for achieving the desired standards without disturbing the use and operation of the facility. Assessment of manpower required needs to be carefully assessed keeping in view all relevant factors.

19.2.2 While carrying out housekeeping activities following aspects should be kept into consideration:

a) All local laws and regulations are abided by, and

b) Required protocols of cleaning for all areas of the building and cleaning schedules for all areas of the building are implemented.

19.2.3 *Tools and Technology*

Cleaning chemicals to be used should have a *p*H value of (1 percent sol) : 9.5-11.0 and it is desirable to use only green seal certified chemicals, certified by an appropriate authority, and manufactured by reputed manufacturers. This is essential to prevent damage to assets and ensure that no harmful impact is caused to facility/users.

Chemicals used should be safe and should display appropriate hazard warnings and material safety data. Storage of the cleaning chemicals should be done properly to ensure that no untoward incident occurs and misuse can be prevented.

Mechanical equipment like, dry vacuum cleaners, dustette, back-pack vacuum, upright vacuum, pile lifter, wet and dry vacuum cleaner, large tank type vacuum cleaners, carpet shampooing machine/steam extraction machine, high pressure washers, scrubbing/polishing machine, etc, may be deployed as required. Selection of cleaning equipment may be made based on:

a) *Floor finish* — Vitrified, carpeted, mosaic, marble, granite, etc;
b) Total area required to be cleaned;
c) Cleaning standards/frequency required to be achieved;
d) Time at which cleaning activity is to be carried out and time duration available to complete the process;
e) Periodicity of the activities, that is, daily, weekly, etc; and
f) Areas/building component required to be cleaned, for example, glass facades, aluminum composite panel (ACP) sheets, atrium, etc.

Periodicity of the activities can be classified into: daily, weekly, monthly or annually.

19.2.4 *Periodic Tasks*

The activities to be carried out at intervals mentioned above shall be enumerated and the facility management team shall be aware of the same and should carry out these activities at specified intervals.

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19.3 Documentation Required to be Maintained for Effective Monitoring

Like other services, proper documentation of housekeeping services shall be maintained to ensure proper execution, review and control. Following details may be maintained:

a) Supervisors check-list;
b) Deployment sheet;
c) Attendance register;
d) Week-end check-list;
e) Incident tracker;
f) Chemical consumption record; and
g) Machinery running and maintenance report.

19.4 Evaluation and Recommended Frequencies

As housekeeping is a function which shall be carried out strictly as per desired schedule, it is desirable that service level agreement (SLA) shall be reviewed and findings documented.

Recommended frequency of evaluation should be once every month.

19.4.1 *Measurements and Recording of Non-conformance*

Non-conformance can be measured through e-mail/ telephonic/written/verbal report received from the employees/end users. Number of times the default has occurred in a month shall also be recorded. Any escalation on the help-desk/help-line will be categorized as non-conformance except for request. Any incident/default will be measured as a single unit.

19.4.2 Non-conformance to SLA may be classified as:

a) *High* — Any event which compromises with business continuity, life threatening incident, loss of reputation, major financial loss.

   Non-conformance recording — Default twice in a month equals to one non-conformance.

b) *Medium* — Default observed in the adhering to bench-marked cleaning standards defined for the property.

   Non-conformance recording — Default thrice in a month equals to one non-conformance.

c) *Low* — Any event causing minor annoyance.

   Non-conformance recording — Default four times in a month equals to one non-conformance.

NOTE — The above being recommendatory, appropriate measures should be taken by the facility management team based on the type of usage of facility.

19.4.3 It is desirable that the facility management team sets benchmarks for measuring performance and non-compliance. It is recommended that a score of 95 percent or above may be accepted as having complied with the SLA and a score of 50 percent or below may be taken as to indicate failure of the housekeeping team.

19.4.4 A typical template for measurement and recording of conformance or otherwise with respect to housekeeping in given at Annex J.

19.5 Training and Skilling

Cleaning supervisor/cleaning personnel (janitor/ chamber-maid) should have required skills and attitude and eye for detailing. Regular onsite training should be carried out. This will help in improving delivery of services by the personnel. During training, housekeeping staff should be sensitized on needs of persons with disabilities, elderly and frail people and children in particular.

Housekeeping staff should also participate in, and also be trained to participate in all safety and disaster related activities.

20 PEST AND RODENTS CONTROL

20.1 Overview

A clean environment and prevention is the starting point of pest control. Keeping harmful pests at bay results in preventing loss and ensures a healthy and safe environment for the users. Pest control is the process of eliminating or minimizing a wide range of undesirable pest and insects. A watchful eye and alertness to detect tell-tale signs of pests helps to take adequate timely action. Certain kind of pests can be a great health risk and can cause safety issues for any premises. Engaging a professional service partner to manage the pest control brings about desired results.

Integrated pest control management is a holistic approach encompassing prevention, monitoring and control techniques with larger goal of suppressing pests by application of least toxic measures. Preparation of an integrated pest management plan can be very useful and following guidelines may be considered in its preparation:

a) Preventive measures should be explored;
b) Alternative methods of control to be evaluated;
c) Timely action for effectiveness and safety;
d) Most effective method to be adopted that has cost benefit and least environment effect; and
e) Adequate monitoring and documentation.

NOTE — It is recommended that control measures be adopted only when the problem occurs.

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20.2 Methodology and Processes to be Adopted

20.2.1 *Tools and Technology*

Various tools and equipment employed in pest control are hand operated sprays, foot operated sprays, gum pads, gel guns/syringes, fogging machines, etc. These may be used/deployed as required.

20.2.2 *General Management*

20.2.2.1 *Prevention techniques*

An important step, as it eliminates the pests by disturbing its environment, can be through physical barriers or elimination of source, as described below:

a) *Elimination of ingress points*:
   1) Allow food and beverage at designated areas only.
   2) Keep areas dry, eliminate stagnant water.
   3) Carpeted areas to be vacuumed frequently.
   4) Precautions for food preparation and serving areas with due attention to storage, cleaning and waste disposal practices.

b) *Monitoring techniques* — Good monitoring is a cost effective aspect of integrated pest management, forming the basis for control techniques. Regular, systematic inspection of the facility is essential to be effective. It may include the following:
   1) *Tell-tale signs* — Sighting of pests, damage, droppings, tracks and traces.
   2) *Thresholds* — Mere presence need not trigger control action but sizeable presence warrant actions.
   3) *Traps* — Very effective method of monitoring and helps reduce usage of chemicals and pesticides.
   4) *Data to be recorded systematically* — Helps to detect pest problems and compare outbreaks season to season. Records should be maintained to capture dates, temperature, location of infestation and control action taken.

c) *Control techniques* — Use of control techniques to be on the basis of proven efficacy, low environmental impact, operational feasibility and cost effectiveness. Control methods by use of chemicals is most effective while cultural, mechanical, physical, biological methods contribute greatly towards prevention. Special control techniques may also be employed based on case specific requirements. Best practices for this aspect include the following:
   1) Training of personnel;
   2) Usage of personal protective equipment (PPE);
   3) Usage of green chemicals; and
   4) Usage of low toxicity chemicals.

Periodicity of activities can be daily, bi-weekly, weekly, fortnightly and monthly.

20.2.2.2 Documents like integrated pest management plan, pest monitoring checklists in appropriate formats should be maintained for effective monitoring.

20.2.2.3 Evaluation and recommended frequencies can be laid down by each establishment depending upon location, use and infestation of pests.

21 SECURITY SERVICES FOR BUILDING OCCUPANTS AND ASSETS/FACILITIES

21.1 The primary aim of security in a building occupied by people for various purposes is to take adequate measures to deny all opportunities of acquiring information, committing sabotage and subversion activities by antisocial elements. The security issues shall be addressed in using integrated design process with an understanding of the impacts and goals of other design objectives. While ensuring safety and security measures adopted, the staff deployed should take into account needs of persons with disabilities, elderly and frail people, women and children in particular.

The physical security addresses the threats, vulnerabilities, and countermeasures that can be utilized to physically protect an asset's resources and sensitive information. These resources include people, the facility in which they work, and the data, equipment, support systems, media, and supplies they utilize. These guidelines assist in the identification of physical security measures that can be applied at facilities to safeguard or protect an organization's asset, that is, people and property. Security measures required for keeping information secure are not covered herein.

There are generally eight main categories of physical security measures used to protect buildings. These categories are listed below and need to be kept in view while planning and providing security services:

a) Crime prevention through environmental design (CPTED);
b) Physical barriers and site hardening;
c) Physical entry and access control;
d) Security lighting/illumination of the vital installation;
e) Intrusion detection systems;
f) Electronic/video surveillance;

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g) Physical deployment (engagement of security personnel); and
h) Security policies and procedures.

21.2 Threat Types

Some types of threats to be considered include the following:

a) Unauthorized entry/trespass (forced and covert).
b) Insider threats.
c) *Explosive threats* — Stationary and moving vehicle-delivered, mail bombs, package bombs.
d) *Ballistic threats* — Small arms, high-powered rifles, drive-by shootings, etc.
e) Weapons of mass destruction (chemical, biological, and radiological).

21.2.1 Suitable measures at design, construction and maintenance stage need to be taken to ensure that threats of unauthorized entry (forced and covert) are taken care of.

21.3 Methodology and Processes

21.3.1 *Threat and Risk Assessment*

A security system is generally not effective unless it is developed based on an understanding of the actual threats and risks it is designed to control. The development of a threat and risk assessment for a facility involves the following steps:

a) *Preparation* — Determining what to protect,
b) *Threat assessment* — Determining what to protect against,
c) *Risk assessment* — Determining if existing or proposed security measures are satisfactory, and
d) *Recommendations* — Identifying what should be done.

21.3.2 *Site Development*

A safeguarding strategy should be defined and used to develop a security site brief (SSB).

The institution or tenant should prepare a SSB for leasing existing facilities, because custodians generally seek existing space as a first option. If it is determined that existing space is not available or is not the first option, then another SSB for constructing facilities should be prepared. Once selected through a build, buy or lease process, the site is subjected to a survey to determine site specific security-related problems. These problems may include neighbourhood vandalism, theft or violent crime. This information is considered along with the facility threat and risk assessment and allows the safeguarding strategy to be adjusted as required and adequate safeguards to be developed for the site.

21.3.3 *Security Strategy*

21.3.3.1 The security strategy should be based upon the following principles:

a) Segregation of public and private areas;
b) Segregation of high and low security level areas;
c) Access control;
d) Surveillance;
e) Alarm generation;
f) Physical security;
g) Screening of personnel and vehicles;
h) Layered security through multiple tiers;
j) Crime prevention through environmental design (CPTED); and
k) Response to potential threats and incidents.

21.3.3.2 *Key security measures*

a) *Vehicle movement plan* — There will be several options available for movement of vehicles. The final plan should be based on smooth flow of traffic that will promote uninterrupted traffic for all types of vehicles. Ideally there should be separate entry and exit points. Security demands minimum entry and exit points to ensure proper screening and checking of vehicles.
b) *Pedestrian movement plan* — Movement of pedestrian should be restricted to one entry, if possible. There should be proper arrangement for screening of pedestrians including cabin for female pedestrians.
c) *Fire engine movement plan* — Arrangement shall be made for entry, exit and movement of fire engine. Adequate turning radius shall be provided within the entire complex. Ideally there should be separate entry and exit point to ensure regular flow of fire engines, if necessary.

21.3.3.3 Security managers/security personnel's responsibilities shall include among other things the following:

a) Physical security of the organization's assets;
b) Development and enforcement of security policy and procedures;
c) Crisis management;
d) Business continuity planning;
e) Executive protection within building/facility;

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f) Preliminary investigation of security incidents;
g) Employee security awareness;
h) Law enforcement and governmental liaison;
j) Workplace violence prevention;
k) Security systems management;
m) Assisting in preventing and fighting any fire incident;
n) Periodic threat assessment of the building;
p) On the job training of the security staff;
q) Regular conducting of evacuation drills;
r) Maintenance and upkeep of the security gadgets; and
s) Monitoring of security situation by electronic surveillance

Security manager can be direct employee or contractor to the organization. Security managers should be assisted by security supervisors and security guards whose duties should be detailed to cover all required aspects as given below:

1) Supervisor should ensure that all the norms related to safety are followed by all.
2) He should be aware of emergency action plan of the premises and ensure that all guards and employees are also aware of it.
3) Security supervisor shall know the locations of fire points, hydrant points, emergency exits, fire alarm break glass switches and first aid junctions, etc within the premises. At the same time he is to take initiatives to ensure that guards and all the employees also know about the above mentioned points.
4) Supervisor shall ensure that telephone numbers of all key personnel and emergency numbers are readily available at each post for the use during emergencies.

21.3.4 *Common Service Standards*

21.3.4.1 *Patrols*

Frequency of patrols shall be agreed and timetabled and records of all patrols shall be kept.

21.3.4.2 *Controlled access during out of hours*

a) During out-of-hours shifts only specified access and egress shall be used which the security staff should control.
b) At no time shall unauthorized individuals be allowed into the premises.
c) Any person not wearing an appropriate pass at any time, including recognized staff, shall be challenged to ensure that any and every person has a valid reason for being on the premises.
d) The scanning/vetting of any items received outside core service hours, other than pre-notified scheduled deliveries, shall be controlled by security staff.
e) All security personnel shall receive adequate training for this purpose.

21.3.4.3 *Vehicle access control*

Vehicles have been a major threat to security of any asset. These can be used for bringing armed intruders, smuggling of explosives, arms and other contraband items. Measures to secure premises/complex should include the following:

a) *Vehicle ramp schemes* — Vehicle barriers, as given below should be designed and installed at all vehicle entry/exit points.
   1) *Boom barriers* — Boom barriers perform the majority of access control functions for regulating vehicular traffic into and out of control areas. The boom barrier can be operated with radio frequency identification (RFID) to enable unobstructed entry to select clients. Tags for smooth flow during peak hours may also be considered.
   2) *Retractable bollards* — Retractable bollards are generally deployed to provide vehicle management for secure areas. Road blockers rise from road level, form a solid barrier and will not allow a vehicle to gain entry or pass by crashing through.
   3) *Sliding gates* — Sliding gates may be installed to reinforce vehicle entry points and delineate the property boundary during demonstrations. Sliding gates are quick to deploy and cannot be easily bypassed by pedestrians. These or any other combination of gates shall be installed for any unforeseen eventuality to prevent entry into the complex by vehicles or pedestrians.
b) *Vehicle screening* — Any method of under vehicle inspection requires regular security officer training and diligence when performing his/her search. Adequate lighting should be provided to screen the vehicle during night. The following options for vehicle screening are available, which should be considered for taking appropriate decision for providing suitable measures:
   1) *Undercarriage vehicle surveillance*

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system (UVSS) — The UVSS provide the operator, through video cameras, with a safe and effective means to search the underside of vehicles for explosives or firearms. The systems are available in fixed or portable units. A UVSS is recommended, however the comparison of vehicle images with a default image is dependent on capability of a security guard. The system can be upgraded to a composite system to include full vehicle search. UVSS with explosive detectors may also be used.

2) *Search mirrors* — This method of screening vehicles for an improvised explosive device (IED) is common throughout the country.

3) *Vapour and particle detectors* — Vapour detectors and particle detectors, generally known as sniffers; identify explosives by their particulate or gaseous elements. When used correctly, sniffers can assist in the detection of a range of explosive compositions. The device collects vapour samples through a vacuum as it is run over a package, then analyses them for vapours generated by certain explosives, however, vapour detectors may miss explosives with a low vapour pressure.

4) *Explosive detection trained (sniffer) dogs* — Explosive detection trained dogs (known as sniffer dogs) used in conjunction with search mirrors is another option for screening vehicles.

5) CCTV surveillance to cover the activities of the vehicle entry point is a very important requirement and should be catered in all cases.

6) Suitable means for automatic number plate reading/recording of the vehicle and for capturing image of the driver can also be provided.

7) Speed breakers can include dynamic speed bumps, rumble strips and speed humps to facilitate vehicle screening.

c) *Car parking* — A car park can be one of buildings busiest and most vulnerable areas. Parking facilities can offer criminals the opportunities to commit personal and property crime without detection. Enhanced security operations in parking areas are supported by intercom systems, emergency phones at strategic locations, duress alarms, CCTV, scream alert detectors and motion detectors in stairwells.

1) *Duress/panic alarm stations* — Duress or panic alarms can be placed at strategic locations to enhance public/tenant safety. When the emergency button is activated, the alarm will alert the operator in the control room and emit an audible alarm and/or strobe light.

2) *CCTV* — The placement of cameras shall be done to provide optimum surveillance in all directions including all entry/exit points and cover all dark corners.

3) *Security patrols* — The guard force shall conduct regular patrols of the all car-parking areas. Installing a guard tour system can enhance patrol coverage and effectiveness.

4) *Roller shutters* — Roller shutters can be installed at all vehicle entry points to secure the area when the circumstances dictate.

d) *Loading bays* — The screening of goods vehicles is difficult and can take time to complete, the size of this development, number of loading bays and expected vehicle traffic in any one day further exasperates the situation. Loading bay has limited space for turning and checking of vehicles. Surveillance measures in form of CCTV cameras should be considered to control and monitor the following:

1) Vehicles;
2) Personnel;
3) Goods loading and unloading; and
4) General area.

e) *Car lift/waiting area in basement* — Basements are vulnerable to vehicle borne explosive devices, theft of vehicles or vehicle parts, theft from vehicles parked in basement, vandalism or damage to vehicle, unauthorized access to basement, damage to car lifts/ systems, placement of explosives in lift lobbies or misconduct in lift lobbies. Measures to mitigate these are as under:

1) CCTV coverage and regular security patrols.
2) Duress alarm/Panic stations.
3) Roller shutter to secure access to/from the car park.
4) Personnel screening prior to entering shuttle lift by security guards through door frame metal detector (DFMD), hand held metal detector (HHMD)

f) *Managing of parking bays* — Outside working hours all parking bays should be closed with

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roller shutters or sliding shutters secured on the inside. During working hours, the bays should be under the control of a custodian or, where the threat is high, closed with electronically operated shutters which are only opened when the incoming vehicle has been identified and, where necessary, searched.

21.3.4.4 *CCTV monitoring*

21.3.4.4.1 Security personnel shall,

a) Be fully trained and conversant in the use of the CCTV equipment on the premises.
b) All staff responsible for monitoring the CCTV shall be rotated at regular intervals to maintain alertness as defined in recognized industry guidelines.
c) Any staff overseeing CCTV monitors shall have immediate recourse to other security staff, including emergency/incident control personnel, at all times, to ensure the safe and secure functioning of the premises and their inhabitants and to facilitate the instigation of action as appropriate.
d) Guidelines for the use and storage of all CCTV footage shall be available to all staff.
e) Any recording material shall be kept in a fire-proof secure facility to allow immediate access to their contents.
f) The maintenance of all CCTV recording material shall be kept in good order to enable ready access on an as-needs basis.
g) All CCTV recording material shall be kept available for review for four weeks.
h) Log books shall be kept of any incidents requiring investigation/intervention by security staff, and shall be available at all times.

21.3.4.4.2 *CCTV control and monitoring*

a) All access areas, such as doorways, lifts and staircases should be covered by CCTV surveillance for both day and night monitoring in large group housing, commercial complexes, hospitals/hotels, airports and railway stations.
b) The CCTV installation shall be interfaced to the Security Management System (SMS) to provide the operator with the facility to capture and display any camera picture.
c) Where necessary, cameras shall be provided with pan and tilt control and be fitted with a motorized lens capable of a zoom range (Pan/Tilt/Zoom or PTZ cameras) appropriate to the designated task. Pre-set capability can be provided for all fully functional camera heads to allow automatic response to adjacent alarms.

All CCTV images shall be recorded. This will provide full flexibility for remote viewing of live and recorded images. The operational requirement of each camera can be stated in terms of monitor and control, detection, recognition or identification.

21.3.4.5 *Screening of personnel entering facility*

Screening personnel and their belongings at entry points can help reduce the likelihood of explosive devices, weapons and other hazardous or prohibited items or materials being brought into buildings or onto sites. Similarly, searching personnel as they exit can help reduce the risk of unauthorized removal of items and information and acts as deterrent. Appropriate screening and detection equipment can offer real benefits where used in support of robust procedures and well trained and motivated staff.

21.3.4.5.1 *Standard operating procedures (SOP)*

In order to provide an excellent security service following security procedures should be adhered to across all buildings and SOPs as per the organization's requirement should be formulated to standardize the processes:

a) Access control;
b) Identification badge;
c) Administration of locks and keys;
d) Sites' opening and closing procedures;
e) Security risk, threat and violation;
f) Card access system;
g) Search procedures;
h) Managing the security control room;
j) Incident management and investigation;
k) Reporting of security incidents and losses;
m) Asset removal;
n) Transportation security; and
p) Site emergency procedures.

21.3.4.5.2 *Perimeter and landscaping*

Perimeter forms an important part of security environment of any complex or asset. Landscaping shall lend itself to strengthen the security instead of creating a hurdle in securing the area. Some of the measures recommended are as under:

a) Perimeter protection through a wall/fence and barriers with adequate height to deter intrusion.
b) Physical and electronic measures to cordon the complex, when desired.

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c) Surveillance of perimeter including intruder detection system and quick response from security.
d) Regular patrolling by security.
e) Provision of armed guards for limited defending capability against armed intruders.
f) All plants and trees to be kept trimmed to minimise the opportunity of concealment and/ or assistance for intruders to unlawfully enter facility.
g) Allocate public space to provide natural barriers to prevent easy targeting for bag snatchers.
h) All plants and trees to be kept trimmed to minimise the opportunity of concealment of improvised explosive device (IED).
j) Provision of good perimeter lighting.
k) Adequate CCTV coverage that will deter, detect and record incidents of concern to the client.

Perimeter landscaping including plants, trees, shrubs, ditches and berms (low earth walls used to provide blast protection) should be constructed, located and maintained to stop, deter and/or delay an intruder. Landscaping shall not provide cover for surprise attacks on persons, and shall not permit entry or a climbing aid. Landscaping shall not obstruct lines of sight, lighting, and CCTV or intrusion detection systems.

Fountains, pools, pieces of sculpture, sizeable boulders, stairs reinforced and anchored benches, concrete planters and bollards strategically placed near a building can be used to deny vehicle access to vulnerable areas and maintain a spatial separation of vehicles from a buildings structure.

21.3.4.5.3 *Service entry/exit*

These areas are vulnerable to unauthorized entry/exit, loitering in premises/landscaped area by anti-social elements and also forced entry by unauthorized vehicle. Some of the measures for securing these should be as below:

a) Install sliding gates at the service entrance.
b) Use the gates at night to restrict access.
c) Create the impression of a 'hard target'.
d) Adequate lighting of building perimeter.

21.3.4.5.4 *Pedestrian entrance/exit*

Entry of pedestrians is another major threat to the asset. Strict security measures shall be implemented to secure the asset from entry of persons into the complex. Pedestrian entry points can be used for unauthorized access of anti-national or anti-social personnel, smuggling of arms, ammunition, explosives and contraband, placement of IEDs or other fire arms/ explosives within premises, removal or theft of items/ articles of value, commit criminal activity, unauthorized reconnaissance or surveillance of premises. Mitigation measures recommended:

a) Mandatory display of ID cards by employees.
b) All non-employees guided to pedestrian lane.
    1) All visitors to be asked to report to the reception desk.
    2) Personnel security screening checkpoint
    3) Visitor registration and issue of photo ID badge.
    4) Screening of only visitors through Hand Held Metal Detector (HHMD) and Door Frame Metal Detector (DFMD).
    5) Checking of visitor's baggage by X-ray scanners.
    6) Random checking of employee bags.
    7) All employees to pass through flap barrier/ turnstiles placed at lift lobby and escalator base landing by using their access cards.
    8) Separate turnstile lane needed for visitors and handicapped persons.
    9) Stairwells should provide egress only from a floor; all ground level doors should be fitted with panic bars and monitored by security/installation of electronic access control lock.

21.3.4.5.5 *Mail and courier handling*

Mails can be a source for sending letter bombs. Letter can also be used for delivery of biological/chemical contaminants. Mitigation measures recommended for prevention of threats from letter bombs can be:

a) Isolation of mail delivery area, that is, mail room;
b) Screening of mail by X-ray scanner, explosive detector (*see* Note);
c) Access control and intruder detection for critical plant rooms, like, BMS, DG room, UPS room, LT Panel, water treatment plant (WTP), AHU, etc.

NOTE — Mail detection devices represent one layer of defence and will not detect every type of explosive material. Detection technologies employed should meet very specific needs. Blast containers should be provided to hold suspect mail, which can be identified and dealt with by the Bomb Detection and Disposal Squad (BDDS) of the police.

21.3.4.5.6 *Glazing*

a) Most glazing materials and components designed to respond to blast loads will be damaged by the blast overpressures. To

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improve the post-damage behaviour of the glazing system, laminated glass is the preferred choice. The minimum overall thickness of laminated glass classed as blast resistant should be designed considering the impact which shall include a polyvinyl butyl (PVB) interlayer of minimum thickness of 1.5 mm.

b) Equally important to the design of the glass is the design of the window frames. For the window to properly fail, the glass shall be held in place long enough to fail. The capacity of the frame system to resist blast loading should therefore exceed the corresponding capacity of the glazing. Finally a glazing and mullion system designed to resist a specified blast load shall be anchored to an adequately designed building wall system. This building skin shall be capable of resisting not only a reflected shock wave but also reactions transferred from the blast resistant glazing system.

21.3.4.5.7 *Door sets*

a) Door sets should be securely fixed into a structural opening of wall construction that shall at least be equivalent strength to the door.

b) *External secure area doors* — External door sets should be sufficiently strong to resist manual attack from assailants with tools, and the locking system should be multi-point bolting with hinges protected by hinge bolts and resistance against levering. External emergency escape doors: Emergency escape doors should be sufficiently strong to resist manual attack from assailants and the locking system should be resistant against levering.

21.3.4.5.8 *Security lighting*

The following areas should be illuminated to provide enhanced security:

a) Perimeter roads;
b) Public spaces;
c) Areas immediately surrounding buildings;
d) Pedestrian walkways/routes; and
e) Car parks.

21.3.4.5.9 *Blast resistant trash bins*

Blast mitigation trash receptacles enhance public safety from terrorist bombs planted inside public trash receptacles. These blast mitigation bomb receptacles are typically used at airports, train stations, sports stadiums, and malls.

21.3.4.5.10 *Baggage inspection*

X-ray scanners have either a fan shaped or scanning X-ray beam that is transmitted through the object to be viewed. Simple X-ray machines rely on humans to serve as pattern recognition devices; in the absence of computer pattern recognition techniques they are very dependent on human factors such as training and competency of the screener.

21.3.4.5.11 *Lift lobby level access turnstiles or panel gates*

These are designed to provide a means of access control in busy office/lift lobby entrances. The gates functions in either an open position that closes the lane in the event of an unauthorized access, or in a closed position that opens the lane for authorized passage. Flap barrier type turnstiles/panel gates are recommended.

21.3.4.5.12 *Electronic security systems*

Electronic security systems provide a control, monitoring, and detection and surveillance capability. Electronic systems are interfaced with physical barriers such as doors, gates and turnstiles. Electronic systems need to be integrated in to a security management system (SMS). The SMS will provide the necessary capabilities to monitor control and manage the security systems.

21.3.4.5.13 *Fire detection and alarm system interface*

The SMS can interface with the fire detection and alarm system. The interface will operate such that, upon the activation of the fire alarm system, the access control system (ACS) controlled door locks, which are designated to operate in a fail-safe mode and release open, shall be de-energized. ACS controlled doors to high security areas, such as computer rooms, will be designated to fail-secure in a fire alarm condition.

21.3.4.5.14 *Access control system* (*ACS*)

A fundamental element in the security strategy is to prevent unauthorized access to restricted areas and, subsequently, to control and monitor the movement of authorized persons within the buildings. This shall be implemented in a manner, which does not inhibit operations.

The system should operate as an integral sub-system of the SMS. The proposed system should utilize the latest developments in access control technology and should be based on proximity card reading technology. The system should limit the ability of individuals without authorization to pass through 'locked' doors based on the time of the day, day of the week, week of the year and the authorization levels allocated to the individual.

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Proximity technology which is extremely 'user friendly' may be used with advantage. The card is not subjected to any form of mechanical wear and the life expectancy of the card is considerable.

All high security areas within the building shall be provided with an appropriate level of access control technology. Personnel traffic shall be monitored and access to individual floors and specific areas within each floor shall be strictly controlled, as appropriate, by use of the ACS.

21.3.4.5.15 *Guard room*

A guard room serves administrative purpose which cannot be carried out from the security control room (SCR), namely:

a) Security management and shift supervision;
b) Radio communications and charging; and
c) Provide a centralized point for security issues and tenant concerns.

21.3.4.5.16 *Guard tour system*

The safety and operational efficiency of the security guard force is critical to the overall security strategy as is the correct and proper patrolling of all external and internal areas. The proposed system will be wireless and operate as an integral sub-system of the access control installation and all patrols details will be displayed on the SMS graphics floor plan. Guard tour radio frequency identification (RFID) tokens presented at designated readers shall be logged and time stamped such that printouts and reviews can be attained of individual Guard tour route.

21.3.4.6 *Miscellaneous systems*

21.3.4.6.1 *Truck screening*

Fixed screening devices allows the user to inspect the contents of cargo containers and vehicles quickly and easily, validate manifests in minutes, and pinpoint weapons, explosives, drugs and other security threats. While vehicles and containers remain stationary, the gantry-mounted X-ray and detectors pass over the object being inspected. A dedicated truck screening system is not recommended.

21.3.4.6.2 *Keys*

To maintain the security of the buildings and areas, the keys and cylinders to the entrance points should be obtained under a key registration system where the keys and cylinders can only be obtained from a nominated manufacturer when the order is approved by an authorized person – usually the department/security manager. Keys should be kept in secure key cabinets where authorized persons only draw them. The key cabinet and key allocation should be controlled using a key management system. The loss or suspected compromise of a security key shall be reported immediately to the Security Manager.

21.3.4.6.3 *Radio communications*

It is recommended that an efficient and well organized communication network should be created to pass information as and when necessary.

21.3.4.7 *Methodology*

Like other services security services can also be carried out by deploying guards by having them on regular rolls of owner/occupant or can be out sourced to specialized agencies. Detailed guidelines on roles/responsibility/ qualification of personnel deployed on security details have been prescribed by Law. For all major complexes and sensitive buildings compliance to *The Private Security Agencies (Regulation) Act,* 2005 shall be ensured as per the directions of the Authority.

22 SOLID WASTE MANAGEMENT

The requirements for waste management in buildings applicable to all large/small facilities that generate, store, or handle any type/quantity of waste are covered in **22.1** to **22.4**. Waste management of townships, etc, are not covered.

22.1 Principles

Following should be the guiding principle for solid waste management:

a) Minimise waste generation;
b) Reuse and recycling of waste;
c) Waste segregation; and
d) Waste disposal.

22.2 Solid Waste Management Planning

Facilities that generate waste should categorize their waste according to composition, source, types of wastes produced, generation rates, or according to local regulatory requirements. Effective planning and implementation of waste management strategies should include,

a) review of new waste sources during planning, siting, and design activities, including during equipment modifications and process alterations, to identify expected waste generation, pollution prevention opportunities, and necessary treatment, storage, and disposal infrastructure.
b) collection of data and information about the process and waste streams in existing facilities, including characterization of waste streams by type, quantities, and potential use/disposition.
c) establishment of priorities based on a risk

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analysis that takes into account the potential environmental, health and safety (EHS) risks during the waste cycle and the availability of infrastructure to manage the waste in an environmentally sound manner.

d) identify opportunities for at source reduction, as well as reuse and recycling

e) detail procedures and operational controls for onsite storage.

f) definition of options/procedures/operational controls for treatment and final disposal.

22.2.1 *Waste Prevention Strategy*

Processes should be designed and operated to prevent, or minimise, the quantities of wastes generated and hazards associated with the wastes generated in accordance with the following strategy:

a) Substituting raw materials or inputs with less hazardous or toxic materials, or with those where processing generates lower waste volumes.

b) Applying manufacturing process that convert materials efficiently, providing higher product output yields, including modification of design of the production process, operating conditions, and process controls.

c) Instituting good housekeeping and operating practices, including inventory control to reduce the amount of waste resulting from materials that are out-of-date, off specification, contaminated, damaged, or excess to building/equipment/plant needs.

d) Instituting procurement measures that recognize opportunities to return usable materials such as containers and which prevents the over ordering of materials.

e) Minimizing hazardous waste generation by implementing stringent waste segregation to prevent the commingling of non-hazardous and hazardous waste to be managed

22.2.2 *Recycling and Reuse*

In addition to the implementation of waste prevention strategies, the total amount of waste may be significantly reduced through the implementation of recycling plans, which should consider the following elements:

a) Evaluation of waste production processes and identification of potentially recyclable materials.

b) Identification and recycling of products that can be reintroduced into the manufacturing process or industrial activity at the site.

c) Investigation of external markets for recycling by other industrial processing operations located in the neighbourhood or region of the facility (for example, waste exchange).

d) Establishing recycling objectives and formal tracking of waste generation and recycling rates.

e) Providing training and incentives to employees in order to meet above objectives.

22.2.3 *Treatment and Disposal*

If waste materials are still generated after the implementation of feasible waste prevention, reduction, reuse, recovery and recycling measures, waste materials should be treated and disposed of and all measures should be taken to avoid potential impacts to human health and the environment. Selected management approaches should be consistent with the characteristics of the waste and local regulations, and may include one or more of the following:

a) On-site or off-site biological, chemical, or physical treatment of the waste material to render it non-hazardous prior to final disposal.

b) Treatment or disposal at permitted facilities specially designed to receive the waste. Examples may include: composting operations for organic non-hazardous wastes; properly designed, permitted and operated landfills or incinerators designed for the respective type of waste; or other methods known to be effective in the safe, final disposal of waste materials such as bioremediation.

22.2.4 Every solid waste generated [except industrial waste, hazardous waste, hazardous chemicals, bio medical wastes, e-waste, lead acid batteries and radio-active waste, that are covered under separate rules framed under the *Environment (Protection) Act*, 1986] shall be managed in accordance with the *Solid Waste Management Rules,* 2016.

22.3 Construction and Demolition Waste Management

Every waste resulting from construction, re-modeling, repair and demolition of any civil structure of individual or organization shall be managed in accordance with the *Construction and Demolition Waste Management Rules*, 2016.

22.4 Hazardous Waste Management

Hazardous wastes should always be segregated from non-hazardous wastes. If generation of hazardous waste

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cannot be prevented through the implementation of the general waste management practices (*see* **22.2**), its management should focus on the prevention of harm to health, safety, and the environment, according to the following additional principles:

a) Understanding potential impacts and risks associated with the management of any generated hazardous waste during its complete life cycle.

b) Ensuring that contractors handling, treating, and disposing of hazardous waste are competent enterprises, and following good industry practice for the waste being handled.

The management of hazardous and other wastes as specified in the schedules to *Hazardous and Other Wastes (Management and Transboundary Movement) Rules*, 2016 shall be done in accordance with the said rules.

22.5 Plastic Waste Management

The plastic waste generated in the premises shall be managed in accordance with the *Plastic Waste Management Rules*, 2016.

22.6 Bio-medical Waste and E-Waste Management

22.6.1 All bio-medical wastes generated in the premises shall be disposed strictly in accordance with the *Bio-Medical Waste Management Rules*, 2016 as may be applicable. Utmost care should be taken to ensure that this does not get mixed with other types of waste. Disposal should be segregated and stored in closed bins, carrying appropriate markings, which should be colour coded as prescribed in the statuary rules only in designated and suitably designed and protected areas till they are removed through and to authorized waste treatment facilities

22.6.2 E-waste generated shall also be disposed of as per *E-Waste (Management) Rules*, 2016 and to authorized e-waste recycling and disposing facilities.

22.6.3 Proper documentation shall be maintained in all such cases in formats as may be prescribed by the concerned authorities.

23 BUILDING MANAGEMENT SYSTEMS (BMS)

23.1 Overview

All buildings have some form of mechanical and electrical services in order to provide the facilities necessary for maintaining a comfortable working environment. These services have to be controlled by some means to ensure, availability of facilities as designed and comfort conditions irrespective of the number of occupants or individual preferences. Basic controls take the form of manual switching, time clocks or temperature switches that provide the on and off signals for enabling pumps, fans or valves, etc. The purpose of a building management system (BMS) is to automate and take control of these operations in the most efficient way possible for the occupiers/business, within the constraints of the installed plants/ installations.

The BMS is a 'stand alone' computer system that can calculate the pre-set requirements of the building and control the connected plant to meet those needs. Its inputs, such as temperature sensors and outputs, such as on/off signals are connected into outstations around the building. Programmes within these outstations use this information to decide the necessary level of applied control. The outstations are linked together and information can be passed from one to another. In addition, a modem can also be connected to the system to allow remote access. The level of control *via* the BMS is dependent upon the information received from its sensors and the way in which its programmes tell it to respond to that information. In addition to offering a precise degree of control to its environment, it can also be made to raise alarm on conditions that can't meet specification or warn of individual items of plant failure.

Occupancy times for different areas are programmed into the BMS such that the facilities are brought on and off to meet the occupier requirements. BMS determines the plant start time based on the outside air temperature, the space temperature and the building structure.

BMS can control the following key operations:

a) HVAC systems, which include air handling units, fan coil units, chillers, pumps and boilers;
b) Lifts (it is normally used to gather information about location/movement of lifts rather than actually controlling their operation);
c) All equipment having variable frequency drives (VFD);
d) Lighting systems;
e) Water supply systems including boilers, water treatment plants, water supply pumps, etc;
f) Sewage treatment plant (STP), effluent treatment plants (ETP);
g) Medical and other gas supply system; and
h) Access control system;
j) Ventilation system;
k) Fire alarm and suppression, fire fighting systems (Sprinklers, hydrants); and
m) CCTV cameras connected to digital video recorders (DVR) or network video recorders (NVR).

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Where a BMS or equivalent arrangement exists for monitoring and controlling mechanical, electrical or other engineering installations, an organization should ensure that the requirements for the maintenance of the BMS are fully incorporated into maintenance programmes. In the event of actuator failures or other faults, corrective actions should be initiated with minimal delay.

23.2 Key Components of BMS

BMS is an intelligent mix of hardware devices which works as data collecting/ warning agents and software which collates data and graphically presents same for better and simple understanding. The following are the key components of BMS:

a) Centralized workstation computer with user friendly software used for everyday building operations;
b) Direct digital controllers (DDC) – micro-processor based pre-configured/freely programmable controllers; and
c) Field devices – temperature sensors, humidity sensors, pressure sensors, valves, actuators, movement sensors, etc.

23.3 Responsibilities Relating to BMS

23.3.1 *Responsibility of Facility Manager*

a) To operate and manage BMS systems, identify faults, and provide the required reports for the tenant, building owner and building maintenance team.
b) Adequate monitoring, zoning, scheduling so as to enable the building to operate at maximum possible energy efficiency consistent with tenant lease provisions.

23.3.2 *Occupants Responsibility*

a) Providing accurate and detailed information on equipment loads.
b) Providing a detailed schedule on occupation and equipment loads of tenanted areas.
c) Early advice on changes to usage of tenanted areas.
d) Vetting staff requests for system adjustments to ensure energy impacts are considered.

23.3.3 *Maintenance Team Responsibility*

a) Daily monitoring of the BMS for faults and exceptions relating plant and equipment.
b) Maintenance of the BMS.
c) Management of temporary or permanent adjustments to control parameters in accord with lease provisions.
d) Ensure timely BMS software and hardware upgrades.
e) Manage upgrading of BMS as required by owner and tenants to support changes in space utilization, equipment upgrades, or energy intensity improvement projects.
f) Providing timely and accurate advice and reports.

23.4 Good Practices

23.4.1 *Mechanical Services*

The software should preferably be optimized for start and stop schedules. Rather than starting to pre-condition a building at a set time, each zone may start just in time to reach minimum set condition as occupants start to arrive. For example, a hot summer's night may need an extra hour of air flow compared to a milder night. This typically means that energy requirements for heating and cooling greater will be extended, on average, by several hours per day. For example, many buildings provide full heating and cooling up to 5:30 or 6:00 pm. In well-built and insulated buildings, chillers and boilers can turn off at 4:00 pm or earlier, and still ambient conditions can remain within agreed temperature parameters for 2 h or more utilizing the heating or cooling energy within the water loops.

BMS should have the following:

a) Provision for automated seasonal temperature adjustment enabling lowering set point temperature at low temperatures and gradually raising through the seasons, giving savings.
b) Remote alarming system.
c) Secure remote access as agreed for fault response, diagnosis, and tenant emergency need.
d) Scheduling calendar so as to be able to check and adjust for daylight saving including for requirements specific to various events, which can be adjusted without programming skills. For example, shutting down unoccupied zones or temporarily varying working hours.
e) Occupancy sensors; many areas have minimal occupancy at any time or highly variable loads such as conference rooms. In such cases, it may be appropriate to provide minimal conditioned air during normal hours, and ramp up only when space is fully occupied (Ramp up can sometimes be most effectively provided by standalone units to avoid over sizing the central plant to respond to low frequency situation.).

Following safeguards should be followed:

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a) Ensure sensors are correctly located. Sensors should be at the correct height, not above heat generating equipment, or hidden behind office fit-out, within supply air flow, or where external events can affect. For example, a thermostat mounted on an external wall shall be insulated from the wall cavity, or it will read cold in winter, and hot in summer. A thermostat used as a coat rack will have a delay in registering actual room temperature. A thermostat above a photo copier may consistently read four degrees higher than actual temperature when copier is at full power to correct temperature when it is in sleep mode.

b) Frequent calibration of sensors may be required. While many modern sensors do not suffer accuracy drift over time, a base line error of up to 1° can occur. Calibration will ensure that BMS utilize a true reading at all times.

23.4.2 *Electrical Services*

Software may be programmed to ensure sensors are activated to provide required illumination controls in following ways to effect efficiency and economy:

a) Lighting is controlled in zones generally of 100 m^2 area (unless special circumstances exist) by occupancy sensors. Fire exit stairs on occupancy sensors with automatic override to full lighting during fire alarm events.
b) Car park daylight adaptation lighting to be dual dimmer controlled by photoelectric (PE) cell and occupancy sensors.
c) Car park lighting to have two stage occupancy sensor control covering normal and out of hours lighting levels.
d) Perimeter office zones to have PE cells operating dimmer controls in addition to occupancy sensors.
e) Entry lobbies to revert to occupancy sensor control outside of operating hours.
f) General security lighting to minimum level required by security cameras. With modern cameras this is very low and less than what human eye requires.
g) Responsive security lighting to be event activated with time controlled manual over ride for emergency situations.
h) Metering of equipment and zones to be integrated through BMS to required reports.
j) Lift operation to be optimized *via* intelligent lift controllers, with activity and consumption reports to BMS.

23.4.3 *Hydraulics*

a) Meters to report to BMS (number shall enable excess consumption to system or zone).
b) Temperature optimization control of boilers, by control strategy.
c) Flow meters to alarm on abnormal consumption.
d) Boiler temperature reset optimization, to match actual and predicted loads.
e) Automated shut down valves in critical areas to avoid waste and damage from major failure, with BMS over ride function.

23.4.4 *BMS Configuration Active Point Control*

a) Shall default to safe condition on failure and trigger alarm.
b) Points to be actively interrogated on status to ensure they are operating and reporting.
c) Point trending and graphing to be flexible and comprehensive.
d) Demand limiting algorithm in place and load shedding if indicated.
e) Alarms have priorities set to at least three levels, are placed in permanent file, with name of operator who responded to alarm. Archive of this information should be permitted only to a person with highest authority level, and only when record is over one year old.

23.4.5 *Graphics and User Interface*

a) To clearly present data required to check status of system or sub-system without clutter and in logical visual presentation.
b) Navigation from a graphic page either up to a system overview or down to sub-unit or point history to be intuitive, point and click.
c) Graphics available of all systems and sub-systems.
d) Temporary trend graphics able to be set up by all users, and not require high level skills or access.
e) A full set of reports is configured to enable effective management of system and building.
f) Four level or equivalent user authorization level control: programmer, system controller, maintenance staff, tenants.
g) Simple click and point to data, graphics, and agreed control functions of each user.

23.5 Documents Required

Most of the data and reports are stored hence no documents are required except for the works which requires manual interface, for example, maintaining

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contacts with appropriate maintenance personnel, logs of maintenance, roaster log, etc.

24 INFORMATION MANAGEMENT

24.1 General

Records and documents relating to the maintenance of the facility should be organized, kept up-to-date and stored in a secure environment.

The following general information should be recorded:

a) *Classification* — The facility and its sub-divisions (that is, rooms and other spaces) should be assigned codes according to type or use to support the management of information and data;
b) Obligations under conditions of lease or occupancy (for example, frequency of repainting);
c) Statutory and insurance inspections;
d) Estate terrier (records of property holdings with legal status);
e) Ownership of and/or maintenance obligations of parties, separating and boundary walls;
f) Rights of way, easements and way-leaves (particularly with respect to buried utilities); and
g) Requirements and restrictions laid down by planning, building regulation control and fire authorities including, in the case of the latter, fire risk assessments.

Elements/sub-elements of the facility should be labelled or marked, as far as is practicable, so that the materials, components, systems, plant, equipment and parts can be easily identified. Where information is limited or lacking, records should be compiled during maintenance. Alternative (or additional) surveys or investigations should be initiated to accelerate the gathering of information for record purposes; photographic records can be of assistance in this respect.

All personnel involved in the maintenance of the asset/facility should be made aware of the existence of records containing information about it. Hazardous areas should be explicitly marked on the records as well as marked in their physical location/site and should be made known to personnel, together with any system of work adopted for use in these areas.

24.2 Documentation

Good records can save owners and users/occupiers from much unnecessary expense and reduce potential hazards in exploration work, when faults arise. Records are of value only if they are kept up to date and arrangements for this should be included in any provision that may be made for records.

Records may be broadly classified as following:

a) 'As built' information, which should have been prepared before the handover of the facility, such as construction details, floor plans, perspectives and as-built drawings showing the location of engineering installations and structural details; and
b) 'As subsequently altered', which need to be kept during the operational life of the facility, such as details of defects, maintenance, alterations and redecoration work.

A record should be kept of all reported defects and the measures taken to rectify them. Details of maintenance should also be recorded and cross-referenced to the reported defect.

Periodic reviews of records should be made and where there are recurrences of the same defect, the causes should be investigated.

24.2.1 *Facility Handbook*

A facility handbook should be prepared as a compilation of records of the asset/facility, which can be stored and retrieved electronically, as well as being reproduced on paper wherever necessary. The form of the handbook should be such that content can be easily updated and future versions of it to be controlled. The handbook should include the records relating to the maintenance of the facility and the documents to support the wider needs of the organization in regard to its facilities management.

Following should be typical contents of the facility handbook:

a) A brief history of property, names and addresses of consultants and contractors.
b) Short specifications, constructional processes, components, material finishes, hidden features, special features, etc.
c) 'As built' plans and as subsequently altered with sections, elevations and other detailed drawings.
d) Foundation and structural plans/sections such as concrete reinforcement drawings.
e) Detailed specification of all materials incorporated, for example, concrete mix, species and grades of timber, etc. Potentially hazardous materials and types or methods of construction that under some circumstances may become hazardous may be identified.
f) Information on house keeping and routine maintenance with details of internal and

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external surfaces and decorations, schedule of cleaning, inspection and maintenance.

g) Information on accessibility features of the building that makes it friendly to users with disabilities and elders.

h) Means of operating mechanical, electrical and plumbing installations.

j) Description of renovations, extensions, adaptations and repair to each elements.

k) All plant, machinery and propriety articles including manufacturers trade literature and instructions for installation, use and maintenance.

m) Methods of work used in construction such as assembly of prefabricated units.

n) All information related to fire such as,
   1) location and service arrangements of all fire alarm and call points;
   2) location and service arrangements of all extinguishers, hose reels and other fire fighting installations;
   3) location of all fire compartment walls, doors, floors and screens;
   4) location of all areas of exceptional fire hazard;
   5) fire escape routes;
   6) details of application of any fire protection treatment; and
   7) location details and description of any installation for smoke control or protection of escape routes.

p) There should be a wall chart showing at a glance the various operations which have to be undertaken. Line drawings of buildings are always useful.

q) Records of security measures should be known to authorized personnel only.

r) Where no records exist, information should be slowly built up as it becomes available during the course of maintenance work.

s) Use of computers for storing information may be preferred.

24.2.1.1 *Drawings*

The records of the facility should include as-built and as subsequently altered drawings [*see* **24.2.1** (c)] and contain, as a minimum, the following:

a) A neighborhood plan, showing the position of the facility and the site upon which it is located in relation to its surroundings;

b) The site plan, showing the facility and other structures forming the facility and external engineering installations, for example drainage runs and incoming public utilities;

c) General arrangement plans of each floor and the roof to a scale not normally greater than 1:50;

d) Elevations and sections;

e) Foundation plans and details, together with available soil investigation reports;

f) Structural plans and sections, including information relating to design parameters, such as permissible superimposed loadings on floors;

g) Structural details, such as structural steel connections and concrete reinforcement drawings and bending schedules; these are particularly important when prestressed or post-stressed forms of structure have been used;

h) Details of the construction of external wall elements and roofs, including insulation materials and vapour barriers;

j) Materials that may be injurious to health and safety;

k) Location of public health (that is, waste) systems;

m) Location of essential intake and shut-off of public utilities (water, electricity, gas and telecommunications).

n) All drawings, including those used in design and construction, should be verified against the as-built facility. Where a discrepancy is found, full details should be recorded and, wherever practicable, the affected drawing(s) should be labelled as subsequently altered.

24.2.1.2 *Specifications and schedules*

The records of the facility should include detailed specifications of,

a) all materials incorporated, for example name of facing brick, mix of concrete, species and grade of timber;

b) materials with properties that can prove injurious to health and safety;

c) all plant and machinery, including manufacturers' trade literature, manuals and instructions for installation, operation and maintenance; and

d) methods of work used during construction, which are unusual or a typical, such as assembly of purpose-made manufactured units.

All specifications and schedules, including those used during construction work, should be verified against

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the as-built facility. Where a discrepancy is found, full details should be recorded and, wherever practicable, the affected specification(s) and/or schedule(s) should be labelled as subsequently altered.

24.2.2 *Asset Register*

Asset register is an important document and shall be maintained for each asset and kept updated. Many organizations maintain this as building register for keeping records of their assets and any modifications/ alterations done during life time of the asset/facility. An organization should include other information and data as may be necessary in the form of a register of its assets/facility, for example:

1) Identification number or unique reference for the asset;
2) Location of asset;
3) Initial cost;
4) Completion cost (component /unit wise if so required);
5) Make and/or model;
6) Manufacturer for machineries and equipments;
7) Vendor, if different to manufacturer;
8) Date of manufacture or year of construction for buildings;
9) Date of acquisition, installation or completion of construction;
10) Details of asset such as area statements, type of structure;
11) Whether or not the asset is subject to a permit-to-work requirement;
12) Predicted lifetime;
13) Specifications;
14) Replacement cycle;
15) Cost breakdown;
16) Servicing requirements, including type and frequency of service;
17) Other maintenance required;
18) Maintenance costs;
19) Accumulated depreciation;
20) Written-down value;
21) Source of components and spare parts, where applicable;
22) Energy consumption and, where applicable, energy efficiency rating; and
23) Identification of hazardous or other risks to people or property.

24.2.2.1 *Engineering installations*

Information describing the facility's engineering installations should be recorded. Details should include points of entry, or termination, of public utilities.

An organization should stipulate the maintenance requirements for its mechanical and electrical installations and fire protection systems; the tasks to be carried out and their frequency should be included. The following attributes of major components should be taken into account:

a) Current condition;
b) Current utilization or output;
c) Maintenance tasks to be performed;
d) Frequency of maintenance; and
e) Estimated cost of maintenance.

24.2.2.1.1 *Warranties, repairs and spare parts*

Details of warranties relating to plant, equipment, components and systems should be recorded and cross-referenced to those operational and maintenance requirements that affect them. Details of repairs should be recorded against the respective item. A list of spare parts should be kept up-to-date. Details should include the following as a minimum:

a) Description of part;
b) Identification number or unique reference for the part;
c) Original manufacturer of part;
d) Contact details of current manufacturer and/ or distributor;
e) Predicted lifetime of part;
f) Operational parameters affecting lifetime of part;
g) Minimum number of parts to be held in stock (within or near to the facility);
h) Where permissible, details of any alternative part and its source;
j) Availability and minimum delivery period;
k) Warranty period;
m) Estimated cost of part;
n) Transportation and logistical considerations;
p) Details of other parts potentially affected by failure and/or replacement;
q) Specialist equipment or tools required;
r) Specific competence required; and
s) Details of special conditions or arrangements when installing.

The details given in (a) to (s) are, in effect, an inventory that should be kept up-to-date if the organization is to minimise disruption and/or loss of business continuity in the event of a breakdown or failure. An organization should determine its policy on the holding of spare parts.

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24.2.2.1.2 *Documentation of mechanical records*

Documentation should record the following as installed:

a) Location, including level if buried, of all public service connections (for example, fuel gas and cold water supplies) together with the points of origin and termination, size and materials of pipes, line pressure and other relevant information;

b) Layout, location and extent of all piped services showing pipe sizes, together with all valves for regulation, isolation and other purposes as well as the results of all balancing, testing and commissioning data;

c) Location, identity, size and details of all apparatus and all control equipment served by, or associated with, each of the various services together with copies of any test certificates for such apparatus, where appropriate. The information with respect to size and details may be presented in schedule form;

d) Layout, location and extent of all air ducts showing dampers and other equipment, acoustic silencers, grilles, diffusers or other terminal components. Each duct and each terminal component should be marked with its size, the air quantity flowing and other balancing data; and

e) Location and identity of each room or space housing plant, machinery or apparatus.

24.2.2.1.3 *Drawings for mechanical installations*

Drawings should record the following as installed:

a) Detailed general arrangements of boiler houses, machinery spaces, air handling plant, tank rooms and other plant or apparatus, including the location, identity, size and rating each apparatus, The information with respect to the size and rating can be presented in scheduled form;

b) Isometric or diagrammatic views of boiler houses, plant rooms, tank rooms and similar machinery, including valve identification charts. It is useful to frame and mount a copy of such drawings on the wall of the appropriate room; and

c) Comprehensive diagrams that show power wiring and control wiring and/or pneumatic or other control piping including size, type or conductor or piping used and identifying the terminal points of each.

24.2.2.1.4 *Electrical installations*

Records should be kept of the following as installed:

a) Main and sub-main cables, showing origin, route, termination, size and type of each cable. Cables providing supplies to specialist equipment, for example data centre equipment, should be identified separately;

b) Lighting conduits and final sub-circuit cables, showing origin, route, termination and size of each, together with the number and size of cables within each conduit. The drawings should indicate, for each conduit or cable, whether it is run on the surface or concealed, for example in a wall chase, in a floor screed, cast *in-situ* or above a false ceiling. These drawings should also indicate the locations of lighting fittings, distribution boards, switches, draw-in-boxes and point boxes, and should indicate circuitry;

c) Details of secondary power sources for inclusion in a safe systems of work regime;

d) Location and purpose of each emergency lighting fitting, including an indication of the circuit to which it is connected;

e) Single and three-phase power conduits and final sub-circuit cables showing locations of power distribution boards, motors, isolators, starters, remote control units, socket outlets and other associated equipment;

f) Other miscellaneous equipment, conduits and cables;

g) Lightning conductor air terminals, conductors, earth electrodes and test clamps;

h) Location of earth tapes, earth electrodes and test points; and

j) Cables providing earth circuits for specialist equipment should be identified separately.

Records should also include, where applicable,

1) distribution diagrams or schedules to show size, type and length (to within 1 m) of each main and sub-main cable, together with the measured earth continuity resistance of each;

2) schedule of lighting fittings installed stating location, manufacturer and type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed;

3) schedule of escape and emergency lighting fittings installed stating location, manufacturer, type or catalogue number together with the type or manufacturer's reference, voltage and wattage of the lamp installed. For battery systems, the position of the battery, its ampere-hour rating and battery system rated endurance, in hours, should be stated;

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4) records of smoke detectors, sprinklers and fire precautions generally, as well as security precautions;
5) incoming supply details including the type of system, voltage, phases, frequency, rated current and short circuit level, with the details of the supply protection and time of operation as appropriate;
6) main switchgear details which, for purpose-made equipment, should include a set of manufacturers' drawings and the site layout;
7) transformer, capacitor and power plant details. for example in the case of transformers, the volt-ampere rating, voltages and type of cooling; and
8) completion certificate.

All records and drawings, including those used during construction work, should be verified against the as-built facility. Where a discrepancy is found, full details should be recorded and, wherever practicable, the affected record(s) and/or drawing(s) should be labelled as subsequently altered.

24.2.3 *Operating and Maintenance Manuals*

24.2.3.1 The engineering services within buildings frequently are dynamic, involving complex systems of integrated plant items. Operation of such plant can require detailed knowledge and direction. Maintenance can also require extensive information to be available. It is, therefore, important to have suitable operating and maintenance manuals to provide the necessary guidance. These should be included as part of the contractual requirements for new installations and should ideally be prepared as reference documents for existing installations where no such information exists.

24.2.3.2 Information and data on the operation and maintenance of the facility, including measures to conserve fuel and power, should be incorporated into the O&M manual. The organization should ensure that provisions made in the facility handbook are satisfied.

Preparation of an O&M manual tailored to suit each facility can offer significant advantages in terms of providing a clear statement of intentions and required actions. Depending upon whether one is responsible for the maintenance of a number of facilities or a single facility, the maintenance manual will be designed and prepared.

An organization's procedures for undertaking maintenance should be formalized in a maintenance manual or manuals. The manual may form part of wider documentation covering operational plans and arrangements. In the event of a change of organization or maintenance advisor, an up-to-date manual and facility handbook should ensure continuity of maintenance. Copies of maintenance manuals should be held by the organization and any maintenance advisor, if appointed.

24.2.3.3 *Structure of operation and maintenance manual*

The maintenance manual should be prepared in two parts: the first part should be addressed to the organization; and the second part should be addressed to those responsible for inspecting the facility and reporting to and advising the organization.

The first part of the manual should,

a) Recommend intervals between,
   1) routine, general and detailed inspections,
   2) inspection and maintenance of each engineering installation and items of special equipment;
   3) maintenance of items which, as recommended by their manufacturers, require regular attention to preserve satisfactory performance, for example the lubrication and adjustment of moving parts in component assemblies and systems; and
   4) other periodic work as experience in use shows to be necessary, for example the clearing of gutters, downpipes or surface water gullies.
b) Draw attention to the need to ensure that a facility's provisions for means of escape in the event of fire, that is, fire resisting self-closing doors and exit hatches, are in satisfactory working order at all times, including those periods during which any maintenance is being undertaken.
c) Draw attention to critical environments, including special arrangements for gaining access for the purpose of inspections or when undertaking maintenance;
d) Specify proprietary maintenance materials, for example floor sealers and polishes likely to offer acceptable service and slip resistance.
e) Set out the names, addresses and other contact details of firms responsible for the following:
   1) inspecting, reporting and advising on the condition of the building fabric;
   2) emergency repairs to the building fabric; and
   3) servicing and emergency repairs for each engineering installation and items of special equipment.

The second part of the manual should,

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a) Consist mainly of selected, concise information, abstracted from the facility handbook, and likely to be needed during inspections; this information should be ordered in the sequence in which examination is likely to be carried out.

b) Schedule those materials and components that experience shows to be prone to failure and/ or to require special attention.

24.2.3.4 *Updating of O&M manual*

The maintenance manual should be reviewed annually and updated where necessary, to reflect changes in legislation as well as current circumstances and arrangements. When changes occur to facilities, or where new information becomes available, all copies of the maintenance manual should be revised accordingly, irrespective of whether it is self-standing or forms an integral part of the facility handbook.

24.3 Storage and Security of Records

24.3.1 *General*

An organization should keep records in a safe and secure location and arrange them in such a way as to enable their rapid retrieval. Records of personnel permitted to access the records and any requirements or conditions attaching thereto should be defined.

24.3.2 *Storage*

The place for storage of records should take into account the form of the records, the media used and the conditions necessary to keep them from damage of any kind; they should also be readily accessible. Backup or duplicate records (electronic and paper-based) should be kept in a secure place in a location other than the facility to which they relate. Both sets should be kept up-to-date.

24.3.3 *Security*

Measures taken to ensure security should be recorded and a copy should be held in a secure location away from the facility to which they relate. The following records should be readily accessible to authorized personnel when required, which may be at short notice and outside normal working hours:

a) Names, home addresses and telephone numbers of key holders;
b) Details of master key system; and
c) Details of intruder alarms and other security systems.

24.4 Computerization of Information Management

An organization should review its requirements for data systems, basic information and communication technology (ICT) facilities and extended services necessary to support its maintenance management. The use of a CAFM or a CMMS as means for managing facility related maintenance information should be evaluated. The following features are likely to provide a suitable basis:

1) Budgetary and other financial controls;
2) Cost accounting;
3) Asset register;
4) Condition-based monitoring of assets;
5) Early detection of problems and rapid fault reporting;
6) Operational plans, including frequency of functions or activities performed;
7) Risk and hazard assessment;
8) Permits-to-work;
9) Personal protective equipment issued and returned;
10) Planned preventive maintenance;
11) Reactive maintenance;
12) Change management;
13) Job orders and other requisitions for goods and services;
14) Job logging, prioritization and tracking, including details of backlogs;
15) Energy use and carbon dioxide (CO_2) equivalent emitted per annum;
16) Resource consumption and productivity measures;
17) Analysis of work undertaken to identify trends;
18) Space planning and space utilization;
19) Workstation location and furniture management;
20) Performance indicators for the delivery of services;
21) End-user experiences of services delivered;
22) Audit trail of system transactions; and
23) Exception reporting for management purposes.

25 CHECK LISTS

In order that the activities of inspection/maintenance of assets may be carried out systematically in a comprehensive manner, certain check lists/proforma may be made available. While these may vary from asset to asset and organization to organization, a few examples of the activities to be covered are given below:

a) *Register of buildings* — Initial cost, cost of additions and alterations year-wise. This is required to verify periodically that all assets

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paid for by the organization are kept duly preserved and maintained.

b) Amount admissible per annum for carrying out maintenance operations related to civil, E&M equipment and establishments, horticulture maintenance works during a year, including,
   1) plinth area rates for maintenance works for base year; and
   2) maintenance cost index, repair cost index.

c) Maintenance norms, frequency of application of finishing items.

d) Guidelines for annual maintenance estimates for horticulture works.

e) Classification of horticulture maintenance works.

f) Inspection lists of general buildings:
   1) Civil,
   2) Electrical, and
   3) Horticulture.

g) Additional inspection lists for critical buildings:
   1) Substation equipment, generating sets, service connection;
   2) Air conditioning plants;
   3) Electrical installations, lifts, water supply pumps, sewage pumps, filtration plants;
   4) Fire alarm, fire fighting;
   5) Public address system; and
   6) CCTV, cable TV, laundry, kitchen, incinerator, etc.

ANNEX A

(*Clause* 9.5.3)

COMMON CAUSES FOR MAINTENANCE PROBLEMS

A-1 The major causes for maintenance problems in different elements of a building are discussed in **A-1.1** to **A-1.5**.

A-1.1 Floors

a) Poor quality of construction which includes quality of construction material and workmanship.

b) Improper slopes, mainly in kitchen, bathrooms/toilets, etc.

c) Lack of rounding at junctions of walls with floors.

d) Lack of damp-proof course treatment in walls and particularly in sunken floors.

e) Poor design of building.

f) Improper waterproofing.

A-1.2 Roofs

a) Inadequate roof slopes.

b) Inferior quality of construction.

c) Cracks on roof surfaces.

d) Inadequate provision of rain water spouts.

e) Blockages in gratings/rain water pipes.

f) Worn out felts/membranes.

g) Bubbling up of tar felt and separation of joints.

h) Improper water proofing or wrong selection of water proofing technique.

j) Leakage from the openings provided on the roof.

k) Improper treatment of expansion/construction joints.

m) Non providing of *Gola* at junction of parapet and wall and roof.

n) Improper execution of *Khurra*.

p) Lack of pre-monsoon inspections

A-1.3 Plumbing

a) Inadequate slopes in soil/waste pipes.

b) Improper joints in pipes.

c) Joints in walls and floors.

d) Improper junctions of stacks.

e) Inadequate cleaning eyes at junctions.

f) Throwing of solid wastes in WC's.

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g) Lack of periodical checking and cleaning.
j) Lack of motivation/education to users for proper use.
k) Overflow from service tanks.
m) Inferior quality of fittings and fixtures.
n) Inadequate design.

A-1.4 Drainage

a) Improper surface dressing around buildings and improper upkeep of surroundings.
b) Growth of wild grass and vegetation.
c) Inadequate drainage system around the building.
d) Inadequate slope of the drains or drainage pipes.
e) Inadequate number of inspection chambers.
f) Theft of manhole covers, etc.
g) Throwing of solid waste in the open surface drains.

A-1.5 Electrical

a) Loose connections.
b) Improper earthing and earth connections.
c) Damages to wires, cables and other installations.
d) Under rated cables/wires and other installations.

ANNEX B

(*Clause* 9.10.3.6)

FORMAT FOR INSPECTION REPORT

Building/Block: ……

(A) INSPECTION OF BUILDINGS (CIVIL)										
(a) House No. and Type:					(b) Location:					
(c) Date of Last Inspection:					(d) Date of Present Inspection:					
Sl No.	Item No.	Needs Repair			Needs Replacement		Priority			
		Action	Quantity	Cost	Quantity	Cost	Immediate	Annual	Routine Repairs	
1.	**Walls**									
1.1	Cracks									
1.2	Repair to plaster									
1.3	Repair to brick work									
1.4	Dampness									
2.	**Floors**									
2.1	Cracks									
2.2	Settlement									
2.3	Slopes									
2.4	Skirting cracks									
2.5	Dados cracks									
3.	**Doors, Windows, Ventilators and Cupboards**									
3.1	Glass panes broken									
3.2	Panels in shutters broken									
3.3	Panels fit improperly									
3.4	Improper/missing fittings									
	3.4.1 Hinges									

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	3.4.2	Handles								
	3.4.3	Tower bolts								
	3.4.4	Aldrops								
	3.4.5	Floor door stopper								
	3.4.6	Knobs								
	3.4.7	Cleats								
	3.4.8	Hooks and eyes								
	3.4.9	Curtain rods								
	3.4.10	Stays								
	3.4.11	Pelmets								
4.	**Roofs**									
4.1	Leakages/damp patches									
4.2	Water proofing treatment									
4.3	*Gola*									
4.4	*Khurra*									
4.5	Brick drip course									
4.6	Rain water pipe									
4.7	Regrading									
4.8	Top layer of tiles									
4.9	Parapet, coping									
5.	**Water Supply and Sanitary Fittings**									
5.1	Leakages in pipe joints									
5.2	Functioning of washers									
5.3	Functioning of traps in fittings									
5.4	Functioning of floor traps									
5.5	Functioning of overhead/low level cistern									
5.6	Air locking									

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5.7	Leakages in pipe joints									
5.8	Condition of overhead tank									
5.9	Cleaning of overhead tank									
5.10	Fittings									
	5.10.1	Washbasin								
	5.10.2	Soap container								
	5.10.3	Mirror								
	5.10.4	Glass shelf								
	5.10.5	Towel rail								
	5.10.6	Hangers								
	5.10.7	Sinks								
	5.10.8	Taps								
	5.10.9	Pillar cocks								
	5.10.10	Showers								
	5.10.11	Cisterns								
	5.10.12	Ball valves								
	5.10.13	Seat cover								
	5.10.14	Steps								
6.	**External Services**									
6.1	Manhole covers									
6.2	Covers to gully traps									
6.3	Cleaning of manholes									
6.4	Plinth protection									
6.5	Cleaning of storm water drain									
6.6	Approach roads									
6.7	Service lanes									
7.	**Finishing**									
7.1	White washing/colour washing/distemper									
	(a)	When was it done last?								

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	(b)	When is it due?								
	(c)	Existing condition.								
7.2	Painting									
	(a)	When was it done last?								
	(b)	Existing condition								
	(c)	When is it due?								
8.	**Common Areas**									
8.1	Railing to staircase									
8.2	Staircase steps									
8.3	Staircase nosing									
8.4	Shafts									

(B) INSPECTION OF BUILDINGS (ELECTRICAL)

(a) House No. and Type :	(b) Location :
(c) Date of Last Inspection :	(d) Date of Present Inspection :

Sl No.	Item No.	Needs Repair			Needs Replacement		Priority		
		Action	Quantity	Cost	Quantity	Cost	Immediate	Annual	Routine Repairs
1.	**Switch Boards**								
1.1	Regulator								
1.2	Switches								
1.3	Fixing of tiles								
2.	**Fans**								
2.1	Canopy fixing								
2.2	Speed and noise								
3.	**Socket outlet points and connection**								
3.1	Tile								

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3.2	Switch								
3.3	Outlet connection, if any								
4.	**Fittings**								
4.1	Reflector								
4.2	Louvres/Perspex cover								
4.3	Suspension rod								
5.	**Exhaust Fans**								
5.1	Speed and noise								
5.2	Louvres								
5.3	Connecting wires including ceiling rose								
6.	**Call bells**								
6.1	Bell push								
6.2	Connecting wire								
6.3	Bell buzzer								
7.	**Sub distribution boards/ BDB/Main Board**								
7.1	Switch covers								
7.2	Fuse kit kats								
7.3	Earth connection								
7.4	Fuse rating								
7.5	Inter connection								
7.6	Boards								
(C) INSPECTION OF BUILDINGS/GARDENS									
1.	**Lawn:**								
1.1	Weeding								
1.2	Patch repair								

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1.3	Renovation																												
1.4	Regrassing																												
2.	**Hedge:**																												
2.1	Gap filling																												
2.2	Replacement																												
3.	**Pruning and Training:**																												
3.1	Naturally required pruning																												
3.2	Pruning required for security purpose of building as well as occupant																												
4.	**Planting Beds:**																												
4.1	Needs replacement																												
4.2	Gap filling																												
5.	**U/F Water Supply:**																												
5.1	Matter to be reported to U/F water division after inspection																												
6.	**Rockeries:**																												
6.1	Gap filling of dead one																												
6.2	Replacement of damaged, weak																												
6.3	Replacement of stones																												
6.4	Thinning, trimming																												
6.5	Redesigning of paths, maintenance of paths																												
7.	**Kitchen Garden:**																												
7.1	Change in site																												
7.2	Plan for planting of vegetables																												

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8.	**Road Side Plantation:**										
8.1	Gap filling Nos.										
8.2	Trimming, pruning										
8.3	Tree guards not required and to be removed/repair/painting, etc										
8.4	Proposal for new plantation, digging of holes, etc										
8.5	Miscellaneous										
8.6	MOU-Detailed report (Performance and financial achievements)										

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ANNEX C

(*Clause* 9.11.1.1)

TYPICAL NORMS FOR EMPLOYMENT OF WORKMEN FOR DAY-TO-DAY MAINTENANCE OF BUILDINGS

C-1 Building maintenance is known to be most labour intensive of the construction industry.

C-2 CIVIL WORKS

Maintenance staff is required for day-to-day maintenance of buildings. The work of carrying out annual repairs to buildings, like white/colour washing, distempering, emulsion painting, enamel paint/polish, etc, works of additions and alternations or minor works not requiring immediate execution are normally not covered in their duties and may be got done through contractors. However, spare capacity, if any, should be utilized in carrying out petty items of works.

C-2.1 Norms for Employment of Workmen

The general norms for employment of workmen for civil works in building is given in Table 1.

C-3 ELECTRICAL ENGINEERING WORKS

C-3.1 Day-to-Day Maintenance

For electrical engineering works, maintenance staff is generally employed on routine maintenance works of internal wiring. Maintenance and repair work of specialized and complicated nature are not covered. The yardsticks given in Table 1 indicate the workmen normally required for day-to-day maintenance of electrical works.

C-3.2 For electrical installations, only the electrician/wireman/assistant wireman holding the valid permit/licence issued by the electrical inspectorate/state administration (of the respective state in which work is to be carried out) shall be deputed on work.

Table 1 General Norms for Employment of Workmen
(*Clauses* C-2.1 *and* C-3.1)

Sl No.	Categories	Number	Residential Buildings	Non-Residential Buildings	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Civil categories[1)]:		Plinth area, in m^2, for which admissible		
	a) Mason	1	25 000	30 000	For public buildings, such as airports, hospitals and hotels, norms will depend upon the facilities and specific requirements
	b) Carpenter	1	30 000	50 000	
	c) Plumber	1	30 000	36 000	
	d) Sewerman	1	30 000	60 000	
	e) Shramik/Beldar		One beldar for each carpenter and mason. Additional as per work requirement	Twice the number of workers in category of mason and carpenter	
ii)	Electrical categories:		No. of points for which one person is required		
	a) Wireman	1	3 300	3 300	For public buildings, such as airports, hospitals and hotels, norms will depend upon the facilities and specific requirements
	b) Khallasi[2)]	1	6 600	6 600	

NOTES
1 These norms are for government buildings where change of users is very often and permanent staff is required on account of sensitivity of users.
2 Actual requirements will depend upon type of structure, its usage and complexity/importance and level of maintenance required.
3 Requirement of other category of maintenance and operational staff will depend upon the type and usage of the facility.

[1)] Number of workmen indicated is where engagement is considered desirable on regular basis for entire year. Night duty staff not included in this norm.
[2)] One khallasi for two wiremen.

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ANNEX D

(*Clause* 11.10.3.3)

METHODS OF OPERATIONAL CHECKS FOR STP

D-1 CODE AND METHOD OF CHECKING

Sl No.	*Code*	*Method*	*How to Check*
(1)	(2)	(3)	(4)
i)	V	Visual	Check for presence (or absence) of the indicated feature
ii)	M	Measurement	Measure the indicated dimensions and compare against specified limits
iii)	T	Performance test	Conduct a test and compare the results against the specified limits
iv)	D	Documentation check	Check in drawings and calculations (typically for aspects that cannot be checked with visual inspection or other testing methods)

D-2 BAR SCREEN CHAMBER

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Working on platform	a) Observe the operator as he collects debris b) Posture is normal during working c) Does not have to balance on platform d) Can see the whole chamber easily e) Not facing any difficulty f) Can easily reach the grill and floor g) No struggle to remove parts stuck in grill	T	If the debris-collection is not comfortable, it will stop in a few days; leading to a clogged and dysfunctional bar screen chamber
ii)	Handling of debris	a) Observe the operator as he disposes off debris b) Operator can easily use the platform (or a basket) to let the debris drip dry c) Operator can easily place the collected debris into a garbage bag	T	Disposal of debris shall be easy and hygienic

D-3 EQUALIZATION TANK

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Actual level fluctuations	Check for overflows – tell-tale colouration on side walls/freeboard	M	To determine if equalization tank size is adequate to handle peak inflows

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Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
ii)	Aeration and mixing	a) Bubbles rise across the entire surface of the aeration tank (no dead zone in any area, especially edges and corners) b) There is no odour c) There is no localized violent bubbling/ boiling	V	This is the end-result of proper diffuser selection and placement; and also correct air pressure
iii)	Maintenance of diffusers	Select a few diffusers (typically the diffuser in the most remote corner) and execute a mock repair cycle and check for the following: a) Easy to isolate from the rest of the system b) Easy to retrieve the chosen element c) Easy to dismantle the element without disturbing the other plumbing d) Easy to clean the element e) Easy to lower it back at the exact spot	T	The STP should allow easy maintenance of diffusers without significant interruption of its process

D-4 RAW SEWAGE LIFT PUMPS TANK

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Easily accessible	Simulate a repair cycle on the pump that is more difficult to access and check the following: a) Easy to isolate from the rest of the system b) Easy to dismantle c) The rest of the plumbing is not disturbed d) Easy to carry it outside its area e) Easy to place it back and assemble it	V	The STP should allow easy maintenance of pumps without significant interruption of its process

D-5 AERATION TANK

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Baffle wall function	a) The sewage is let into the baffle zone – No splash or overflow b) There is no bubble-free dead zone adjacent to the baffle wall on the tank	V	These signs indicate wrong dimensions of the baffle wall
ii)	Diffuser function	a) Bubbles rise uniformly across the surface b) No dead zone (especially near walls and corners) c) No large bubbles bursting through	V	To get optimum results, you may need to adjust the placement of diffusers and/or air pressure in individual diffusers

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Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
iii)	Maintenance of diffusers	Simulate a service cycle on sample diffusers (select the most remote elements) and check for the following: a) Easy to isolate from the rest of the system b) Easy to retrieve the chosen element c) Easy to dismantle the element without disturbing the other plumbing. d) Easy to clean the element e) Easy to lower it back at the exact spot	T	Maintenance of diffusers should not disrupt the STP functioning
iv)	Membrane type diffuser	Pull out and check if membranes are in good condition	V	—
v)	Split aeration tank	Easy to isolate and empty each tank for repairs a) Cut off compressed air (Check safety function) b) Equal flow of sewage and recycle sludge to each compartment	V	—
vi)	Biomass in Aeration tank	a) Healthy brown biomass b) Check MLSS level in aeration tank	V T	— —

D-6 SECONDARY CLARIFIER TANK

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Settling of sludge	a) Sludge settles without vortex b) No sludge drawn up near the weir c) No significant sludge trace in the launders d) No clumps/ balls of rising sludge	V	—
ii)	Fine mesh basket at outlet	Easy to service the mesh, for which check the following: a) Easy to remove b) Easy to clean c) Easy to fit it in place	T	—
iii)	Bridge	a) Bridge allows safe travel up to motor and gear box b) The safety railing has closely spaced balusters to prevent accidental fall from under the railing	T	—
iv)	Maintenance of motor and gearbox	Simulate a repair cycle for the motor and gearbox a) Safe access to the motor and gearbox b) Allows safe removal of motor and gearbox c) Allows safe carrying of parts out of tank d) Allows safe re-fitting of parts e) Check rotational speed of rake	T M	If the motor and gear box cannot be made functional within 30 min, the bacteria may start dying

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Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
v)	Weir level	Check for uniform overflow of water over the entire length of the weir(s)	T	—

D-7 SLUDGE RECIRCULATION PUMPS — AIRLIFT

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Air lift	Check if recirculation sludge flow is roughly between 60 and 100 percent of sewage inflow	V	—

D-8 SLUDGE RECIRCULATION PUMPS — ELECTRIC

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Air lift	Check if recirculation sludge flow is roughly between 60 and 100 percent of sewage inflow	V	—

NOTE — Based on the STP design, select the previous table (for an airlift pump) or this table (for electric pumps used in direct-suction or buffer sump variations).

D-9 SLUDGE RECIRCULATION SYSTEM — WITH A BUFFER SUMP

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Aeration and mixing in sludge sump	a) Bubbles rise across the entire surface (no dead zone in any area, especially edges and corners) b) There is no odour	V	This means the system does not pose a threat to the bacteria
ii)	Maintenance of pump	Simulate a repair cycle (select the pump that is more difficult to access) and check for the following: a) Easy to cut off from the rest of the system b) Easy to remove c) Easy to carry outside STP d) Easy to assemble back. e) Check if recirculation sludge flow is roughly between 60 and100 percent of sewage inflow	T	Although availability of a standby drastically reduces the risk, it should be easy (and fast) to repair a defective pump

D-10 CLARIFIED WATER TANK

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Aeration and mixing	a) Bubbles rise across the entire surface (no dead zone in any area, especially edges and corners) b) There is no odour c) No accumulation of solids in the tank	V	—

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D-11 FILTER FEED PUMPS

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Maintenance of pump	Simulate a repair cycle (select the pump that is more difficult to access) and check the following: a) Easy to cut off from the rest of the system b) Easy to remove c) Easy to carry outside STP d) Easy to assemble back	T	—

D-12 BACKWASH PUMPS

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Maintenance of pump	Simulate a repair cycle (select the pump that is more difficult to access) and check the following: a) Easy to cut off from the rest of the system b) Easy to remove c) Easy to carry outside STP d) Easy to assemble back	T	—

NOTE — This table is applicable only when the design uses a separate set of pumps for backwash (not by reversing the flow of the filter-feed pumps)

D-13 PRESSURE SAND FILTER

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Filter operation	Filter is able to handle design flow of water without excessive pressure drop	T	—
ii)	Filter Backwash	Backwash filter for 5-10 min and check if initially lot of solids come out, gradually becoming clearer and finally clear water is observed	T	—

D-14 ACTIVATED CARBON FILTER

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Filter operation	Get analysis reports and compare quality at inlet to filter and outlet of filter	T	—
ii)	Filter Backwash	Backwash filter for 5 min and check if initially lot of solids come out, gradually becoming clearer and finally clear water is observed	T	—

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D-15 DISINFECTION SYSTEM

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Hypo dosing	Check residual chlorine level with test kit It shall be more than 1 ppm after 30 min of standing	T	—

D-16 SLUDGE-HANDLING SYSTEM

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Filter press operation	Run an entire sludge dewatering cycle of one batch, and check quantity (weight) of sludge cake produced	T	—

D-17 AIR BLOWERS

Sl No.	*Check*	*Acceptance Criteria*	*Method*	*Rationale*
(1)	(2)	(3)	(4)	(5)
i)	Noise	Measure the noise. Results more than 80 dB(A) indicate corrective measures are needed	T	—
ii)	Capacity	Check if air in sufficient quantity is delivered to all connected tanks simultaneously, as visual indications for each tank as described above	T	—

ANNEX E

(*Clause* 13.3.7)

GUIDELINES FOR MAINTENANCE OF ELECTRICAL EQUIPMENT

E-1 In case of electrical appliances, manufacturer's instructions for the usage and maintenance of the equipment should be strictly followed.

E-2 The detailed/working drawings of all the components of electrical installations should always be available with the maintenance unit. Following records should be available:

a) Manufacturer's name;

b) Name plate of the equipment and its salient features such as capacity, rating, etc;

c) Manufacturer's recommendations regarding availability/usage of spare parts;

d) Manufacturer's recommendations for periodical maintenance and post fault maintenance;

e) Details of the maintenance operations performed in the past; and

f) History card of equipment shall be maintained and made available when required.

E-3 Care should be taken while selecting replacement parts. The spare parts should be correct and suitable, preferably as recommended by the manufacturer concerned. During the placement of order for the supply of spare parts, nameplate particulars and serial number should be quoted.

E-4 The space where the equipment is kept should be clean and properly ventilated. Equipment should not be disturbed needlessly. Before cleaning, the equipment should be made dead. For internal cleaning a section cleaner should be used.

E-5 Covers and doors should not be left open unnecessarily during maintenance. Afterwards they should be promptly and correctly closed and locked.

E-6 Before removing the covers and connections, all covers and cable terminations should be marked to ensure correct replacements. Disturbed connections

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and temporary connections should be marked to facilitate reconnection. Temporary connections and markings should be removed before the installation is put to use.

E-7 Those connections which have not been disturbed should also be checked for soundness and overheating.

E-8 All insulations should be regularly checked. Solid insulations should be checked for cracks and other defects. Fibrous and organic insulations should be checked for sign of blistering, delamination and mechanical damage. For insulating oils the interval between tests should be carried out as per the recommendations of the manufacturer and keeping the adverse environmental conditions in mind or at least once in an year.

E-9 It should be ensured that the earthing connections are sound and all contact screws are tight.

E-10 During the examination of interlocks it is necessary to take precautions to prevent danger to plant or persons in the event of malfunction or inadvertent operation. A person responsible for checking and maintaining any interlock system should have thorough knowledge of the extent, nature and function of the interlock.

E-11 If the equipment is ventilated then it should be ensured that the airflow is smooth and not restricted. If filters are provided, they should be cleaned or replaced as necessary.

E-12 The standby system for tripping and closing supplies should always be kept in good order. Indicators and alarms should be maintained in time with the manufacturer's instructions.

E-13 Tools, spares and instruments should be stored near to the installation. These should be regularly checked against an inventory.

E-14 Before the start of maintenance of the circuit switches it should be ensured that all incoming and outgoing main auxiliary circuits are dead and remain so during the maintenance. Over heating of the circuit switches is the root cause for faults. Overheating may be caused by inadequate ventilation, overloading, loose connection, insufficient contact force and misalignment.

E-15 Some circuit breakers are not intended to be maintained, such as miniature circuit breakers (MCBs). Such items should not be dismantled for maintenance. These should be renewed if not found functional.

E-16 For the maintenance of fuses periodical inspection should be done for correct rating, security, overheating and correct location/orientation. Element of renewable fuses should be renewed when the deterioration is apparent. The availability and correct replacement of fuse links should be ensured.

E-17 If a fuse link of certain rating has failed and is replaced, then all fuse links of same rating apparently subjected to the fault should be destroyed and replaced by new fuse links.

E-18 In order to be reasonably sure that circuit breaker is capable of operation when required, these should be tripped and reclosed at regular intervals. Tripping should be proved manually and where possible electrically *via* the protective relay contacts. The leakage of oil, sign of corrosion, and any unusual smell which may indicate over-heating should be detected through inspections.

E-19 Timing devices are mostly designed for specialist maintenance. These should not be dismantled for maintenance or overhaul purposes unless specifically recommended by the manufacturers'. Actual timing periods should be verified with set values and application requirements.

E-20 In case of cable boxes and terminations, security of mounting and earthing should be examined. Exposed tails should be inspected for good conditions of insulation and freedom from moisture.

E-21 Battery cells should be inspected for shedding of active material, sedimentation and buckling of plates. Level of electrolyte should be regularly checked and the level should be corrected with distilled water.

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ANNEX F

(*Clause* 14.6)

FORMAT FOR PREVENTIVE MAINTENANCE PROFILE OF LIFTS

		Maintenance S1 (*See* Note)					*Maintenance S2* (*See* Note)					*Maintenance S3* (*See* Note)				
	Components	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
	Tasks															
0	Contact customer															
1	Car interior calls, indicators, fixings	×	×		×		×	×		×		×	×		×	
2	Car lighting and diffuser	×	×		×		×	×		×		×				
3	Car door safety devices		×	×				×	×				×	×		
4	Levelling accuracy/jerk free/noise	×		×				×		×		×		×		
5	Landing operating panels, optical, acoustical fixings	×	×		×		×	×		×		×			×	
6	Controller: protection cover, lock, documentation	×	×	×	×		×	×	×	×		×			×	
7	Date check, error-log, LEDs check	×	×	×			×	×	×							
8	RAM/Trip counter/long-term tasks	×	×	×	×	×	×	×	×	×	×					
9	Manual/automatic passenger rescue device	×	×				×	×				×				
10	Alarm, communication systems two way with main power ‘ON’												×			
11	Emergency car communicate and lighting systems	×	×				×	×				×	×			
12	Connections, contactors, relays, electrical protections	×	×		×		×	×		×		×				
13	Floor level indicate, LED control	×	×				×	×				×				
14	Control booklet of maintenance visits and break downs according to local regulation	×					×					×				
15	Car relevelling/blocking/speed control devices		×					×					×			
16	Final limit switches		×					×								
17	Hoistway lightning		×		×				×				×			
18	Remote control devices for speed governor and machine brake		×					×								
19	Safety gear						×	×	×	×	×					
20	Maintenance operating device/short head room device		×					×					×			
21	Car top/maintenance platform, car blocking device	×			×		×	×		×						
22	Inspection: top of hoistway travel limit		×					×								
23	Motor: frame, fan, bearing Lubrication and level, fixings, pulleys	×			×	×	×			×	×					
24	Gear: tachometer, backlash, thrust bearing, oil level	×		×	×	×	×		×	×	×	×				
25	Machine brake: mechanical and electrical, coupling rubbers, brake contact		×	×	×	×		×	×	×	×	×				

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		Maintenance S1 (*See* Note)					*Maintenance S2* (*See* Note)					*Maintenance S3* (*See* Note)				
	Components	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
	Tasks															
26	Frequency converter	×			×		×					×				
27	Speed governor	×			×		×	×		×		×				
28	Car fixings	×		×												
29	Car suspension fixations and slack-rope contact	×	×		×		×			×		×				
30	Car guide shoes and lubricators/rollers	×		×	×	×	×			×	×	×				
31	Hoistway doors mechanical and electrical	×	×	×	×	×	×	×	×	×	×	×	×		×	
32	Hoistway information and connections	×		×	×		×		×	×						
33	Guide rail fixations	×		×												
34	Counter weight: guide shoes and lubricators, frame, suspension/divertor pulley fixation	×		×	×	×	×		×	×	×					
35	Counter weight: weight fixation/anti-jump/anti-twist buffer plate/compensation	×			×		×			×		×				
36	Speed governor rope	×										×				
37	Suspension ropes/STM condition and tension	×		×			×					×				
38	Door drive mechanical and electrical	×	×	×	×	×	×	×	×	×	×				×	
39	Car door safety contact		×	×	×			×	×	×			×			
40	Car door coupling to landing doors	×	×	×			×	×	×							
41	Hoistway pit safety set		×		×			×		×						
42	Hoistway/hoistway pit/oil collectors	×			×		×			×					×	
43	Speed governor rope tensioning pulley and contact		×	×	×	×		×	×	×	×	×				
44	Buffers	×	×		×	×	×					×				
45	Safety gear/buffer plate/guide shoes						×	×	×	×	×	×				
46	Suspension ropes/STM position, pulleys and retainers	×			×	×			×			×				
47	TSDs topper plate fixation and safety contact	×					×			×	×	×				
48	Compensating chain/rope and pulley	×		×	×	×		×		×		×				
49	Travelling cable and attachments	×						×				×				
50	Counterweight distance to buffer when car at top	×		×				×		×			×			
51	Load measuring device		×	×	×			×	×	×						
52	Fireman’s control, special options, automatic evaluation	×	×					×					×			
53	Feedback to customer, if any	×						×				×				

NOTE — A = Visual check, B = Function check, C = Measurement, D = Cleaning, and E = Lubrication.

S1 and S2 : Inspection to be carried out once in 6 months; and

S3 : Inspection to be carried out once in 3 months.

ANNEX G

(*Clauses* 14.7.1 *and* 14.7.2)

TYPICAL CHECKLISTS FOR MAINTENANCE OF LIFTS AND ESCALATORS

G-1 TYPICAL CHECKLIST FOR DAILY MAINTENANCE OF LIFTS

DAILY CHECKLIST FOR LIFTS:														
Site Name:									Month:		Date:			
Sl No.	*Toner/ Lift No.*	*Emergency Light and Car Light*	*Hooter/ Alarm*	*Intercom*	*Door Sensor*	*All Calls and Indicat-ions*	*Floor Level*	*Any Noise Vibration*	*Music/ Floor Voice Announ-cement System*	*Car Fans/ Blowers*	*Car Sill and Landing Door Sills*	*CCTV*	*General Clearing*	*Remarks*
i)														
ii)														
iii)														
iv)														
v)														
vi)														
vii)														
viii)														

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G-2 TYPICAL CHECKLIST FOR MONTHLY MAINTENANCE OF LIFTS

MONTHLY CHECKLIST FOR LIFTS:

Site:		*Location:*	*Lift No.:*	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	
Sl No.	*Activity to be Carried Out*	*Status of Activity Carried Out*	*Details of the Parts Replaced, if Any*													*Remarks*
i)	All daily checks															
ii)	Check the oil level in machine gear box															
iii)	Inspection of ropes and its tension															
iv)	Lubrication of guide rails															
v)	Check bearing/ bush noise in machine room															
vi)	Door sensors/ alignment															
vii)	Check of hall/car call buttons and signal															
viii)	Governor checks															
ix)	Landing doors/car gate checks															
x)	ARD and controller checks															
xi)	Pit equipment checks															
xii)	Fireman operation															
xiii)	Hoistway equipment checks															
xiv)	Car signages and aesthetics															
	Signature OBM:															
	Signature Shift Engineer:															
	Signature Facility Manager:															

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G-3 TYPICAL CHECKLIST FOR DAILY MAINTENANCE OF ESCALATORS

SITE NAME:			**DAILY CHECKLIST FOR ESCALATORS:**									**Date:**	
Sl No.	*ESC No.*	*Location*	*Escalators Light (Comb Light, Handrail Light and, Traffic Light, Step Light)*	*Skirting/ Skirt Light and Skirt Brush*	*Balust-rade*	*Floor Plates Up/ Down*	*Steps*	*Auto/ Manual Sensors*	*Decking*	*Comb Plate*	*Handrail*	*Noise, if any*	*Remarks*
	Signature OEM:												
	Signature Shift Engineer:												
	Signature Building Manager:												

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G-4 TYPICAL CHECKLIST FOR MONTHLY MAINTENANCE OF ESCALATORS

MONTHLY CHECKLIST FOR ESCALATORS:														**Date:**		
Site:	*Locations:*	*Esc. No:*		*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Remarks*
Sl No.	*Activity to be Carried Out*	*Status of Activity Carried Out*	*Details of the Parts Replaced, if any*													
i)	All daily checks															
ii)	Check the oil level in machine gear box															
iii)	Chain tension checks															
iv)	Lubrication of all moving parts															
v)	Check bearing/ bush noise in machine															
vi)	Roller checks															
vii)	Floor plates sensors															
viii)	Hand rail speed monitor															
ix)	Step missing sensor															
x)	Broken steps chain monitor															
xi)	Broken hand rail monitor															
xii)	Over speed monitor															
xiii)	Skirt missing sensor															
xiv)	Anti-static brush															
xv)	Emergency switch Up/Down															
xvi)	Controller checks															
xvii)	Signages and aesthetics															
	Signature OEM															
	Signature Shift Engineer:															
	Signature Building Manager:															

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ANNEX H

(*Clause* 18.5.6)

TYPICAL CHECK LIST FOR LANDSCAPE AREAS

H-1 A typical checklist for landscape areas is given below:

a) Mow and edge lawns, if needed.

b) Prune back any shrubs overhanging kerbs or sidewalks.

c) Prune back any groundcover overhanging kerbs or sidewalks.

d) Remove litter and leaves from plants, planters, and parking lots.

e) Remove any broken or fallen branches from trees. Remove sucker growth from tree trunks.

f) Remove any weeds larger than 50 mm high or wide from planters. Weeds 50 mm and larger shall be removed, not just killed.

g) Replace bark mulch which has been knocked or washed out of planters. Smooth mulch layer, if it has been disturbed.

h) Replace decorative rock which has been knocked or washed out of planters. Smooth decorative rock surface, if it has been disturbed.

j) Check plants for signs of stress or disease. Replace any plants that meet conditions for replacement. Request authorization to replace other dead or missing plants (*see* Note 1).

k) Sweep or blow clean all walkways, curbs, and gutters.

m) Treat for any signs of disease or pest infestation.

n) Complete any items required on the monthly checklist.

p) Hand water any plants that are dry and stressed.

q) Check the irrigation system. Make emergency repairs as needed or request authorization to make major repairs (*see* Note 2).

r) Adjust the irrigation controllers for current water needs of plants.

NOTES

1 Request authorization to make replacements within one week of the damage becoming evident.

2 Request authorization for repairs within one week of the damage becoming evident.

ANNEX J

(*Clause* 19.4.4)

TYPICAL TEMPLATE FOR HOUSEKEEPING OF HOTELS

GENERAL CLEANING							
Month :							
Sl No.	*Indicative Scope of Work*	*Time-lines*	*Reference Document*	*Impact*	*Incident Tracker*	*Non-Conformance*	*Total Conformance*
i)	General cleaning		Supervisor checklist	Medium			
ii)	Supply of people related, housekeeping equipment, housekeeping chemical		Deployment sheet/attendance register	Medium			
	Daily activities to be completed with minimal disruptions during office hours						
iii)	Sweeping floors/wet mopping	Daily twice		Medium			

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iv)	Washroom cleaning	Daily once		High			
v)	Cleaning of dustbins	Daily twice		High			
vi)	Cleaning lift, cabin, floor and carpet	Daily once		High			
	Repetitive daily activities (Consumables inventory)						
vii)	Clean all unwanted materials collected from all floors to the main dustbin after security verification	As and when required	Supervisor checklist	Medium			
viii)	Dusting the window glass	Once	Supervisor checklist	Medium			
ix)	Clean the staircase and ensure the area is mopped and railings cleaned	Once and as and when required	Supervisor checklist	Medium			
	Weekly activities						
x)	Wet mopping of emergency stair case of all floors	Once a week	Weekend checklist	Medium			
xi)	Deep cleaning of plant rooms			Medium			
xii)	Wiping of plumbing in STP, HT/LT room and pump room			Medium			
xiii)	Cleaning of storage area			Medium			
xiv)	Terrace area			Medium			
	Fortnightly activities						
xv)	Clean the cob-webs at all floors	Once a fortnight	Weekend checklist	Medium			
xvi)	Polishing of lift cabin with relevant chemicals to maintain the shine			Medium			
xvii)	Water cleaning of the parking area using high pressure jet			Medium			

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LIST OF STANDARDS

The following list records those standards which are acceptable as 'good practice' and 'accepted standards' in the fulfillment of the requirements of the Code. The latest version of a standard shall be adopted at the time of enforcement of the Code. The standards listed may be used by the Authority for conformance with the requirements of the referred clauses in the Code.

In the following list, the number appearing in the first column within parentheses indicates the number of the reference in this Part.

	IS No.	*Title*
(1)	15183 (Part 2) : 2002	Guidelines for maintenance management of buildings: Part 2 Finance
(2)	15183 (Part 3) : 2002	Guidelines for maintenance management of buildings: Part 3 Labour
(3)	11208 : 1985	Guidelines for registration of plumbers
(4)	13182 : 1991	Waterproofing and damp-proofing of wet areas in building — Recommendations
(5)	2064 : 1993	Code of practice for selection, installation and maintenance of sanitary appliances (*second revision*)
(6)	2190 : 2010	Selection, installation and maintenance of first-aid fire extinguishers — Code of practice (*fourth revision*)
(7)	2189 : 2008	Selection, installation and maintenance of automatic fire detection and alarm system — Code of practice (*fourth revision*)
(8)	15301 : 2003	Installation and maintenance of fire fighting pumps — Code of practice
(9)	13039 : 2014	External hydrant systems — Provision and maintenance — Code of practice (*first revision*)
(10)	3844 : 1989	Code of practice for installation and maintenance of internal fire hydrants and hose reels on premises (*first revision)*
(11)	15105 : 2002	Design and installation of fixed automatic sprinkler fire extinguishing systems — Code of practice

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BUREAU OF INDIAN STANDARDS

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